

A Service-Dominant Logic View of Retail On-Shelf Availability

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Abbreviations

<i>ASO</i>	Automated Store Ordering
<i>Avg.</i>	Average
<i>FMCG</i>	Fast-Moving Consumer Goods
<i>FP</i>	Foundational Premise
<i>G-D</i>	Goods-Dominant
<i>RQ</i>	Research Question
<i>S-D</i>	Service-Dominant
<i>UK</i>	United Kingdom of Great Britain and Northern Ireland
<i>Univ.</i>	University
<i>USA</i>	United States of America
<i>wk</i>	Week

Notation

A	Across
a_t	Quantity ordered in period $t = 0, 1, 2, \dots$
β	Severity of impact of an out-of-stock on S
C_{OOS}	Costs of out-of-stocks
c_S	Cost c of recovering from an out-of-stock to S
$D_{d,L}$	Demand during lead time in d -th review period within a season
$D_{d,R}$	Total demand during the d -th review period, $D_{d,R} = D_{d,L} + D_{d,R-L}$
$D_{d,R-L}$	Demand after the receipt of the order in d -th review period within a season
d_t	Season index for period t , $d_t = 1, 2, \dots, \bar{d}$
δ	Severity of impact of an out-of-stock on the networks of ρ, M, S
FS	Friday-Saturday
FSS	Friday-Saturday-Sunday
h	Holding cost per unit of inventory (charged at the end of the period)
ι_1	Impact of shopper response on $s_{\rho,M}$
ι_2	Impact of shopper response on $l_{\rho,M}$
I_t	Inventory on hand at the beginning of period $t = 0, 1, 2, \dots$
K	Fixed cost per order
K_1	Handling cost per batch
K_2	Handling cost per unit
L	Lead time ($0 \leq L \leq R$)
$l_{\rho,M}$	Long-term sales losses l for ρ and M
M	Manufacturer
ω	Out-of-stock type (i.e. where it occurs), duration and sales velocity
p	Penalty cost for each unit of sales lost during a period
q	Fixed (exogenously determined) batch size, $q = 1, 2, \dots$
R	Review period
ρ	Retailer
S	Shopper (including the user)
$s_{\rho,M}$	Short-term sales losses s for ρ and M

SS	Saturday-Sunday
t	Period index, $t = 0, 1, 2, \dots$
$v_{\rho, M, S}$	Value network impact v of out-of-stock on ρ, M, S
V_A	Across-review periods demand variation measure
V_W	Within-review periods demand variation measure
W	Within
WW	Weekday and weekend

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Executive Summary

Providing products on store shelves is a key function of retailing, but it comes at a price. Retailers spend 5% of the global \$13.9 trillion sales on logistics. 45% of logistics expenses are caused by store inventory handling and holding. Improvements in store inventory management are therefore a primary objective for retail managers. Over the last decades, research and practice have devoted considerable attention to reducing inventory management costs. Retailers improved logistics efficiency and introduced new technology in the pursuit of providing constantly high levels of on-shelf availability. However, this approach may be very costly if it does not meet shopper demand.

This research investigates the benefits of improving retail on-shelf availability by advancing customer and demand integration. It develops and applies Service-Dominant (S-D) logic, which is based around value co-creation in service networks, and transcends the traditional role of retail inventory from the protection against demand towards the goal of service provision and value-creation with customers. It shows empirically when and how incorporating customer and demand considerations in inventory management improves on-shelf availability in business practice.

The S-D logic view of on-shelf availability is addressed in three complementary levels: theory, conceptual development and empirical research. Theoretically, this research reviews comprehensively and synthesizes the advances and applications of S-D logic since its introduction in 2004. It suggests redundancies in S-D logic, identifies future topic areas and guides research and practice in its application and development. Specifically, it points to the investigation of value attenuation – opposed to co-creation – and the empirical validation of phenomena uncovered by the S-D logic perspective.

Conceptually, this research transcends the traditional view of the effects of retail out-of-stocks on sales losses to a S-D logic view that unveils out-of-stocks to attend value across suppliers, retailers, shoppers and their respective networks. It develops a model of value co-creation where manufacturer supply and shopper demand meet in the retailer's realm. The model identifies the shopper as an active entity whose response to out-of-stocks redistributes value within the retail ecosystem. It proposes that co-creation of value through on-shelf availability takes place in the spatio-temporal integration of actor

resources and suggests improving value creation by incorporating shopper/user network considerations and demand variation in on-shelf availability.

Empirically, this research uses inventory modeling to investigate the value of adjusting on-shelf availability to account for demand variation. It transfers the S-D logic concept into a single-location, single-item periodic-review lost sales inventory model with non-stationary demand. In a first step, it analyzes numerically the performance of inventory policies taking into account varying degrees of demand variation using a cost structure comprised of costs for ordering, handling, holding, and for retailers and customers, the cost of out-of-stocks. In a second step, it uses a real life replenishment setup and actual sales data to investigate the value of accounting for demand variation in practice, putting a novel focus on demand variation within and across days. The analysis shows the value of accounting for demand variation to retailers is substantial, especially when demand varies while fix costs are low.

Zusammenfassung

Die Bereitstellung von Waren zum Verkauf ist Kernfunktion des Handels. Weltweit entstehen dem Handel dadurch Logistikkosten in Höhe von 5% des Umsatzes, wovon 45% auf die Filialebene entfallen. Die filialbezogenen Logistikkosten stehen daher immer wieder im Fokus von Kostensenkungsinitiativen.

Forschung und Praxis haben sich in den letzten Jahrzehnten intensiv mit Effizienzsteigerungen in der Filiallogistik befasst. Ziel dieser Ansätze war es, möglichst hohe Verfügbarkeit zu niedrigst möglichen Kosten zu erreichen. Diese Herangehensweise stösst allerdings dann an ihre Grenzen, wenn Nachfrage und Kundenbedürfnisse schwanken und dies nicht in der Bestandsführung berücksichtigt wird.

Die vorliegende Arbeit befasst sich daher mit der Bereitstellung von Handelswaren mit unterschiedlichen, von der Kundenwertschöpfung geleiteten Verfügbarkeitsniveaus. Theoretisch basiert diese Arbeit auf Service-Dominant logic, deren Forschungslandschaft grundlegend analysiert und aufbereitet wird. Konzeptionell entwickelt die Arbeit eine gemäss Nachfragestruktur und Kundenwertschöpfung ausdifferenzierte Regalverfügbarkeit. Dabei wird die bestehende Forschung zu Regalverfügbarkeit in die Service-Dominant logic transzendiert und erweitert.

Die Arbeit überführt und testet das Konzept in einem Bestandsmodell mit nichtstationärer Nachfrage unter Berücksichtigung von Bestell-, Handling- und Haltungskosten sowie der Fehlmengenkosten der beteiligten Akteure. Aus den Ergebnissen leitet die Arbeit Implikationen für die Praxis und weiteren Forschungsbedarf ab.

Chapter 1

Introduction

1.1 Motivation and objectives

1.1.1 The managerial relevance of on-shelf availability

On-shelf availability, i.e. providing items as desired by shoppers, is the key function of retailing that lies at the heart of retail logistics management, and is debated frequently in business practice (Helm and Stölzle, 2009). On-shelf availability comes at a price. In 2010, global retail sales amounted to \$13.9 trillion (IMAP, 2010). On average, retailers spend 5% of sales on logistics (Sivakumar, 2010). The largest part of these costs are caused on the store level by inventory handling (38%) and holding (7%; van Zelst et al., 2009; see also Hofer, 2009). Improvements in store inventory management are therefore a primary objective for retail managers and essential to retailer profitability (Butner, 2005). Over the last decades, research and practice have devoted considerable attention to reducing inventory management costs by improving store logistics efficiency, preventing out-of-stocks, and improving the flow of goods through automated ordering and tracking technologies in the pursuit of providing constantly high levels of on-shelf availability.

Continued economic uncertainty and investor expectations to improve on inventory management has forced retailers to reconsider this practice (Gaur et al., 2005). Stocking too much entails markdown and obsolescence costs, and even the risk of bankruptcy (Fisher and Raman, 2010): At the end of October 2011, US retailers held \$469,037 million in inventories¹, which equals 80% of Switzerland's Gross Domestic Product in 2010 (U.S. Census Bureau, 2011; BFS, 2011). However, stocking too little is costly, too. Out-of-stocks cause lost sales, dissatisfy shoppers and diminish store loyalty (Gruen et al., 2002). The global retail executive survey by Baird and Rosenblum (2010, p.1) puts “underperforming inventory on the one hand, and out-of-stocks on the other as the

¹Figure adjusted for seasonal and holiday variations.

biggest challenges retailers face.”

Traditionally, to protect themselves against dissatisfying shoppers with out-of-stocks, retailers implemented inventory policies that aim for permanently high on-shelf availability (Tan and Karabati, 2004; Aastrup and Kotzab, 2010; Ehrenthal and Stölzle, forthcoming). This approach bears three major problem areas. Firstly, from a store inventory management perspective, permanent availability is very costly. In the absence of shopper demand, items may be shelved when they are not required, lying idle and tying down logistics resources that would be more productive elsewhere (Broekmeulen et al., 2007). Yet, shopper demand is known to vary with a given demand structure (Placzek, 2007), e.g. grocery sales peaks on Saturdays (van Donselaar et al., 2010). Secondly, a lack of demand integration in replenishment may lead to structural out-of-stocks. As shown by Gruen and Corsten (2008), shelf replenishment that is unsynchronized with demand cycles causes frequent and persistent out-of-stocks. Thirdly, aiming for permanently high on-shelf availability incurs the risk of markdowns and waste, which decrease profit margins (Fisher and Raman, 2010).

Today, with advances in technology, more detailed demand and inventory data are at the retailers’ disposal to achieve a higher level of synchronicity of demand and supply on the retail shelf. Consequently, and in line with recent research substantiating the potential of demand and customer integration in on-shelf availability (e.g. Kotzab et al., 2005; Stölzle and Placzek, 2006, 2008; Gruen and Corsten, 2008; Aastrup and Kotzab, 2010), this research seeks to investigate the benefits of improving on-shelf availability by advancing customer and demand integration.

1.1.2 The current state of retail on-shelf availability research

Previous research has addressed the problem of on-shelf availability from two different point of views: the logistics management perspective, which investigated the operational shortcomings leading items being non-available, and the marketing perspective, which focused on how shoppers respond to non-availability at the retail shelf and the financial impact of out-of-stocks. While the logistics perspective has focused on the cost of goods provision and the operational and organizational resources necessary to improve stockout rates, the marketing perspective was driven by loyalty and sales considerations. As a basis for this research, key insights on retail on-shelf availability from these two research streams will be outlined briefly in the following sections.

The current state of logistics research into retail on-shelf availability

Logistics research has greatly contributed to our understanding of the extent and the causes of retail out-of-stock, and identified management levers to improve defective processes and out-of-stock levels.

Consistent with retailers' aim of providing high on-shelf availability, a series of investigations have been undertaken to identify and eliminate the causes for out-of-stocks in retail supply chains (e.g. McKinnon et al. 2007; Kucuk, 2008; Fernie and Grant, 2008; Grant and Fernie, 2008; Trautrim et al., 2009; Aastrup and Kotzab, 2009; Hofer, 2009). These studies, which have focused on fast-moving consumer goods retailing, report on-shelf availability of around 92% and show that availability is greater in the upstream supply chain (Gruen et al., 2002; ECR Europe, 2003; McKinnon et al., 2007; Gruen and Corsten, 2008; Aastrup and Kotzab, 2009).

Logistics research has identified several instore (downstream) and prestore (upstream) factors that lead to out-of-stocks. The general consensus among the studies is that the vast majority of out-of-stocks are caused at the store level, mostly through poor ordering and shelf replenishment. Prestore causes for out-of-stocks, while of lesser extent, include delivery problems either at the supplier or the retail distribution center, ordering issues, unsuitable case pack quantities, inaccurate forecasts as well as handling problems in the retail distribution center (Emmelhainz et al., 1991b; ECR Europe, 2003; McKinnon et al., 2007; Aastrup and Kotzab, 2009; Hofer, 2009).

More recently, several studies examined the store-level causes for out-of-stocks (e.g. Angerer, 2006; McKinnon et al., 2007; Van Woensel et al. 2007; Grant and Fernie 2008; Curşeu et al., 2009; Hofer, 2009; Trautrim et al., 2009; and van Zelst et al., 2009). These studies provide great details on the instore causes for out-of-stocks and consequential management levers for improving on-shelf availability levels. The causes for out-of-stocks on the store level concern execution issues, including deficient order augmentations by store managers, poor inventory record keeping, disorganized shelf replenishment and waste return processes. Furthermore, category/item characteristics have been connected to out-of-stocks (Placzek, 2007), and out-of-stock levels are found to vary greatly among categories, items, and stores (Gruen et al., 2002; McKinnon et al., 2007). Recent studies have emphasized the role of on-shelf availability for the entire retail supply chain (Kuhn and Sternbeck, 2011), and shown how improvements to store organization and replenishment tactics leads to sustained minimization of stockouts (Ehrental and Stölzle, forthcoming).

A recent review of the past 40 years of on-shelf availability research by Aastrup and Kotzab (2010, p.157) concludes that “the underlying (probably implicit) premise of most [out-of-stock] related contributions is that [out-of-stocks] should be minimized. ...none

of the reviewed contributions refer to optimal [out-of-stocks/on-shelf availability] levels. Instead they discuss how to improve [out-of-stocks] levels, that is, decrease [out-of-stocks] levels” Consequently, Aastrup and Kotzab (2010) identify the need for a modeling and optimization of on-shelf availability, which requires the balancing inventory overage and underage cost given some demand structure.

The current state of marketing research into retail on-shelf availability

Marketing research regarding on-shelf availability has focused on understanding shopper response to out-of-stocks and their financial impact. Like the logistics research, the marketing view advocated stockout minimization (e.g. Helnerus, 2007). Stockouts have a negative impact on retailers and brand manufacturers, both directly on sales and profit and indirectly on customer satisfaction and store or brand loyalty respectively (Campo et al., 2000, 2003; Fitzsimons 2000; Anderson et al., 2006; Musalem et al., 2010). For retailers, stockouts lead to lost sales, dissatisfy shoppers, diminish store loyalty and jeopardize marketing expenses. To brand manufacturers, stockouts for a specific brand may lead to losses in brand sales and decrease brand loyalty (Sloot et. al, 2005).

Marketing research has investigated shopper response to out-of-stocks and its antecedents in depth. When shoppers encounter a stockout, they respond in two general ways: either they purchase a substitute item or they chose not to do so. In the case of substitute purchasing, shoppers switch items, i.e. they chose an item of a different variety but of the same brand. They also switch categories, i.e. buying a substitute from a different product category. Or shoppers switch brands, which means buying an item from another brand within the same category. In the case of not substituting, shoppers switch stores, i.e. purchasing the same item at another store promptly after encountering a stockout, they postpone the purchase until the next trip to the store, or they do not purchase the item at all (Schary and Christopher, 1979; Motes and Castleberry, 1985; Emmelhainz et al., 1991a; Verbeke et al., 1998; Fitzsimons, 2000; Campo et al., 2003; Sloot et al., 2005; Gruen and Corsten, 2008).

Studies on the factors influencing stockout response identify a wide array of variables including brand-related antecedents (e.g. brand equity and brand loyalty), product-related and category-related antecedents (hedonic level), store-related antecedents (e.g. service-related or price-oriented store, store loyalty and alternative stores in the proximity), shopper-related antecedents (e.g. shopper age, shopping experience and shopping frequency), and situational antecedents (e.g. urgency of purchase, day of the week, personal use of product)(Sloot et al., 2005; Breugelmans et al., 2006; Van Woensel et al., 2007; Sloot and Verhoef, 2008; Hegenbart, 2009). Concerning brand-related antecedents, shoppers value high-equity brands more than low-equity brands, this effect being stronger

in hedonic categories (Sloot et al., 2005). With respect to product-related and category-related antecedents, the availability of acceptable substitutes and the risk perceived from these alternatives are negatively related to store-switching and brand-switching (Campo et al., 2000; Emmelhainz et al., 1991a). Helm et al. (2012) find that loyalty and the suitability of available alternatives have the highest impact on shopper response to stockouts. Also, brand-loyal shoppers are more inclined to switch stores than to substitute brands (Campo et al., 2000; Emmelhainz et al., 1991a; Verbeke et al., 1998). Similarly, Helm and Stölzle (2005, 2006) show that for high involvement items, customers switch stores and item size rather than substitute within the same store. Likewise, buyers of private-label items show a reduced tendency to switch stores (Schary and Christopher, 1979). As to shopper-related antecedents, while a positive shopping attitude increases the likelihood of store-switching, time constraints tend to decrease it (Campo et al., 2000).

Closely connected to shopper-related antecedents are situational factors affecting response to stockouts. Most importantly, the urgency of purchase is negatively related to postponement and store-switching, whereas it is positively related to item-switching and brand-switching (Campo et al., 2000; Emmelhainz et al., 1991; Zinn and Liu, 2001, 2008). Finally, the type of trip (e.g. weekly shopping trip versus ancillary purchases) affects response to stockouts. Shoppers on habitual, large shopping trips are less likely to switch stores and more likely to substitute (Campo et al., 2003).

While the knowledge on shopper response to out-of-stocks is abundant, the results of marketing research are rarely integrated into logistics considerations, which has limited previous solution attempts to the on-shelf availability problem towards optimal solutions (Aastrup and Kotzab, 2010; Kotzab et al., 2005; Stölzle and Placzek, 2006, 2008).

1.2 Research positioning, research questions and course of investigation

1.2.1 Research positioning and research questions

Based on the business need for improving inventory performance, and past research in on-shelf availability calling for the combination of insights from logistics and marketing research to work towards optimal on-shelf availability, this research is concerned with investigating the benefits of improving on-shelf availability by adding insights on value-creation through on-shelf availability among the actors involved, and consequentially combining supply and demand considerations to achieve higher quality outcomes.

To obtain theoretical, conceptual and methodological/empirical insights to advance research and benefit business practice, we take on a S-D logic view of retail on-shelf

availability. Acknowledging that the central role of retail on-shelf availability is service provision, we select S-D logic with the following rationale:

First, S-D logic delineates extensively the service provision nature of retail on-shelf availability in the context of supply chain management, logistics and operations. On a wider scale, this view is part of a broad movement reflecting changes in business practice. As argued by Lusch et al. (2010), Chen and Paulraj (2004), and Larson et al. (2007), supply chain academia and business practice have been increasingly centering their efforts towards the goal of service provision, re-thinking the purpose and processes of supply chains accordingly. Drawing on Bovet and Martha (2000), Hoyt and Huq (2000), Gunasekaran and Ngai (2004), Min et al. (2007), and Spekman et al. (1998), Lusch et al. (2010) observe that this shift has extended the focus to encompass relationships, networks, and value-creation. This research finds these emergent themes to be useful to retail on-shelf availability, with its previously investigated manufacturer-supplier relations, supply network aspects, and the pronounced exchange of goods between the supply side and the demand side in retail stores outlined earlier. Gummesson (1995, 2008) sees the goal of supply chain management in supporting customer value creation, and S-D logic as a balanced centrality of supply and demand processes. Lusch et al. (2010) take up this view, stating that supply chain and operations “research and practices fit naturally with this service-centered view because it implies that [supply chain management] is concerned with developing and integrating resources to create competitively compelling value propositions.” We follow this view of S-D logic thinking for the special case of retailing, where goods are distribution mechanisms for service, and constitute inputs to the customer’s own value-creating processes (Vargo and Lusch, 2004) because we see it as a potentially insightful approach in addressing the persistent issues in on-shelf availability research. Thus, following Ballantyne and Varney (2008), who see the firm’s objective in an S-D logic context as innovating resource integration necessary for service provision, this research attempts to advance on-shelf availability research and practice by applying the S-D logic view.

Second, the S-D logic view has been identified by Hult (2011) and Lusch et al. (2010) as a suitable framework for integrating marketing and supply chain approaches, perspectives and practice, which is one of the research gaps identified for on-shelf availability in Aastrup and Kotzab (2010) and others. Based on Achrol and Kotler (1999), Grönroos (1994, 2000), and Sheth and Sisodia (2006), Lusch et al. (2010) argue that the opportunity for such integration is reinforced by the apparent shift in marketing research and practice away from manufacturing and distribution towards multi-level relationships, network perspectives and service provision, which is convergent with the evolution of supply chain research. On-shelf availability, as the merging-point of supply chain and marketing

efforts (see also Lusch and Vargo, 2011), may therefore benefit from these shifts. Moreover, Lusch et al. (2010) show that the S-D logic view, despite originating in marketing, coincides with Metz’s (1998) observation of supply chain management’s changing ‘super role’ integrating marketing, product development, and customer service (for repercussions for marketing see, for instance, Wernerfelt, 2005). Thus, S-D logic encompasses the convergence in marketing and supply chain research and practice. This connection has been made as well in other research integrating S-D logic and supply chain management (Flint and Mentzer, 2006; Payne et al., 2008) and is in part concordant with the notion of demand chain management, which aims at designing business processes from the demand side (Jüttner et al., 2007), which has also found resonance in on-shelf availability research (e.g. Placzek, 2007). Both integratability and parallelism in marketing and supply chain in the better understanding of service provisions makes the S-D logic view particularly attractive for consolidating and re-configuring the marketing and logistics views of on-shelf availability.

Third, S-D logic evolves around value creation, specifically “about *servicing* customers’ needs, wants and desires, at appropriate monetary and nonmonetary cost” (Esper et al. 2010, p.10). Frequent critique of on-shelf availability research has been the lack of customer integration (Kotzab et al., 2005; Stölzle and Placzek, 2006, 2008; Aastrup and Kotzab, 2010; Ehrenthal and Stölzle, forthcoming), and the lack of balancing supply and demand considerations in providing on-shelf availability (Aastrup and Kotzab, 2010). S-D logic becomes useful in annihilating this problem as it frames the customer as a coproducer/co-creator (Vargo and Lusch 2004), i.e. the customer is inseparable from value creation and service provision. The key rationale for using an S-D logic view for on-shelf availability here is that rather than viewing retail on-shelf availability as a supply-side output, it is viewed as input to customer value creation and service provision. As noted by Esper et al. (2010), this customer-value centric view overcomes the predominant notion of ‘value-added’ in supply chains, which implies that in every step along the supply chain value is added to and stored in the product. On-shelf availability research shows this not to be the case in its many investigations of customer response to out-of-stocks. As an alternative, S-D logic puts forward that “value is, and always has been, created at the point of use, meaning when the customer uses/consumes the product or service, whether an internal or external customer. People, business functions, business units, and firms, are constantly engaged in processes where ‘suppliers’ and ‘customers’ are creating value for each other at hundreds of links within organizations and throughout supply chains” (Esper et al., p.10). This argument is to be seen in context with Payne et al. (2008), who highlight that encounter processes play a decisive role in these value-creating relationships. In the case of the retail industry, on-shelf availability

enables encounter processes and links supplier and customer processes in the retail store. Embracing the S-D logic view may therefore lead to a better understanding of the effects and mechanisms surrounding value creation of which retail on-shelf availability is a central element, departing from common thinking about on-shelf availability and stockouts to a broader context of value attenuation and customer value co-creation through on-shelf availability. This approach is consistent with Granzin and Bahn's (1989) consumer logistics framework, which proposes to consider the decisions and activities of consumers in logistics.

Fourth, S-D logic aligns well with the research domain closest to this research, supply-demand integration. According to Williamson et al. (1990), supply-demand integration is concerned with linking a company's internal operations with its customers. It entails the understanding of customer demand and requirements, and balances these with the capabilities and constraints of the supply chain (Lambert and Cooper, 2000; Croxton et al., 2002; Jüttner et al., 2007; Rexhausen et al., 2012). In retailing, demand-supply integration efforts become apparent in Efficient Consumer Response, a "collaborative efforts of retailers and their suppliers that suggests the functional integration of retailers and manufacturers in category management, continuous replenishment programs . . . , cross docking, collaborative planning, forecasting and replenishment . . . , efficient unit load . . . , and standards for item identification and communication in supply chains" (Aastrup et al., 2008, p.247), and its development and refinement for on-shelf availability in integrated logistics approaches (Stölzle and Placzek, 2006, 2008; Placzek 2007) as well as specializations to store logistics processes (Hofer, 2009; Ehrenthal and Stölzle, forthcoming). We respond to calls in this line of research to advance the integration of customer and demand considerations (Kotzab et al., 2005; Stölzle and Placzek, 2006, 2008; Aastrup and Kotzab, 2010; Ehrenthal and Stölzle, forthcoming). While this research draws on the results obtained in the connected studies, we are concerned with a higher-level service-dominant representation of on-shelf availability based on customer value co-creation, which follows Esper et al.'s (2010) argument that S-D logic's view of value-creation may serve as a foundation for the further integration of demand-focused activities and supply-focused activities in supply chains.

Finally, the provision in S-D logic of customer-value focus and value creation in networks leads us to dismiss the use of several other approaches not uncommon to this line of research (see inventory of theories in supply chain and logistics research Defee et al., 2010). Specifically, we opt against Systems Theory, Contingency Theory, and the Resource-based View, around which previous on-shelf availability research was loosely based (Aastrup and Kotzab, 2010). We also point towards similarities and touching points of these approaches to S-D logic.

Systems Theory, which is grounded in the view of systems as a collectives of multiple interrelated elements (von Bertalanffy, 1969; Kast and Rosenzweig, 1972), investigates phenomena through the consideration of interdependencies in networks of entities within larger systems (Scott and Davis 2007). While this approach to research lends itself well to investigating decision making in complex and complicated system environments, and serves well to not under-specify modeling approaches (Hult, 2011), it lacks the service provision nature and goal, which is self-evident, emergent, and at the core of S-D logic.

With the same reasoning, we revert from applying the closely related Contingency Theory, which is “guided by the general orienting hypothesis that organizations whose internal features best match the demands of their environments will achieve the best adaptation . . . the best way to organize depends on the nature of the environment to which the organization relates” (Scott 2005, p.89). As such, it provides an excellent framework to investigate a firm’s adaptation to its external environment. Yet, this research is concerned with internal and external forces that, rather than investigating impulses and responses, require a higher-level abstraction of analysis. In addition, on-shelf availability research has shown that many problems occur indigenously (stockouts caused by the retailer) or in closer relationships (between a manufacturer’s key account management and the retailers purchasing department), and repetitively (e.g. recurring shelf replenishment issues). However, we embrace Gailbraith (1973), who argues that Contingency Theory suggests that – transferred to on-shelf availability – there is no single best approach to solving the on-shelf availability problem, and that each approach may not be equally effective. Further, we acknowledge that various demand conditions need solutions with differing characteristics. For instance, differences in demand, planning, and stocking may be required to cater for different channels, categories or store types (for examples, see Placzek, 2007; Hübner et al., 2010). In fact, S-D logic reflects this in its contextual definition of exchange and value (Vargo and Lusch, 2004).

Further, we dismiss the Resource-based View of the firm (Wernerfelt, 1984), which sees the firm as a bundle of resources unevenly distributed amongst competitors (Barney, 1991). Applied to on-shelf availability, the Resource-based View would view a retailer’s marketing and logistics units as a bundle of resources, which is pronounced differently among its competitors, yet rooted in an equilibrium-seeking process under perfect competition (for the general case, confer Hunt and Morgan, 1995; Wernerfelt, 2005). Value is realized if the retailer is able to execute its resources. This makes the Resource-based View particularly insightful for investigating operational issues, such as supplier management, instore execution, and delivery scheduling (for an application to on-shelf availability, see Hofer, 2009). Yet, it is not the goal of this research to detect such resources and to show whether they can or do lead to a competitive advantage, but rather to take on a

broader view of value-creation through on-shelf availability. However, we draw on S-D logic’s partial relation to resource approaches. Specifically, S-D logic’s inclusion of operant resources, i.e. knowledge and skills, and its application to another entity in the value-creation process (Vargo and Lusch, 2008). Further, S-D logic “implies that the goal is to customize offerings, to recognize that the consumer is always a coproducer, and to strive to maximize consumer involvement in the customization to better fit his or her needs” (Vargo and Lusch, 2004, p.12). Thereby, S-D logic overcomes the critique of the customer value theory of the firm, that resource theories are limited by a lack of attention to the customer, as put forward in Slater (1997). While we dismiss the above approaches, certain elements are integrated in S-D logic as outlined and benefit this research.

Overall, the S-D view is a logic based around value co-creation in service networks. Due to the service nature of retailing, and on-shelf availability as retailing’s quintessential service offering, it seems a fruitful avenue for on-shelf availability research to embrace and utilize S-D logic in response to the emergent shifts and insights in marketing and logistics. S-D logic is well equipped to account for the interdependencies in the user/shopper-retailer-manufacturer triad in retailing and to provide an accurate representation of the structure of the on-shelf availability problem.

Yet, S-D logic is a nascent field with diverse applications that necessitate structuring. To date, no systematic analysis of the abundant research on S-D logic research exists. Common themes and generally agreed-upon notions of established theories, approaches and research conventions are thus absent. As a necessary step in the definition, discussion, development, diffusion, and application of S-D logic, also specific to this research, and to serve as an introduction, we thus arrive at Research Question (RQ) 1. It seeks to provide a theoretical foundation for this research by exploring and organizing and structure and the developments in S-D logic research 2004 through 2011, asking:

RQ1: What are advances, applications, and research opportunities in S-D logic?

Building on the results obtained, we aspire to frame the on-shelf availability problem using the S-D logic perspective, combining ‘classic’ S-D logic research with recent research of S-D logic in supply chains, and then applying this to on-shelf availability in a retail setting of fast-moving consumer goods products. In doing so, we follow the rationale for S-D logic outlined above, respond to the need for building compelling integrated marketing-logistics frameworks in on-shelf availability research as (e.g. Aastrup and Kotzab, 2010), and we seek to generate new insights for business practice and to derive a conceptual to guide retailers in orchestrating their value network to build value propositions for their customers and with their other value network partners. We also seek to generate

insights for S-D logic, specifically by investigating the implications of non-availability, and intertemporal issues in provision, purchase and use. In an attempt to transcend on-shelf availability research into S-D logic, we therefore target answering Research Question 2:

RQ1: What is the S-D logic view of on-shelf availability?

In order to generate an empirical characterization, we aim to transfer the new insights from the S-D logic view to retail inventory management, i.e. store ordering. Specifically, we seek to develop an inventory control model that allows for incorporating demand variation and the different levels of cost incurred in retail operations by all actors. In doing so, we aim at transcending the prevailing thought of supply-side cost minimization to a goal of service provision that incorporates shopper availability requirements to a new extent. Also, we respond to persistent calls for sales-related modeling under variable demand (Bijvanc and Vis, 2011; Dekimpe and Hanssens, 1995), as well as broader calls in the integration of supply and demand processes, both within and across companies (Mentzer et al., 2008; Richey et al., 2010), such that demand information is integrated into supply side decision making (Hübner et al., 2010; Nachtmann et al., 2010; Williams and Waller, 2010). We focus on retail inventory management for several reasons. First, the inventory decision is the core of on-shelf availability and research frequently points to inventory management decisions as a lever for improving on-shelf availability (see, for instance, Gruen and Corsten, 2008; Angerer, 2006). Second, past research on supply chain collaboration to improve on-shelf availability and recent retail logistics research results show the limitations of improving the logistics activities and processes surrounding the inventory decision, e.g. store processes (Hofer 2009; Ehrental and Stölzle, forthcoming). Third, inventory models can be designed to incorporate and investigate a wide array of factors, environments and constraints, and deliver exact mathematical evidence. They are thus particularly suitable for balancing and investigating the multiple counter-directional factors that have been identified for on-shelf availability in previous research and that uncovered by the S-D logic perspective. In their exact specification of problem sets, they facilitate scholarly debate and progress. Therefore, we chose a modeling approach for Research Question 3:

RQ3: What is the cost of neglecting demand seasonality in retail inventory control?

In addition, to benefit business practice, we aim at providing empirical insights from numerical calculations and real life data to investigate quantitatively the effects of retailers adopting differentiated levels of on-shelf availability compared to the non-differentiated

case. In detail, we investigate for which types of products the cost of neglecting demand seasonality is significant and provide an analysis as to how far retailers should incorporate demand seasonality into their inventory management given restraints of their ordering systems as subsets of Research Question 3.

1.2.2 Course of investigation

As outlined above, this research ventures from the synthesis of S-D logic to the conceptual application of S-D logic to on-shelf availability and translates the new findings generated into a novel inventory control model for retailers. Figure 1.1 gives an outline over the entire course of this research and shows the relations of the chapters. The present Chapter 1 motivates the investigation from business practice and current research, summarizes the main results and the core advances of this research, it offers some key practical insights and implications for managers, and points towards future research based on the limitations encountered and paths outlined.

The remainder of this research following the present Chapter is structured as follows. Chapter 2 lays the theoretical basis for the research, examining and mapping the body of S-D logic research 2004-2011. Chapter 3 applies S-D logic to retail on-shelf availability, drawing on the body of logistics and marketing research into retail on-shelf availability. Chapter 4 transfers the S-D logic view of on-shelf availability into a store/item-level retail inventory control model, combining the literatures and methods of lost sales inventory models and non-stationary demand inventory models. Each chapter states their respective research design and scope, limitations, summarizes key insights and points towards further research.

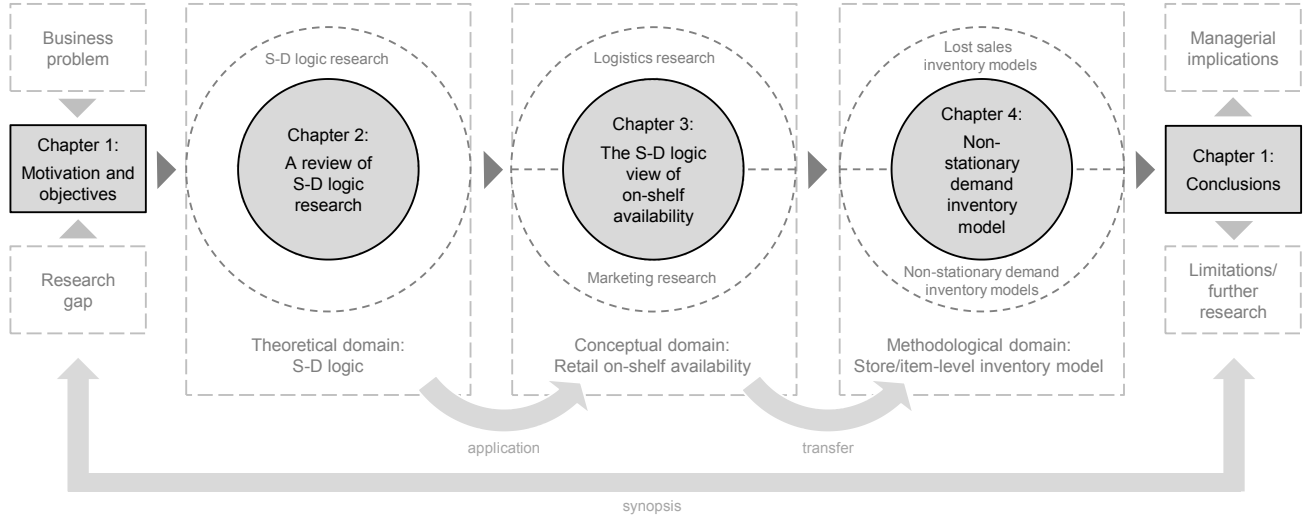


Figure 1.1: Outline of the course of this research

The following sections detail the outline of the respective Chapters.

Theoretical foundation: Advances, applications and opportunities in Service-Dominant logic research

As the theoretical foundation, we conduct a literature review of publications on S-D logic published between 2004-2011 in Chapter 2. We analyze each publication's content with respect to their conceptual, methodological and substantive domain. The resulting data basis were 1294 publications categorized in 131988 data points. Three results of the review are central to this research. (1) S-D logic seems to have evolved from services marketing towards a broader conceptualization of value-creation in networks. It thus appears particularly useful in analyzing logistics problems. (2) The existing premises of S-D logic enable the framing of occurrences and problems with multiple causal relationships, as in on-shelf availability. (3) Two key areas for further research in S-D logic are apparent. We find that the notions of value attenuation, as opposed to value creation, and physical availability are overlooked in current S-D logic research, and that few publications attempt to provide quantitative support for advances and applications of S-D logic. The synthesis of S-D logic research further yields insights into the scientific application of S-D logic, which are a necessary foundation for the following Chapters 3 and 4. In addition, insights for managers, research implications beyond this research, and practical guidelines on conducting S-D logic research are given.

Conceptual development: The Service-Dominant logic view of retail on-shelf availability

In Chapter 3, we examine on-shelf availability and the effects of out-of-stock items through the (S-D) logic lens. We present a conceptual study in which value attenuation due to out-of-stock is examined in the context of fast-moving consumer goods retailing. Combining S-D logic research with recent applications of S-D logic in supply chains, this chapter examines the role that out-of-stock items play in value attenuation throughout the retail supply chain and its networks of actors. It argues that value-creation through on-shelf availability arises through the spatio-temporal integration of actor resources. It identifies the shopper as an active entity whose response to out-of-stocks redistributes value within the retail service ecosystem. An additional model is developed that illustrates the new costs of a stockout that are uncovered by the S-D logic perspective. Moreover, it shows how this perspective can bring previously misaligned incentives of supply chain actors into alignment and how retailers can facilitate value-co creation by better matching supply and demand. Chapter 3 suggests further research into customers' spatio-temporal availability requirements as a starting point for co-creation of value in retail supply chains. Chapter 3 therefore motivates Chapter 4.

Methodological application: The value of accounting for demand seasonality in retail inventory control

In Chapter 4, we translate the S-D logic concept of value co-creation through spatio-temporal resource integration into an inventory model, as inventory models are underlying retailer's on-shelf availability considerations. We investigate the value of adjusting on-shelf availability to match shopper demand, i.e. the value of accounting for demand seasonality. Drawing on the knowledge that on-shelf availability must be managed on the store-item level, we develop a novel single-location, single-item periodic-review lost sales inventory problem with non-stationary demand. Shopper demand is cyclical, the lead time is shorter than the review period, and orders are placed as multiples of fixed batch sizes. We consider the cost structure to match retailing and to comprise costs per order, per batch and per unit as well as holding costs and a penalty for stockouts. To investigate the value of accounting for seasonality, we simulate the performance of four optimal policies that take into account varying degrees of seasonality using the long-run average cost criterion (69696 calculations). We apply the problem to a real life setting, using actual Point-of-Sales data and replenishment information (16200 calculations). Our data sheds new light on to the variation of demand across and within days in a retail setting. Chapter 4 provides quantitative insights on the benefits of adopting a S-D logic

view and incorporate on-shelf availability to match variation in shopper demand over the case of aiming to provide constantly high levels of on-shelf availability. Please note that this research embraces the customer perspective, and relies on previously identified issues and solutions, specifically the improvement of store operations (e.g. Gruen et al. 2002, Hofer 2009, Ehrental and Stölzle, forthcoming), and directly models all cost changes (including handling) that are caused by changes to the order quantity. The resulting solution, then, is optimal given extensive and realistic model assumptions. Please further note that the model uniquely service-dominant as it transitions retail inventory decision making from a goal of low availability cost to a broader model that embraces the cost of non-availability to retail customers in finding optimal on-shelf availability solutions as well as demand considerations, which previous models have lacked (Aastrup and Kotzab, 2010).

1.3 Conclusions

This research explores the S-D logic view of on-shelf availability in retailing. To this end, it utilizes S-D logic, in three steps. First, it gives a comprehensive synthesis of S-D logic research. Second, it applies S-D logic to on-shelf availability conceptually. Third, it translates the insights generated into a retail inventory control model. Conceptually, the research provides the S-D logic concept of spatio-temporal resource integration for the co-creation of value through on-shelf availability, with the retailer acting as the prime resource integrator. Results from testing a retail inventory model that includes shopper demand and response to non-availability and allows for setting differentiated levels of on-shelf availability support the S-D logic perspective and indicate under which circumstances its application may benefit retailers. To the best of our knowledge, this research provides the first comprehensive review of S-D logic research, the first application of S-D logic to retail on-shelf availability, and the first retail inventory model of its kind. The multi-level theoretical, conceptual and empirical work as well as the consolidation of logistics and marketing research brings a rich and unique combination to this research. The following concludes major findings of each of this research.

What are advances, applications, and research opportunities in S-D logic? Chapter 2 reviews and synthesized the diverse structure of S-D logic research since 2004 based on the validity schema. In addition to its mapping of the S-D logic research landscape, it indicates redundancies in S-D logic, identifies future topic areas and guided research and practice in the application and development of S-D logic, which by itself has been scarce. Chapter 2 thereby derives the need for empirical validation of S-D logic and concepts derived from S-D logic, and provides starting points for refinements and simplifications

of S-D logic. To this end, it identifies suitable inferential tools and methods, and outlines the many research opportunities that arise in the testing of S-D logic’s assumptions, on S-D logic (network) modeling, and on reconciling different techniques of causal analysis, investigating multiple relationships. While our results suggest a broad range of substantive areas and methodological approaches to fruitfully apply S-D logic in further research, future contributions to S-D logic should be targeted towards advancing its evolutionary development. Specific to this research, Chapter 2 proposes to investigate value attenuation, as research in S-D logic had previously focused on value creation, which limited its applicability for service failures, such as retail out-of-stocks. Mapping the scientific landscape, this Chapter adds to this dialogue and debate on S-D logic and guides future applications and advances of S-D logic, showing how S-D logic facilitates theory development in a (partially) unified research environment. It proposes a structure for future research as well as some boarder insights for business practice, which we hope to provide a common framework for constant future theory development, which will remain the prime source of S-D logic’s productivity, as is evident by the abundant conceptual research ongoing as this research is in press.

What is the S-D logic view of on-shelf availability? Chapter 3 is concerned with the S-D logic perspective on retail on-shelf availability. It addresses the issue of out-of-stocks as supply chain failures and their consequences when a shopper encounters an out-of-stock of a desired item at a retail store. Previous research from the G-D perspective had focused on the costs and causes of out-of-stocks, seeking ways to improve the on-shelf availability of products on the retail shelf through improved supply chain practices. Chapter 3 transcends this view, and from a service-dominant perspective developed and presented a model of value co-creation where manufacturer supply and shopper demand meet in the retail store. Failures in on-shelf availability may render service-exchange and the co-creation of value impossible, alter a firms’ value proposition, and attenuate value: Based on shopper response to out-of-stocks, value becomes redistributed throughout the retailing ecosystem, impacting both retailer and manufacturer in previously understated ways. While showing the various value-attenuating effects caused by non-availability, it concludes to provide retail on-shelf availability as to spatio-temporally support shopper value creation. The S-D logic view of retail on-shelf availability unveils and characterizes an array of effects related to value-creation and value attenuation on multiple levels in the retail ecosystem. It points towards new common grounds and mechanisms for retailers and consumer goods manufacturable to work towards improving on-shelf availability and sheds new light on the shopper-user implications with respect to on-shelf availability. The multitude of effects is re-arranged and presented in a model for value attenuation that encompasses overall effects, as well as new and relationship related severity parameters,

which calls for further research.

What is the cost of neglecting demand seasonality in retail inventory control? Chapter 4 translated the S-D logic concept to retail inventory control. Specifically, it developed a single-location, single-item periodic-review lost sales inventory problem with non-stationary demand. In an addition to developing the mathematical model, Chapter 4 investigates the value of differentiated on-shelf availability levels empirically from a numerical and a real life retail setting. It compares different inventory policies on the basis of long-run average costs. The inventory policies are distinguished by the degree as to which they can account for non-stationary demand as well as differing sophistication levels of ordering systems. Ordering, replenishment and cost structures are modeled as they occur in practice, and shopper response to non-availability and demand variability are included in this model. The results pointed towards situations where an implementation of differentiated on-shelf availability levels is beneficial to retailers. Cost savings are higher for fast-moving items with high demand variability across review periods and low case pack size. When demand is high, and cyclical demand variation is high, when ordering and handling costs are low and out-of-stocks are costly, accounting for non-stationarity in demand is most beneficial. Cost savings are higher for fast-moving items, low case pack size and high demand variability across review periods. e.g. the days of the week. More broadly, Chapter 4 transcended the reasoning for holding retail inventory as protection against demand towards a goal of co-creation of value with customers, and shows its boundary conditions. This part of the research integrates logistics considerations with non-availability impact as well as impact severity as represented in demand variation, which is implied in the S-D logic perspective of balancing the customer (network) perspective and with resource integration aspects of the offering retailer network. Despite these advances in customer and demand integration and the evidence favoring such integration under the specified circumstances, the model can only be a starting point for refinements towards building compelling retail service offerings (through on-shelf availability) at adequate cost. On a very practical level, it shows that even a partial integration of customer and demand considerations can lead to considerable cost reductions, which, in terms of S-D logic, delivers a more attractive value proposition to shoppers. Further research avenues and applications to related industries are highlighted.

The implications for management, limitations and resulting avenues for further research are given in the following sections.

1.3.1 Implications for management

Despite its basic research nature, there are significant learning opportunities to be gained from the S-D logic view of retail on-shelf availability and its application in inventory

decision-making. First, retail managers are offered a view that, centered around customer value-creation, traverses firm boundaries and transcends the traditional view of on-shelf availability as protection against stockouts towards a goal of service provision, which can be used as a starting point to effectively and efficiently develop the service offering and orchestrate the value network accordingly. Second, managers in the consumer goods industry (i.e. retailers and manufactures) are offered new insights on the opportunity of collaboration towards jointly improving on-shelf availability as a vehicle for customer value-creation. Third, retail managers are given empirical evidence on when, why and how they can expect benefits from taking on a S-D logic approach to improving on-shelf availability in inventory control. Specifically, this research offers the following insights and actionable implications for management to improve on-shelf availability, which we summarize embedded in adjacent research results as:

(1) Cut costs by adjusting on-shelf availability to match shopper demand patterns. Our numerical experiments and real-life calculations show substantial gains in store inventory handling and holding cost by adjusting shelf inventories to match shopper demand patterns. In environments with high sales, constrained space and large demand variation, such as airports, railway stations, and convenience stores, the impact is most likely to be highest. However, our real-life example shows that even in mid-sized stores with limited demand variability, adjusting inventories to match demand patterns can lead to substantive cost improvements. Cost gains are most likely to be greatest for retailers with sophisticated ordering systems (i.e. low ordering costs), high inventory accuracy (i.e. visibility of demand patterns) and excellent instore execution (i.e. low item handling costs). Guidelines and practical cases on how to improve in these areas are given in research by Angerer (2006), Placzek (2007), Hofer (2009) and cases in Helm and Stölzle (2009). As the model accounts for different levels of sophistication in retailer ordering systems, it also becomes practical in estimating the benefits of related technology investments.

(2) Use the inventory model to justify change towards improved on-shelf availability. The inventory model provides a way of calculating the benefits of adjusting on-shelf replenishment to match shopper demand patterns, and can be used to identify suitable stores and items for pilot projects - if an application is justified by simulation results. The model holds for any given demand pattern and can be modified to match a variety of replenishment setups and costs and programmed into a heuristic tool. Historical sales data and replenishment schedules are readily available to retailers. The cost structure can be obtained from internal cost and productivity reporting or approximated from industry benchmarks (e.g. Curşeu et al., 2009; Gruen and Corsten, 2008). Our analysis is designed to incorporate an out-of-stock severity measure based on shopper behavior, which retailers may estimate from their customer satisfaction surveys or model as an array of realizations

as sensitivity analysis. Fisher and Raman (2010) provide an easy-to-use calculation to link inventory performance to profits and earnings per share. In combination, retail logistics managers have robust quantitative support to justify investments in inventory management improvements.

(3) Identify collaborators for on-shelf availability improvements. We identify different motivations and incentives for retailers and manufacturers to engage in on-shelf availability improvements. These insights can be used for a structured identification of potential partners (and co-financiers) of on-shelf availability improvement projects. With the benefits mapped out quantitatively, and by addressing specific partner's goals in on-shelf availability, finding common ground for joint projects is facilitated. The new insights on the broad negative effects of out-of-stocks on the retailers and manufacturers, spanning across different functions and levels, may provide a starting place to begin to co-create value through joint solutions to improving on-shelf availability.

(4) Innovate logistics management using the Service-Dominant logic view. The S-D logic view helps retail logistics management in finding the best 'when and where' to position their offerings to shoppers, and thereby to grow their business as prime resource integrators that enable and facilitate the exchange of service. Fostering distribution thought and management towards a goal of service provision, S-D logic may provide the grounds for logistics management in other environments to co-create value with network partners in solving related availability problems, such as in spare parts management and performance-based contracting.

1.3.2 Limitations and directions for future research

This research extends the S-D logic literature by a comprehensive synthesis and by considering value attenuation through failures in Physical Distribution & Logistics management. It extended S-D logic literature by investigation value attenuation, the retail on-shelf availability literature by showing out-of-stock based value attenuation in the retail ecosystem and its actors and networks, and it extended retail inventory modeling by developing a lost-sales inventory model for non-stationary demand, and more broadly, to research attempting to integrate customer, supply and demand considerations. During the course of the investigation, several promising directions for further directions were identified. Furthermore, several limitations of this research provide interesting ground for future research, stimulating at least the research streams of S-D logic, retail on-shelf availability, and retail inventory modeling.

Concerning the S-D logic, Chapter 2 identifies numerous avenues for further research. Most importantly, S-D logic and concepts derived from S-D logic need validation. To this end, we propose to translate S-D logic's foundational premises into testable hypotheses

for qualitative and quantitative validation. Future research should also target eliminating potential redundancies in the foundational premises, for which Chapter 2 provides a starting ground. The use of S-D logic as a structuring framework as well as its capability to investigate multi-causal phenomena in relational networks leave a wide array of application areas of S-D logic. Consequentially, content areas with a network character and some form of collaboration seem particularly fruitful future areas of application. These include, but are not limited to, supply chain management, sustainability/ethics, and channels/organization. Future research can improve on our methodology by applying advanced bibliometric analyses. This will be particularly useful as the literature base on S-D logic is likely to expand further in the future, making the manual coding and analysis less effective. Further, Chapter 2 gives practical advice on conducting S-D logic based research, in an attempt to provide structure for future applications and extensions. By giving practical advice on conducting S-D logic research as well as towards its practical application, we aim to contribute to the discussions, dialogue and debate on S-D logic. Open ends in S-D logic research are ample, and requirements of the further conceptual and empirical work is needed.

Two promising research possibilities are opened up when adopting an S-D logic view of on-shelf availability in Chapter 3, retailer-manufacturer misalignment and supply-demand mismatches. The first area concerns the relationship of the manufacturer and the retailer, as the retailers' and manufacturers' incentives to reduce to improve on-shelf availability are misaligned, leading to lost potential for value co-creation in the upstream retail supply chain. Future research could consider the factors that lead to such instances (e.g. channel power and complacency) and solution mechanisms. The second area concerns improving the spatio-temporal availability of to support shopper value creation. With the inventory model, this concept has been applied to retailing. Further research is needed into the concept of value attenuation derived, especially of the shopper and the interrelations of user and shopper. On the whole, we believe that the concept presented may be transferable to other industries concerned with availability, such as spares and performance contracting, and used to conduct further research into customers' spatio-temporal availability requirements as a starting point for co-creation of value in supply chains. Nevertheless, quantification of the effects identified and a further empirical validation of the S-D logic view of retail on-shelf availability lie ahead.

The inventory model developed in Chapter 4 has several limitations that provide opportunities for further research and concerning its application in retail practice. These include modeling minimum stock requirements and shelf-space restrictions to account for goods presentation and allow retailers to optimize replenishment cost and shelf space simultaneously. For retailers using advanced inventory monitoring technologies, the model

could be changed from the periodic to the continuous-review case. Furthermore, the model could be embedded into a larger multi-item, multi-location, and multi-echelon system for holistic retailer decision support. We strongly suggest the further integration of customer and demand knowledge of on-shelf availability research into inventory modeling. Likewise, we encourage the further development of modeling approaches to investigate S-D logic phenomena and to validate insights. This study can only serve as a starting point for such research. Last, pilot studies, as currently ongoing in connection with this research, will be valuable in identifying success factors for implementation, especially concerning instore operations. The results of the ongoing and related pilot study on adjusting on-shelf availability to better match shopper demand by the University of St.Gallen’s Chair of Logistics Management should shed light on implementation issues and provide schemes and tools for the everyday practice of retail on-shelf availability management.

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Chapter 2

A review of Service-Dominant logic research 2004-2011

by Joachim C.F. Ehrental

After its introduction in 2004 by Vargo and Lusch, S-D logic has received unparalleled attention from diverse practices and academic disciplines. In order to advance the development of S-D logic and to facilitate its application, this paper reviews the literature published on S-D logic as identified in Google Scholar 2004-2011 in a sample of 1294 publications. Following Brinberg and McGrath (1985), three main study characteristics are reviewed for each publication: the content domain, the methodological domain, and the substantive domain. Mapping the scientific landscape, this paper adds to this dialogue and debate on S-D logic and guides future applications and advances of S-D logic. It proposes a series of simplifications, and a structure for future research.

Keywords: Service-Dominant logic, theory development, structured literature review

2.1 Introduction

The evolution of the business environment has prompted business scholars to reconsider how value is created with customers and suppliers. This representation of economic exchange and business based on value co-creation in service networks is known as Service-Dominant (S-D) logic. Service-Dominant (S-D) logic was formally introduced to the marketing community by Vargo and Lusch (2004) in their article, “Evolving to a New Dominant Logic for Marketing,” which appeared in the *Journal of Marketing*. The article, which is concerned with organizing the past century of marketing research and practice, is the *Journal of Marketing*’s most cited article since 2000 (AMA, 2011). S-D logic contributions in other journals have also received considerable attention. These are among most cited articles over the last five years in the *Journal of the Academy of Marketing Science*, the *European Management Journal*, *Industrial Marketing Management*, *Organizational Dynamics*, *Australasian Marketing Journal*, *Journal of Retailing*, and the most cited article in the history of *Marketing Theory* (Vargo and Lusch, 2012). In spite of massive attention in academic research, S-D logic has neither been universally accepted nor has its place in marketing thought been clearly understood or recognized.

From 2004-2011, Google Scholar has tracked and linked over 2500 citations of the seminal article on S-D logic and its later extension (Vargo and Lusch 2008). This rapid dissemination and intense dialogue and debate has produced a somewhat cluttered and unstructured landscape of S-D logic thought and use. In order to identify emergent structures and to enable the advancement of S-D logic, we present a comprehensive review of S-D logic research, providing an organizing structure for future research and identifying research opportunities.

Taking on the assumption that scientific inquiry develops over time (Kuhn 1996), this review paper has the following objectives: (1) to show comprehensively the structure of research on S-D logic 2004-2011; (2) to identify research opportunities; and (3) to provide avenues to advance the application of S-D logic in research and business practice.

To achieve these objectives, this review follows recent researcher approaches in conducting a literature review based on Brinberg and McGrath’s (1985) validity schema. This approach organizes research as involving the combination of three basic domains: (a) the conceptual domain, which includes the consideration of concepts and relations in their abstract form; (b) the methodological domain, which is concerned with the instruments and methods used in obtaining and relating observations; and (c) the substantive domain, which includes the actual phenomena under investigation.

This research collects, codes and synthesizes the research on S-D logic from 2004-2011

as obtained through Google Scholar¹ to capture various forms of scholarly communication. The particular interest is how S-D logic was used in research and how the field developed. We present our findings chronologically and show the inter-relationships among streams of research. In addition to reviews based on Brinberg and McGrath (1985), details on the academic structure of S-D logic research, such as the types of publication and geographic origin of the research, are included. This shows patterns in the diffusion of S-D logic in publishing and identifies centers of research, the understanding of which may facilitate further scholarly development.

Our analysis shows that while S-D logic has been debated extensively in a wide variety of settings, little research has specifically targeted developing and testing S-D logic. The development of S-D logic has focused on improving the foundations of S-D logic, with the majority of publications being conceptual. Research is needed in testing S-D logic or new insights gained through the S-D logic perspective quantitatively. To guide future research and advancements in S-D logic, and to assess its usefulness and applicability, we propose a structuring framework for further research, as well as simplifications in an attempt to work towards a testable grounding of S-D logic. Our broad approach, covering the main modes of scholarly communication and research fields, brings rich insights and reliable documentation to the debate on S-D logic.

The remainder of this research is organized in four sections. First, we provide a primer on S-D logic with definitions. Second, we present the details regarding the method of the analysis. Third, we present the results of our extant review of the literature on S-D logic 2004-2011. Fourth, we conclude with a discussion outlining future research, application of S-D logic in research and business practice, and discussing the limitations of this research.

2.2 A primer on Service-Dominant logic

In their seminal article, and with later extensions, Vargo and Lusch (2004, 2008) propose a mindset, or logic, for economic exchange and business based on value co-creation in service networks. Their work is grounded in their observations of the changes in the predominant thought in economics, marketing research and business over the past century (for detailed discussions of S-D logic, see Vargo and Lusch (2004; 2008)).

The S-D view is contrasted with a (neoclassical) Goods-Dominant (G-D) view. In the G-D view, value is embedded in a product in the production process, stored in the product and the pre-determined level of utility (i.e. value) is released upon the product's consumption, which is where the value chain ceases. In contrast, S-D logic

¹Please note that Google Scholar references to scientific databases that were used to access the publications.

argues that instead of a consumptive goal, goods are bought to render various types of service (e.g. warmth from clothing), that goods carry a wide array of intangibles (e.g. image, meaning), and that they are inputs to experiences and parts of applications in a broader context, which leads to a different understanding of value creation.

S-D logic views value as being co-created by the reciprocal application of operant resources (knowledge and skills) by resources integrators (actors) and their networks (e.g. a firm and its suppliers) to the benefit of a receiving entity (e.g. a customer). Service is exchanged for service, and value is defined by the recipient in the context of its application (value-in-use). S-D logic sees value creation as continuous through the relational interaction in networks of actors integrating resources within their networks to create a desired service, eventually forming ecosystems of service offerings and exchange (Vargo and Lusch, 2004; Vargo and Lusch, 2008; Chandler and Vargo, 2011; Grönroos, 2011).

Like theory, S-D logic provides set of principles for explaining observed phenomena (see Table 2.1), yet superseding theory, S-D logic provides a view of the world for the unified understanding of the functioning of organizations (e.g. firms, markets) and institutions (exchange, theory, etc.). As such, S-D logic stands above theory, providing a higher level representation by which the purpose and actions of actors can be viewed around the core function of value.

Figure 2.1 summarizes the S-D logic view of value co-creation and exchange of service between a value-offering firm and the receiving customer who both integrate their value-network resources to exchange service and co-create value in ecosystems.

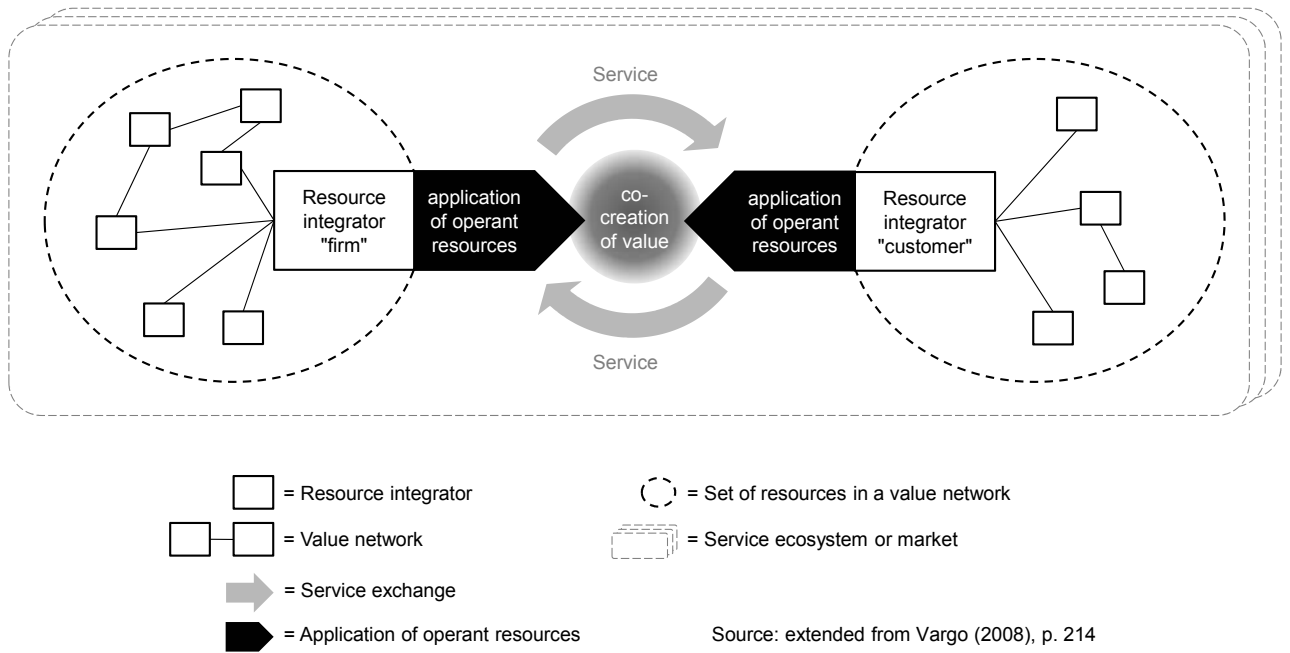


Figure 2.1: An overview of Service-Dominant logic

2.3 Review methodology

Research progress occurs through a combination of some set of theories and concepts, methods and substantive events that constitute alternative paths for research (Brinberg and Hirschman, 1986). To investigate the structure of S-D logic research, we follow recent research that uses the validity schema of Brinberg and McGrath (1985) to develop research fields (Ladlik and Stewart, 2008). These include Grewal and Levy (2007), who extract avenues for further research in the Journal of Retailing analyzing the articles published therein during 2002-2007, which is later complemented by Brown and Dant (2008) with a focus on the methods and inferential tools used in retailing research in the same journal and time period. Other recent applications include the examination of marketing in society as reflected in the Journal of the Academy of Marketing Science since its foundation (Wilkie and Moore, 2011) and the structure of research in strategy and social entrepreneurship (Hamby et al., 2011).

Brinberg and McGrath (1985) provide a framework for the analysis of the research process referred to as validity schema (Brown and Dant, 2008). Brinberg and McGrath (1985) emphasize three interrelated domains: (1) the conceptual domain (theory that may provide insight into the substantive issues under study); (2) the methodological domain (research tools and techniques to grasp the substantive and conceptual domains and validate theory); and (3) the substantive domain (i.e. the problems facing researchers):

The *conceptual domain* concerns theory, i.e. conceptual causes and their relation-

ships. Thus, the conceptual domain addresses potential explanations to the substantive domain. The elements in this domain are constructs, that is, concepts or ideas that provide the building blocks for a theory or model (Hamby et al., 2011). The relations among these elements reflect the theory or model that is applied to better understand some phenomenon of the substantive domain. Research emphasizing this domain will aim at theory-building and opening new fields of investigation.

The *methodological domain* concerns the rigor of an investigation, including research design, data gathering/generation, and analysis and inference (Brown and Dant, 2008). The elements in this domain reflect the measures used to represent the constructs in the conceptual domain (Hamby et al., 2011). Research emphasizing this domain is concerned with testing a theory or concept quantitatively or creating a method or by refining an existing method that may be of use to one or many conceptual domains.

The *substantive domain* describes the real world phenomena and problems of a study's concern, i.e. the study's context and its relevance to the target audience. The elements of the substantive domain are phenomena or states or actions of entities that exist irrespective and independent of the research (Hamby et al., 2011). The substantive domain frames a study in a setting that enables the target audience to identify specific characteristics that may limit or argue for the generalizations of a concept studied in a certain substantive and methodological domain.

We use Brinberg and McGrath's (1985) validity schema to organize S-D logic research into the conceptual, methodological and substantive domain for structuring purposes and as a means to derive implications for further research. The following sections describe the corresponding data gathering and selection process, as well as the coding procedure.

2.3.1 Data gathering and selection

We assume the citation structure of S-D logic to relate to either the introductory article by Vargo and Lusch (2004) or their 2008 clarification paper. We therefore limit ourselves to review all publications citing either article from 2004-2011.

Since it is the goal to capture the entire resonance of the scientific community to S-D logic, and to S-D logic found interest by researchers of many different fields, often highly specialized, publications on to S-D logic have a very broad publication base that may not be captured by focused databases. A recent survey by Chen (2010) shows that Google Scholar covers 98 to 100 percent of scholarly journals from publicly accessible contents and subscription-based databases partnering with Google Scholar. We therefore use Google Scholar as an entry point to direct us to the various specialized databases at our disposal. Other search engines, especially Thomson Reuters ISI Web of Knowledge and Scopus, as well as databases such as EBSCO, Elsevier, Emerald and Proquest were

used to complement the information gathered on Google Scholar if necessary. With this strategy, the vast majority of publications in a given field should be retrieved (Eisend, 2010). The authors had access to all business sciences and related databases and other online research tools available at major universities in the USA and Europe today (for details, please see HSG, 2011; UCCS, 2011; UNH 2011; and TUE, 2011). All data was extracted via Google Scholar USA (.com), which returned most search results in our pre-tests. For instance, Google Scholar Germany (.de) returned 10 citations less for Vargo and Lusch (2004) on July 1, 2011.

Our approach is a reverse application of online tools compare to previous literature reviews in related fields, which conduct a computerized bibliographic keyword analysis in the scientific databases and then complement results with an internet search using Google Scholar (e.g. Eisend, 2009; Hunter and Schmidt, 2004). This is because our analysis does not rely on accurate and standardized keywords, as provided by Web of Knowledge, for instance, but analyze the body of literature citing Vargo and Lusch's seminal 2004 and 2008 articles on S-D logic.

Furthermore, we look beyond journal publications to cover other modes of scholarly communication. Firstly, S-D logic is a nascent theory and may therefore not be accepted in top-tier journals over established fields (MacInnes, 2011). Secondly, a decline of conceptual articles in top-tier journals has been noted in recent years (e.g. for the Journal of Marketing, see Yadav, 2010). As theory building relies strongly on the conceptual domain (Brinberg and McGrath, 1985), this may lead to overlook discussions and debate elsewhere. Thirdly, the time-lag in scientific discovery and publishing may lead to less insightful results in the already short period of time from 2004-2011. Fourth, using Google Scholar and alternative means of academic communication has become part of common scholarly work (Lutz, 2011). This investigation reflects this development. Lastly, we only consider studies published in English to ensure the reproducibility of the analysis by a broad audience and to prevent translation errors. To evaluate a potential bias and to account for contingent losses of information due to dropping publications because of language and non-availability, we track and report these instances (see below).

The general process of publication retrieval was structured as follows: July-September 2011, we conducted a Google Scholar search for the two seminal works on S-D logic 2004-2010, we filtered the results for the year of publication and for each year, we retrieved the publications as full text (from all sources at our disposal, if necessary from the author), and numbered and saved the documents as our review library and remove duplicate entries. The deadline for publication retrieval from authors and library services was July 1, 2011. This date was chosen to allow for sufficient time for authors and for Google Scholar to be updated through 2012, for which Google estimates a 3-6 months lag. After

publication retrieval, we scanned all documents for citations of the two seminal works on S-D logic and eliminated any falsely detected documents. We tracked these instances as 'phantom citations'. Then, we eliminated all non-English and non-available publications, and tracked all removal instances. Finally, we removed conference and working paper publications that were published in scholarly journals later to prevent duplicate data. We removed such events based on a judgement of content proximity. Again, we track these instances. We then proceeded to study and analyze the publications. We repeat the procedure for the 2011 publications in July 2012, with July 1 2012 as the final date for publication retrieval. For the analysis, we followed the coding outlined in the following sections. To ensure data quality, we follow a four-eye policy and conduct consistency checks on the data.

2.3.2 Coding of publication contents

We code the conceptual, methodological and substantive domains as well as other aspects as outlined below. All data was extracted from the Google Scholar USA (.com) and assembled in a Microsoft Excel file for analysis.

Coding the conceptual domain of Service-Dominant logic research

S-D logic is built on ten foundational premises (FPx), introduced by Vargo and Lusch (2004), with a later modifications by Vargo and Lusch (2008). These premises constitute the elements that make up the conceptual domain of S-D logic. We therefore classify each publication with respect to the foundational premises addressed, albeit not necessarily in an explicit manner. If, for instance, an article cites Vargo and Lusch (2004) and argues that service is the fundamental unit of exchange and that value is always co-created, we would classify this as using FP1 and FP6 without the necessity of an explicit reference to the FP number. For instance, Vargo and Lusch (2008) was classified as using all FPs. If we do not find any reference to an FP, but only a reference to either seminal paper, we classify this as not referencing to any FP. In practice, this determination of FP usage is easily applicable without ambiguity. The following Table 2.1 gives the foundational premises of S-D logic as stated in Vargo and Lusch (2008).

Modified foundational premises of Service-Dominant logic	
FP 1	Service is the fundamental basis of exchange
FP 2	Indirect exchange masks the fundamental basis of exchange
FP 3	Goods are a distribution mechanism for service provision
FP 4	Operant resources are the fundamental source of competitive advantage
FP 5	All economies are service economies
FP 6	The customer is always a cocreator of value
FP 7	The enterprise cannot deliver value, but only offer value propositions
FP 8	A service-centered view is inherently customer oriented and relational
FP 9	All social and economic actors are resource integrators
FP 10	Value is always uniquely and phenomenologically determined by the beneficiary

Source: Vargo and Lusch (2008), p.7

Table 2.1: Coding of Service-Dominant logic research according to the foundational premises

For the development of the conceptual domain, we distinguish between publications that use S-D logic in the following ways: (a) mentioning (tangential), (b) acknowledging, (c) supporting (e.g. commenting on the usefulness of S-D logic), (d) applying (e.g. to an existing problem or an industry), (e) extending (e.g. argue for an additional foundational premise) or (f) testing S-D logic, i.e. using qualitative and quantitative methods to validate foundational premise or an idea/concept directly derived from the S-D logic view. (a)-(c) relate to the diffusion of S-D logic, whereas (d)-(f) relate to its development. Note that all types of uses can also include criticism of S-D logic. Table 2.2 summarizes the coding as to the use of S-D logic in a given publication.

Measure of	Classification	Explanation
Diffusion	<i>Mentioning</i>	A tangential reference to S-D logic.
	<i>Acknowledging</i>	Referencing to an element of S-D logic, e.g. 'co-creation'.
	<i>Supporting</i>	A statement of usefulness on S-D logic.
Development	<i>Applying</i>	Applying S-D logic to a problem or industry.
	<i>Extending</i>	Specific proposal to extend S-D logic.
	<i>Testing</i>	Testing of S-D logic or related idea, e.g. quantitatively.

Table 2.2: Coding of Service-Dominant logic research with respect to the use of Service-Dominant logic

Coding the methodological domain of Service-Dominant logic research

For classification of the methods used, we build on the items provided in Brown and Dant’s (2008) review of scientific methods in retailing research. They classify data sources into student surveys, customer surveys, secondary data, laboratory experiments, industry surveys and a residual of ‘other’ sources. Further, Brown and Dant (2008) distinguish among the following inferential tools: qualitative, modeling, regression, ANOVA/MANOVA, structural equation modeling, analytical modeling, and again classify the remainder of methods into ‘other’. For a study that uses a combination of approaches, more than one data point for studies was generated. For instance, Richey et al. (2010), who examine collaborative supply chain service technologies by surveying members of the Council of Supply Chain Management Professionals, was classified as using an industry survey and using regression analysis, because of their use of hierarchical linear regression method. In addition, we classify each publication into broad categories of research type, i.e. conceptual, qualitative, and quantitative. Table 2.3 summarizes the coding used for data sources and inferential tools used in S-D logic research.

Data sources	Inferential tool
<i>Student survey</i>	<i>Qualitative</i>
<i>Customer survey</i>	<i>Modeling</i>
<i>Secondary data</i>	<i>Regression</i>
<i>Laboratory experiment</i>	<i>ANOVA/MANOVA</i>
<i>Industry survey</i>	<i>Structural equation modeling</i>
<i>Other</i>	<i>Analytical modeling</i>

Source: Brown and Dant (2008)

Table 2.3: Coding of Service-Dominant logic research with respect to data source and inferential tool usage

Coding the substantive domain of Service-Dominant logic research

For the substantive domain, we extend the content areas of retailing research outlined by Grewal and Levy (2007). The original elements are: pricing and promotions, product and branding, services, loyalty, consumer behavior, channels and organization, internet/e-commerce and a residual group of ‘other’. Based on our review, we add the following classifications: marketing theory, relationship marketing, social media, supply chain, ethics/corporate social responsibility, innovation, information technology, knowledge management, technology, sales, health care/life sciences, competition, international business, entrepreneurship, operations, political marketing and education/teaching. For a study that relates to several substantive domains, more than one data point for studies was

generated. For example, Shaw and Jones (2005), who reflect on the history of schools of marketing thought, was classified as marketing theory. For each publication, we note the main contribution of S-D logic research with respect to the substantive domain (if any). Table 2.4 gives an overview of the coding of S-D logic research with respect to the substantive domain under investigation.

Content areas by Grewal and Levy (2007)	Extensions to the set of content areas
<i>Pricing and promotions</i>	<i>Marketing theory</i>
<i>Product and branding</i>	<i>Relationship marketing</i>
<i>Services</i>	<i>Supply chain</i>
<i>Loyalty</i>	<i>Ethics/corporate social responsibility</i>
<i>Consumer behavior</i>	<i>Information technology</i>
<i>Channels and organization</i>	<i>Knowledge management</i>
<i>Internet/e-commerce</i>	<i>Technology</i>
<i>Other</i>	<i>Sales</i>
	<i>Health care/life sciences</i>
	<i>Competition</i>
	<i>International business</i>
	<i>Entrepreneurship</i>
	<i>Operations</i>
	<i>Political marketing</i>
	<i>Education/teaching</i>
	<i>Adding social media to 'Internet/e-commerce'</i>

Source: extended from Grewal and Levy (2007)

Table 2.4: Coding of Service-Dominant logic research with respect to the substantive domain

Further attributes captured

To capture the demographics of a publication, and to investigate further elements of the structure of S-D logic research, we include the following information in the coding process: the journal/publication and year of publishing, the lead author, the lead author's institution, and the location of the lead author's institution as given in the publication. We include this information to deduct information on the geographical diffusion of S-D logic in academia as well as identifying key authors and research institutions contributing to S-D logic research.

Moreover, to better assess the impact of S-D logic on different types of scholarly communication, we classify each publication according to its type, i.e. regular journal article, special issue journal article (not necessarily a special issue on S-D logic), commen-

tary/editorial material, conference paper, working paper, and part of an edited volume or book. Journal articles are classified according to the 2011 Thomson Reuters Journal Citation Reports® Impact Factor (Thomson Reuters, 2012), the 22 rankings collated in Anne-Wil Harzing’s Journal Quality List as of April 1, 2012 (Harzing, 2012), as well as Google Scholar Metrics’ h-index (Google Scholar, 2012). Thomson Reuters’ Social Science edition covers more than 2900 journals, Anne-Wil Harzing’s Journal Quality List covers 934. For Google Scholar Metrics, we extract h-indices for 973 journals. For a discussion of journal rankings, we refer to Harzing and van der Wal (2008) and Adler and Harzing (2009).

Overall, we analyze each publication according to 102 distinct criteria, 64 thereof binary.

2.4 Review results

The following sections describe our sample and give a synthesis of S-D logic research 2004-2011.

2.4.1 Sample description

As of July 1, 2012, Google Scholar identifies 2650 citing publications. Out of these, Google Scholar cannot retrieve 200 online or in library systems, leading to 2450 citations. Within these, we identify 350 double entries and 20 ‘phantom citations’ which are counted as citing publications by Google Scholar but do not contain a reference to either seminal paper. This leaves us with a total of 2080 usable citations. As described above, we then eliminate 345 non-English publications, and 440 publications due to non-availability, mostly masters’ theses and dissertations. Also, we removed one conference paper that was published in a journal with the same wording in the following year. This yielded 1294 publications for analysis, 62.21% of all usable citations, or 131988 data points collected for this study (82816 thereof binary).

The number of new publications in our sample rises from 13 in 2004 to 377 in 2011. The majority of publications are journal articles (58.89%). The publications include conference proceedings (17.00%), books/edited volumes (8.35%), special issues (7.81%), and working papers (6.65%). Thus, our sample stems from various sources of scholarly communication, with a focus on journal publications, and reflects the growing scholarly attention to S-D logic. Table 2.5 shows the types of publications in our sample and their years of publication.

Publication	2004	2005	2006	2007	2008	2009	2010	2011	Σ	%
Regular article	6	21	49	87	110	126	147	216	762	58.89%
Conference paper	2	2	7	12	23	26	58	90	220	17.00%
Book/volume	1	1	29	8	8	13	23	25	108	8.35%
Special issue article	1	6	16	3	12	3	45	15	101	7.81%
Working paper	1	2	2	7	7	11	26	30	86	6.65%
Editorial/commentary	2	0	6	4	1	3	0	1	17	1.32%
Σ	13	32	109	121	161	299	300	377	1294	100%
%	1.00%	2.47%	8.42%	9.35%	12.44%	14.06%	23.18%	29.06%	100%	

Table 2.5: Types of publication in our review sample throughout 2004-2011

Concerning the journals, out of the top 10, which make up 31.21% of our sample, only one is on general management (Journal of Business Research, which noteworthily has a marketing editor and a marketing section), while all others are marketing-related. The top 10 journals include several of the most highly regarded journals in marketing research. Overall, we include articles from 304 journals in our sample, which display a wide variety of foci. The average journal quality, as measured by the average Google Scholar h-index is 24.04 for the journals ranked by Google Scholar and 17.29 over all. The average impact factor of the journals tracked by Thomson Reuters is 1.67, 0.81 over all. Hence, we capture developments on S-D logic published in different research fields and include research from top journals, as well as others. Table 2.6 gives the top 10 journals in our sample. The conferences and edited books included in the sample come from a wide array of areas, but display a focus on service sciences. The working papers come from a diverse set of universities and topical areas.

	Journal	Number of publications	Percentage of total
	Marketing Theory	42	4.78%
	Industrial Marketing Management	38	4.33%
	Journal of the Academy of Marketing Science	38	4.33%
	Journal of Marketing Management	29	3.30%
	Journal of Marketing	24	2.37%
	Journal of Service Research	22	2.51%
	European Journal of Marketing	21	2.39%
	Journal of Business Research	21	2.39%
	Journal of Macromarketing	21	2.39%
	Journal of Strategic Marketing	18	2.05%
<i>Accumulated percentage of top 10: 31.21%</i>			

Table 2.6: Top 10 journals in our sample

With respect to geographical distribution of publication, our sample shows the following structure: 46.14% of the publications have a lead author from an institution based in Europe, followed by 33.77% of lead authors from an institution in North America, and

11.36% from Australia (the continent). Thus, despite originating in North America, S-D logic has been taken up in Europe and other parts of the world. Note that with a combined 0.93%, very little research in our sample is from South America and Africa. Table 2.7 shows the geographical distribution of S-D logic research in our sample by continent.

Region	Number of publications	Percentage of total
Europe	597	46.14%
North America	437	33.77%
Australia	147	11.36%
Asia	101	7.81%
South America	8	0.62%
Africa	4	0.31%

Table 2.7: International distribution of the publications in our sample by lead author institution continent

More specifically, the top five countries in our sample, as measured by the location of the lead author's institution, are the USA (31.07%), the UK (13.52%) and Australia (7.96%), followed by Sweden (7.19%), and Finland (5.80%). Note that Scandinavian countries account for 15.53% of publications in our sample. Overall, our sample includes 54 countries, 26.34% of all countries in the world as measured by membership within the United Nations system (United Nations, 2011). So, despite a logical predominance of countries with English as native language (58.89%) as well as dominance of European countries (46.14%), our sample reflects international developments in S-D logic research. Table 2.8 shows the top 15 countries in our sample. They comprise 89.64% of all publications in our sample.

Country	Number of publications	Percentage of total
USA	402	31.07%
UK	175	13.52%
Australia	103	7.96%
Sweden	93	7.19%
Finland	75	5.80%
Germany	67	5.18%
New Zealand	44	3.40%
Canada	34	2.63%
Italy	32	2.47%
Taiwan	28	2.16%
The Netherlands	27	2.09%
France	22	1.70%
Switzerland	22	1.70%
Japan	19	1.47%
Norway	17	1.31%
<i>Accumulated percentage of top 15: 89.64%</i>		

Table 2.8: Top 15 countries in our sample by lead author institution location

Concerning the leading institutions in our sample, as measured by the number of publications, we find a diverse base of research. The top universities in our sample seem to share either one or several of the following features. They have a strong reputation for service research, such as the universities of Karlstad and Linköping. Also, they have a strong reputation for working closely with industry, such as Cranfield University and the University of St.Gallen. Furthermore, they may share a proximity to the originators of S-D logic, such as the University of Hawaii and Arizona. With IBM Research, the third strongest contributing institution in our sample is a publicly held company. Note that eight out of the top 15 institutions are based in Europe and that 27.95% of the research in the top 15 group originates in countries that do not have English as their native language. Hence, the sample criterion of English as publication language appears to be no problem to top universities. Consequentially, our sample is likely to underestimate the use of S-D logic in countries with a native language other than English. Table 2.9 gives an overview of the top 15 institutions publishing research on S-D logic from our sample, which account for 19.63% of the total.

Institution	Country	Number of publications	Percentage of total
Karlstad University	Sweden	34	2.63%
University of Hawaii	USA	30	2.32%
IBM Research	USA, Japan, India	27	2.09%
University of Arizona	USA	19	1.47%
University of New South Wales	Australia	17	1.31%
University of San Francisco	USA	15	1.16%
University of Exeter	UK	14	1.08%
Hanken School of Economics	Finland	14	1.08%
Cranfield University	UK	14	1.08%
University of Auckland	New Zealand	13	1.00%
University of St.Gallen	Switzerland	12	0.93%
University of Otago	New Zealand	12	0.93%
University of Manchester	UK	11	0.85%
University of Cambridge	UK	11	0.85%
Linköping University	Sweden	11	0.85%
<i>Accumulated percentage of top 15: 19.63%</i>			

Table 2.9: Top 15 institutions in our sample by lead author institution

In line with expectations, the originators of S-D logic, Stephen Vargo and Robert Lusch are among the top contributors in our sample (combined 2.87%). Although the number of publications is no gauge for impact or quality, we find that most of the top 15 researchers in our sample are senior researchers and well respected in their fields. Their backgrounds include research and practice of marketing, service, tourism, retail, distribution, manufacturing, and information technology. Overall, we identify 960 unique lead authors in our sample, i.e. the publication base of researchers covered in our sample is very broad. Table 2.10 gives the top 15 authors in our sample, which account for about one in ten publications in our sample (accumulated 10.05%).

Lead author	Institution	Country	Number of publications	Percentage of total
Vargo, Stephen L.	University of Hawaii at Manoa	USA	22	1.70%
Alter, Steven	University of San Francisco	USA	18	1.39%
Lusch, Robert F.	University of Arizona	USA	14	1.08%
Edvardsson, Bo	Karlstad University	Sweden	10	0.77%
Ng, Irene C.L.	University of Warwick	UK	9	0.70%
Grönroos, Christian	Hanken School of Economics	Finland	8	0.62%
Gebauer, Heiko	University of St.Gallen*	Switzerland	7	0.54%
Baron, Steve	University of Liverpool	UK	6	0.46%
Brodie, Roderick J.	University of Auckland	New Zealand	6	0.46%
Doherty, Bob	Liverpool John Moores Univ.	UK	5	0.39%
Enquist, Bo	Karlstad University	Sweden	5	0.39%
Fragidis, Garyfallos	University of Macedonia	Greece	5	0.39%
Spohrer, Jim	IBM Almaden Research Center	USA	5	0.39%
Tadajewski, Mark	University of Strathclyde	UK	5	0.39%
Wild, Peter J.	University of Cambridge	UK	5	0.39%

*Accumulated percentage of top 15: 10.05%. *Please note that Heiko Gebauer is now working for the Swiss Federal Institute of Aquatic Science and Technology.*

Table 2.10: Top 15 lead authors in our sample

To summarize, our sample of 1294 publications covers the main modi of scholarly communication. It spans across various research areas, geographical regions, countries, institutions (including private business research), and exhibits a broad author base. Hence, while our sample covers 61.10% of the usable citations identified in Google Scholar, we assume that our sample represents a comprehensive representation of S-D logic research.

2.4.2 The conceptual domain of Service-Dominant logic research

This section investigates the conceptual domain of S-D logic research as operationalized in the Foundational Premises. It also examines the use of S-D logic in a given publication.

We find that 63.83% of S-D logic research gives a specific statement to a foundational premise (see also Table 2.11). Out of these, a little less than every third publication is concerned with the co-creation of value (FP6, 31.67%). 15.27% of publications reference to FP4, which deals with operant resources and competitive advantage. FP1, which states that service is the fundamental basis of exchange, is used by 11.81%. The aforementioned FPs 6,4 and 1 account for an accumulated 58.75% of S-D logic research. The use of all other FPs ranges between 4.25% (FP2) and 8.30% (FP3). Table 2.11 shows the frequency of use for the FPs in S-D logic research. Note that multiple entries are possible.²

²work in progress: inclusion of FP additions prior to 2008.

FPx	2004	2005	2006	2007	2008	2009	2010	2011	Total	Percentage
FP 1	9	11	29	28	28	32	48	54	239	11.81%
FP 2	3	0	9	8	12	11	18	25	86	4.25%
FP 3	3	7	16	10	26	25	39	42	168	8.30%
FP 4	4	1	20	21	37	57	78	91	309	15.27%
FP 5	3	2	10	10	12	11	18	24	90	4.45%
FP 6	4	14	47	50	70	87	148	221	641	31.67%
FP 7	3	3	13	10	24	21	36	44	154	7.61%
FP 8	2	1	8	6	15	24	25	34	115	5.68%
FP 9	0	1	9	7	12	11	30	55	125	6.18%
FP 10	0	0	6	5	12	13	26	35	97	4.79%

Table 2.11: An overview of the Foundational Premises used in Service-Dominant logic research

Not all the publications using S-D logic, however, are concerned with its development. The use-indicators of diffusion (mentioning, acknowledging, supporting) account for 71.48% of all S-D logic research that gives specific reference to FPs. The use-indicators for application and development of S-D logic (applying, extending, testing) account for 28.52% of S-D logic research. While most supportive publications and applications are based around the major FPs 6,4,1, extensions of S-D logic, such as Vargo and Lusch (2008), who revise the Foundational Premises, give a more balanced attention to all FPs. Table 2.12 shows the frequencies of the FPs used with respect to the use of S-D logic for those publications giving special reference to FPs.

Use of S-D logic	FP1	FP2	FP3	FP4	FP5	FP6	FP7	FP8	FP9	FP10
Mentioning	12	1	3	8	1	15	3	2	4	1
Acknowledging	39	10	21	40	9	119	12	9	10	14
Supporting	63	24	51	106	23	227	51	34	43	23
Applying	89	30	62	114	33	221	53	46	41	34
Extending	30	20	29	34	22	51	33	23	25	22
Testing	6	1	2	7	2	8	2	1	2	3

Table 2.12: An overview of the use of Service-Dominant logic

When analyzing all S-D logic publications under investigation, we find that 36.17% do not give reference to a specific FP, but rather comment on S-D logic as a whole. This entails that not all research using S-D logic is concerned with its details or developments (see Section 2.4.4). Further, we observe that 32.53% of publications reference on a single FP and 15.38% use two FPs. Using three or more FPs is far less frequent with an

accumulated 15.92%. Table 2.13 illustrates the concentration of S-D logic publications on few FPs.

Number of FPs used	Instances absolute	Percentage of total
0	468	36.17%
1	421	32.53%
2	199	15.38%
3	77	5.95%
10	58	4.48%
4	29	2.24%
5	19	1.47%
8	15	1.16%
9	4	0.31%
7	3	0.23%
6	1	0.08%

Table 2.13: Details on the use of Foundational Premises in Service-Dominant logic research

With respect to the absolute number of combinations of FPs, we find the following: Firstly, S-D logic research connects FP6 and FP4 (226 instances), i.e. the customer as co-creator of value with operant sources as the fundamental source of competitive advantage. Secondly, FP6 is frequently used in combination with FP1 (159), FP3 (138), FP9 (115), and FP8 (105). S-D logic research therefore combines these FPs to an argument string: value creation is an interaction where resources are used to exchange service (which may be stored in physical goods) in a multi-actor setting in which value is determined by the service user. Thirdly and similarly, FP1 is often connected to FP4 (133) and FP3 (113), which leads to the conclusion that S-D logic research has evolved primarily around value, its creation and distribution. FPs 7, 8, 9, and 10 exhibit fewer instances of combinations, which may indicate that they have been less relevant to S-D logic research. Table 2.14 shows the combinations of FPs used in S-D logic research 2004-2011. Please note that the main diagonal shows the sum of a Foundational Premise being referred to in isolation.

Combinations	FP1	FP2	FP3	FP4	FP5	FP6	FP7	FP8	FP9	FP10
FP1	237	83	113	133	86	159	97	85	78	67
FP2		86	81	79	78	83	77	75	65	60
FP3			168	112	82	138	97	81	75	65
FP4				309	84	226	105	89	85	72
FP5					90	84	81	77	66	60
FP6						641	138	105	115	84
FP7							154	84	73	68
FP8								115	67	64
FP9									125	71
FP10										97

Table 2.14: An overview of the types of research using Service-Dominant logic research

Compared to the considerable attention as measured by the number of citations, few publications have worked towards the further development of S-D logic. However, by looking at the entire publication base, some trends emerge that entail potential paths for the development of S-D logic. On the one hand, few publications aim to extend and test S-D logic. On the other hand, the Foundational Premises of S-D logic seem to include some redundancies. In combination, a reduction of the Foundational Premises and their translation from into testable hypotheses may foster the development of S-D logic towards increased conceptual validity.

2.4.3 The methodological domain of Service-Dominant logic research

This section explores the nature of the research in our sample, the data sources and the inferential tools used in quantitative analysis.

S-D logic research is dominated by conceptual publications. 68.08% of S-D logic research is conceptual in nature, while 16.31% of S-D logic research contains quantitative analysis. The remaining 15.61% is qualitative research. Table 2.15 illustrates the prevailing nature of S-D logic research in the methodological domain. Please note that 67.31% of qualitative and quantitative research involving S-D logic occurred 2010-2011.

Type of research	Absolute	Percentage
Conceptual	881	68.08%
Qualitative	202	15.61%
Quantitative	211	16.31%

Table 2.15: An overview of the types of research using Service-Dominant logic research

Approaches to data gathering and coding vary greatly in S-D logic research. We find that the most S-D logic research uses secondary data (40.89%), which includes literature analyses and examples from previous research. 24.24% of publications contain no substantial data gathering, which can be attributed to the large body of conceptual research in S-D logic research. Paralleling the qualitative research approaches observed, we also find qualitative information to play a major role in S-D logic research (11.76%). The remainder of data gathering methods includes industry surveys (7.09%) and customer surveys (4.68%). To a lesser degree, modeling approaches are used (4.18%), as well as student surveys (1.91%). The residual group of 'other' approaches to data gathering include citizen, management, and employee surveys. Table 2.16 summarizes the approaches to data gathering and coding in S-D logic research.

Approach	Absolute	Percentage
Secondary data	581	41.47%
No data	339	24.20%
Qualitative	169	12.06%
Industry survey	98	7.00%
Customer survey	66	4.71%
Laboratory experiment	62	4.43%
Modeling	56	4.00%
Student survey	27	1.93%
Other	3	0.21%

Table 2.16: Approach to data gathering and coding in Service-Dominant logic research

Out of the 16.31% of S-D logic research that employ quantitative methods, we observe the following inferential tool usage. Most quantitative publications use some form of regression analysis (55.87%). 21.80% of the quantitative publications apply structural equation modeling. Other publications use analyses of variance, i.e. ANOVA/MANOVA (10.43%), and analytical modeling (7.58%). Remaining inferential tools used include, for example Bayesian modeling and simple descriptive statistics. Table 2.17 collates the inferential tool usage in S-D logic research.

Inferential tool	Absolute	Percentage
Regression	120	56.87%
Structural equation modeling	46	21.80%
ANOVA/MANOVA	22	10.43%
Analytical modeling	16	7.58%
Other	7	3.32%

Table 2.17: Inferential tools used in Service-Dominant logic research

Concerning the methodological domain of S-D logic research, we find no apparent trends over time. Most research is of conceptual nature. While the inferential tools used point towards investigating phenomena with underlying multi-causal structures, we find no indication of a standard approach to doing S-D logic research methods. At current, the methodological domain remains dominated by conceptual research. Complementing the findings in the conceptual domain, very few publications have aspired to test S-D logic or a concept derived by S-D logic qualitatively or quantitatively. Rather, a substantial domain is the focus of consideration of most quantitative and qualitative research using S-D logic.

2.4.4 The substantive domain of Service-Dominant logic research

This section investigates the substantive domain of S-D logic research, i.e. in which fields it has been used. Most prominently, S-D logic has received attention in the area of services research (37.09%). Marketing theory (11.44%), consumer behavior (9.27%), and product/branding (5.87%) are further content areas using S-D logic to a larger extent. In non-marketing research areas, such as supply chain (management), researchers have recently started using S-D logic. For the major substantive domains using S-D logic (top 4, 48.63%), the number of publications is globally rising in time (with the exception of consumer behavior research with S-D logic, which peaked in 2010). However, in the research areas with less than a total of 70 publications 2004-2011, no clear trend to the use of S-D logic is apparent. The 'other' category includes project management and economics, among others. Table 2.18 shows the application of S-D logic to different research areas 2004-2011.

Substantive domain	2004	2005	2006	2007	2008	2009	2010	2011	Total	Percentage
Services	4	9	28	26	60	67	121	164	479	37.02%
Marketing theory	1	5	23	22	22	21	17	37	148	11.44%
Consumer behavior	0	5	6	16	18	13	32	28	118	9.12%
Product and branding	0	2	10	4	7	15	18	20	76	5.87%
Relationship marketing	1	5	13	6	4	9	12	14	64	4.95%
Internet/e-commerce/social media	3	0	3	7	7	13	16	14	63	4.87%
Innovation	0	0	1	3	8	5	9	14	36	3.09%
Information technology	0	0	3	3	7	1	8	14	36	2.78%
Ethics/corporate social responsibility	0	1	6	6	5	5	7	5	35	2.70%
Supply chain	1	1	4	2	4	2	14	7	35	2.70%
Channels and organization	0	0	1	3	2	2	15	5	28	2.16%
Technology	1	0	2	0	0	1	4	14	22	1.70%
Education/teaching	0	1	2	2	3	1	7	3	19	1.47%
Pricing and promotion	0	0	1	1	4	4	1	6	17	1.31%
Sales	0	0	0	1	4	5	1	6	17	1.31%
Health care/life sciences	1	0	0	1	2	3	0	7	14	1.08%
Operations	0	0	0	1	0	3	2	6	12	0.93%
Entrepreneurship	0	0	0	2	1	2	2	4	11	0.85%
Knowledge management	0	0	1	1	0	3	2	2	9	0.70%
International business	1	0	0	3	1	1	3	0	9	0.70%
Loyalty	0	1	0	3	1	0	2	1	8	0.62%
Competition	0	1	2	2	0	0	1	2	8	0.62%
Political marketing	0	0	0	3	0	4	0	1	8	0.62%
Other	0	2	3	2	1	2	5	3	18	1.39%

Table 2.18: An overview of the substantive domain of Service-Dominant logic research

Analyzing the substantive domain of S-D logic with respect to the use of FPs (i.e. with the conceptual domain) yields further insights. Service research, as well as marketing theory-related research shows the substantial use of all FPs, with FP6 (co-creation) being addressed most often. In product/branding research, as well as in relationship marketing FPs 1, 4 and 6 are used most often. In consumer behavior research, FP4 and 6 are utilized most often. With the exception of ethics/corporate social responsibility, which also exhibits a pronounced use of FP6, the other substantive domains of S-D logic research show no clear structure in the use of the FPs. Table 2.19 shows the combinations of research areas and FPs used therein.

Combinations	FP1	FP2	FP3	FP4	FP5	FP6	FP7	FP8	FP9	FP10
Services	121	48	90	142	51	258	76	58	64	45
Marketing theory	22	13	25	24	12	58	17	14	19	14
Consumer behavior	8	3	7	32	4	71	12	7	10	10
Product and branding	13	3	7	16	2	33	8	4	6	4
Relationship marketing	13	2	4	10	2	34	3	4	3	2
Internet/e-commerce/social media	8	2	3	11	1	30	5	4	1	2
Innovation	7	2	3	8	2	18	5	5	4	5
Information technology	5	0	1	4	0	14	3	0	2	0
Ethics/corporate social responsibility	7	2	3	5	2	16	2	3	3	2
Supply chain	5	2	5	13	1	13	3	1	1	2
Channels and organization	2	0	1	6	0	12	2	0	0	0
Technology	3	1	1	4	1	11	2	2	2	1
Education/teaching	3	1	3	3	1	12	2	1	2	1
Pricing and promotion	2	0	0	0	1	9	2	1	0	2
Sales	4	0	1	6	0	12	1	1	0	0
Health care/life sciences	1	0	1	3	1	7	1	0	0	1
Operations	2	0	2	3	0	8	0	0	0	0
Entrepreneurship	3	3	3	4	4	7	2	3	4	3
Knowledge management	0	0	0	3	0	1	1	0	0	0
International business	4	0	1	5	0	2	1	0	0	0
Loyalty	1	1	1	1	1	3	1	2	1	1
Competition	1	1	1	3	2	3	1	1	1	1
Political marketing	1	0	0	1	0	3	2	1	0	0
Other	2	2	4	2	2	6	2	3	2	1

Table 2.19: An overview of the use of Foundational premises in the substantive domain of Service-Dominant logic research

The substantial domain of S-D logic research exhibits wide variety of research fields. On the whole, the diffusion of S-D logic throughout various content areas is increasing with time. In the cases of service research, consumer behavior, and branding, S-D logic appears to have become established. The developments in the substantive domain shows that S-D logic is particularly used in setting that are related to (1) service, (2) innovation/creation, (3) interaction/relation, (4) and networks. Considering the importance of physical products in the exchange of service, i.e. availability as part of the value proposition, and the frequent combination of FP6,3,4 (see Section 2.4.2), research on S-D logic and supply chain management/operations seems underdeveloped.

As with the conceptual domain, the substantive domain of S-D logic exhibits foci on fewer than the ten Foundational Premises, which again suggests redundancies. In addition, as the substantive domain of S-D logic research focuses on the creation of value (FP6), S-D logic may be extended by investigating and incorporating obstruction and destruction of value, which is also observable in practice, such as with service failures.

2.5 Discussion

This review used Brinberg and McGrath's (1985) validity schema to investigate the structure of S-D logic research 2004-2011. Our key findings are that (1) S-D logic has evolved from services marketing towards a broader systems framework to address value-creation in networks. (2) S-D logic is well suited to investigate multi-causal problems. (3) While S-D logic research has focused on the co-creation of value, little attention has been given to value-attenuation. (4) While many publications have used S-D logic to generate new insights for other areas, theoretical and conceptual advances of S-D logic itself are rare. In particular, (5) few publications attempt to provide qualitative or quantitative validations for advances and applications of S-D logic. Furthermore, we show potential redundancies in the Foundational Premises as a starting point for the further development of S-D logic.³

2.5.1 Implications for research

Our synthesis of S-D logic research yields several implications for S-D logic research and provides directions for further research. While our results suggest a broad range of substantive areas and methodological approaches to fruitfully apply S-D logic in further research, future contributions to S-D logic should target its development. Most importantly, as suggested by the validity schema, S-D logic lacks qualitative and quantitative validation. S-D logic researchers should therefore work towards deriving testable hypotheses for S-D logic. Our analysis of the use of S-D logic with respect to the Foundational Premises, which in their present state seem to have some redundancies, provides starting points for this research. For validation of S-D logic concepts, researchers may apply inferential tools that enable the validation of multi-causal phenomena. Furthermore, using a common framework is important to S-D logic research, as to provide the constant theory generation organizing structure as S-D logic evolves. This is needed due to the extant volume of work on S-D logic and its continued, rapid growth.

Strong contributions to the S-D logic literature will not solely come from the applications of S-D logic from new content domains. While issues such as the relation of S-D logic as a systems perspective to other systems perspectives/networking fields (e.g. supply chain) may provide a further clarification of S-D logic concepts, and implications for new research fields may benefit from an application of S-D logic, S-D logic development must be encouraged. This may continue conceptually, as well as in iterations with business practice through cases and field studies, as well as industry surveys. We outline many open ends in S-D logic (e.g. directing research towards understanding non-value-

³work in progress: improving the entire discussion/implications/future directions.

creation and value obstruction as opposed to focusing on value creation, to clarify value, to investigate shared values etc.).

Our review of the methodological domain of S-D logic research shows that it embraces a variety of methodological approaches. We show that various content areas in S-D logic research have applied different data sources and inferential tools. Qualitative research methods have flourished in S-D logic research and have been used to investigate a wide range of issues. This seems logical as much of S-D logic research has (in the words of Smith, 2003) focused on showing the boundary conditions of the G-D view and consequential 'gap-filling'. However, the use of quantitative tools lags other methodological approaches; methodological contributions from S-D logic research are scarce. Therefore, research needs to attribute more efforts into how to model and test S-D logic phenomena. Research opportunities include testing the assumptions on which S-D logic relies, modeling, reconciling different techniques of causal analysis, investigating multiple relationships and network modeling may be good starting points. Only in doing so, the proposed differences of the G-D and S-D views can be analyzed and grounded empirically.

On a broader level, our results raise new questions. For instance, how do researchers understand S-D logic, and how do practitioners? Has S-D logic facilitated theory development? What makes researchers cite and then not use S-D logic? Why is S-D logic so prominent in Scandinavia (cultural issues?) and why is South America and Africa not taking up S-D logic research despite its open-access character (is S-D logic unable to explain phenomena in the context of those continents?). What advances has S-D logic fostered new insights in specific domains? In order to answer these and the host of research on S-D logic, we propose a self-structuring of research into the broad categories of a) testig/methods b) applications to theory c) applications to practice d) theory/logic building (definitions, terminology, and comparability with other approaches). We hope our research to provide a mapped landscape of S-D logic research as well as as some guidance for future research.

Appendix provides researchers and reviewers with some guidance on building and evaluating contributions in the field of S-D logic.

2.5.2 Implications for managers

S-D logic has implications for management. S-D logic research highlights and re-examines issues central to business: value and markets. It does so by advocating an interactional systems perspective of economic exchange and value as value-in-use. In value creation, the importance of interactions with customers is emphasized, enabling managers to create and manage interactions in a way that supports the customers' value creation. This has implications for firm strategy, marketing and operations. Firm strategy can be aligned to

facilitate the customer's own value creation. Implications for marketing managers arise by focusing on utilizing customer interaction. Operations benefits from the dynamic networks perspective, of changing roles and compositions of the supply basis and workload share. S-D logic may thus help to better understand customer value creation, and rethink business models and processes and position themselves as resource integrators in subsets of value networks and ecosystems, i.e. fundamental relationships linking value creation. S-D logic thus reflects the changes in the business landscape that has been well documented for advanced economies. For business, S-D logic provides a balanced systems representation of business, with value-in-use at the core, and a set of multi-resource-integrator network system at its disposal.

Therefore, to managers, insights from S-D logic are on a broader level as holistic business logic and structuring tool, or as a means to understand the interaction with partners and customer value creation. It help managers to analyze and solve the myriad of customer wants and needs and to organize value creation facilitating processes and products with customers and supplier networks. It directs attention to the firm's offering when used, yielding information for product design and delivery. However, further research is needed for S-D logic to provide business practice with empirical insights and tool sets.

2.5.3 Limitations

Our methodology has some limitations which have implications for further research. Firstly, the coding process has the potential for human error, which we aimed to reduce by conducting consistency checks within our data and preventing distortions over time by bundling the workloads. Secondly, our level of analysis provides a one-way citation structure. Future research could employ advanced methods of bibliometric analyses to analyze further the developments of S-D logic, broadening its foundations base (i.e. two-way citation structure). Such an approach may uncover efforts paralleling S-D logic research and shed more light on its pedigree in economics and marketing research. However, such methods generally require longer time-periods as inputs and automated bibliographic analysis, for which Google Scholar is not suited in its current form (for recent advances see Chabowski et al., 2010). Thirdly, while a very economical resource discovery platform, Google Scholar does not share its data gathering algorithm (Bakkalbasi et al., 2006), and we must acknowledge the presence of 20 'phantom citations', i.e. errors in citation tracking. While our data basis was manageable manually, studies of a similar kind with a larger publication base may need to account for a citation tracking error in Google Scholar. Yet, the advantage of using Google Scholar is that it searches beyond journal literature to cover other means of scholarly communication. For the purpose of this study, we deliberately incurred the tradeoffs outlined. The high-level nature of our

analysis may be complemented with targeted reviews. A self-structuring mechanism for S-D logic research is proposed in the next section that would aid scholarly reflection and development.

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2.7 Appendix

This appendix gives recommendations on creating meaningful and easy to use S-D logic contributions. Table 2.20 gives recommendations for applications, extensions and tests of S-D logic. This kind of research may be used in the development/capture of a new construct, dimensions, concept, phenomenon, mechanism, method, revisiting previous research from a S-D logic perspective, proposing new relationships between constructs and identifying mechanisms previously found or developing new methods suited for the above, etc.

1	How is S-D logic used (applied, extended, tested)?
2	How is S-D logic applied/extended/tested?
3	Why is S-D logic being used?
4	What is new for S-D logic?
5	What is uncovered/overcome using S-D logic?
6	What difference does S-D logic make in the context and to whom?
7	Does S-D logic lead to different predictions/outcomes to a phenomenon and how?
8	How is S-D logic related to/different from the existing research in the field?
9	Are S-D logic terms defined up-front and used coherently throughout?
10	For applications: is the existing/related work transcended into the S-D logic view?
11	For extensions: are testable hypotheses derived for future research?
12	For testing: is the operationalization appropriate?

Table 2.20: Recommendations for applications, extensions and tests of S-D logic

Table 2.21 gives recommendations to research mentioning, acknowledging and supporting S-D logic without an explicit focus on S-D logic. This may be possible in a call for further research from a S-D logic perspective, for instance.

1	Do you articulate how current thinking and behavior would change as a result of using S-D logic?
2	Is the potential value-add of S-D logic (or its components) derived logically from your results?
3	Can you link your results to specific S-D logic publications (rather than the seminal articles)?
4	Do you state the potential contribution of an application of S-D logic to S-D logic?
5	Reconsider why S-D logic is needed and check if Table 2.20 may be more appropriate.
6	Is the minimal S-D logic terminology needed for your purposed defined?
7	How is S-D logic related to/different from the existing research in the field?

Table 2.21: Recommendations for mentioning, acknowledging and supporting S-D logic without a focus on S-D logic

Chapter 3

Value attenuation and retail out-of-stocks – a Service-Dominant logic perspective

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The goal of this paper is to transcend the Goods-Dominant view of the effects of retail out-of-stocks on sales losses to a Service-Dominant (S-D) logic view that unveils a broad swath of value attenuation across the actors (suppliers, retailers, and shoppers) and their respective networks. It seeks to show that the S-D view provides an innovative way for researchers and practitioners to address out-of-stocks. This paper is conceptual, combining classic S-D logic research with recent research of S-D logic in supply chains, and then applying this to out-of-stocks in a retail setting of fast-moving consumer goods products. The paper develops and presents a model of value co-creation where manufacturer supply and shopper demand meet in the retailer's realm. It identifies the shopper as an active entity whose response to out-of-stocks redistributes value within the retail service ecosystem. An additional model is developed that illustrates the new costs of a stock-out that are uncovered by the S-D logic perspective. Moving distribution thought and management towards a goal of service provision, the paper suggests further research into customers' spatio-temporal availability requirements as a starting point for co-creation of value in supply chains. The paper concludes with managerial implications showing how the S-D perspective can bring previously misaligned incentives of supply chain actors into alignment. Previous research from a Goods-Dominant perspective showed little common ground for manufacturers and retailers to lower out-of-stock levels. With the service-dominant view, compelling rationale to lower out-of-stock levels by both parties is demonstrated. The paper extends the S-D logic literature by considering value attenuation through failures in Physical Distribution & Logistics management. The paper extends the retail out-of-stocks literature by showing the ecosystem created by its actors and their networks. It gives new directions in the modeling of spatio-temporal resource integration to improve on-shelf availability.

Keywords: Service-Dominant logic, on-shelf availability, out-of-stock, supply chain, value attenuation, retail, fast-moving consumer goods

3.1 Introduction

Since the publication of the seminal article of Service Dominant (S-D) logic in marketing (Vargo and Lusch, 2004a), the topic has received widespread attention in academia (Aitken et al., 2006; Lusch and Vargo, 2006; 2008a,b; Lusch et al., 2007). Contrasted with the Goods-Dominant (G-D) logic that, according to Vargo and Lusch (2004a) has dominated marketing thought, “a service-centered dominant logic implies that value is defined by and cocreated with the consumer rather than embedded in output” (Vargo and Lusch, 2004a, p.6). More recently, scholars have applied S-D logic to supply chain management (Mentzer and Gundlach, 2010; Lusch, 2011; Tokman and Beitelspacher, 2011), discussing goods as service provision mechanisms in value networks (Lusch et al., 2010), along with the co-creation of value in supply chains (Esper et al., 2010; Richey et al., 2010; Yazdanparast et al., 2010). In both marketing and in supply chain management, value creation is a central topic in S-D logic research.

But what happens to value creation when a desired item is not available, such as when a shopper encounters an out-of-stock item he or she wants to purchase in a retail store? Logistics researchers have long addressed this topic with the focus on the effects of retail out-of-stocks (Gruen et al., 2002; McKinnon et al., 2007; Kucuk, 2008; Fernie and Grant, 2008; Grant and Fernie, 2008; Trautrimis et al., 2009; Aastrup and Kotzab, 2009). The topic of out-of-stock items has been also recognized as an important topic in marketing (Hanssens, 2009, p.82), which-from a G-D perspective-focuses on the direct sales losses that result from the lack of on-shelf availability. In both the logistics and marketing fields, S-D logic would view an out-of-stock as creating a situation where value is attenuated, and applying S-D logic to out-of-stock situations provides a broader perspective and enhanced understanding to how value is destroyed, well beyond immediate sales losses that is the focus of the G-D view. In the same way that previous research using S-D logic has examined value creation through networks of actors, we seek to explore the consequent attenuation of value in the case of non-availability. The exploration of service failures from an S-D logic perspective, such as that which occurs in a retail out-of-stock situation, has been suggested as being a fruitful area of research for supply chain researchers (Tokman and Beitelspacher, 2011).

The goal of this Chapter is to apply the S-D logic perspective to uncover and identify the variety of effects that attenuate value when an item that a shopper wants to buy is not available. We contribute to the emergent stream of research on S-D logic by investigating the effects of non-availability on the co-creation of value in distribution networks in the context of retail out-of-stocks. Due to the abundance of previous research from a G-D perspective in the fast moving consumer goods (FMCG) industry,

the focus of this research is out-of-stocks applied primarily to that same industry, e.g., categories like personal care/health & beauty (over-the-counter medicines, toothpaste, shampoo), fabric care & cleaning (detergents, sponges), pet care (dog food, kitty litter), baby care (diapers, formula), packaged food & beverages, among others. FMCG products are primarily sold through grocery, drug, mass merchant, and convenience retail formats. Our view spans the entire network of multiple shopper-retailer-manufacturer triads, with shopper referring to a buying entity (either individuals or multiple individuals, such as a wife and husband) in a retail store that has an intention to purchase one or more items. Examining the dimension of value attenuation through spatio-temporal non-availability, the S-D logic perspective yields important insights for supply chain research and practice. S-D logic helps identify and understand the myriad of value-attenuating effects that are launched when an out-of-stock occurs, provides a broad perspective to analyze these effects, and points to new directions to address solutions to non-availability. The implication is that through understanding the extent of costs incurred by shoppers, retailers, and manufacturers, any of the three acting parties will be more willing to apply resources and attention to addressing levels of out-of-stocks that have been consistently shown to average at nearly 8% in the FMCG industry (Gruen and Corsten, 2008).

The remainder of this Chapter is organized as follows. First, we examine previous research on retail out-of-stocks, and then introduce S-D logic in the FMCG context. Second, we examine out-of-stocks from a S-D perspective and provide a comprehensive perspective from each of the three actors-manufacturers, retailers, and shoppers. Third, we discuss findings and propose promising implications to research and managerial practice.

3.2 Background

3.2.1 Out-of-stocks from a Goods-Dominant perspective

Research on out-of-stocks has focused on the retailer and logistics causes, shopper reactions and factors influencing shopper response, and the effects on store sales. Previous research in this area has defined on-shelf availability as the percent of items (typically SKUs, or stock-keeping units) that are available on the store shelf at a given point in time, as a portion of the total number of items that were intended to be on the shelf as identified by store planograms or similar planning mechanisms (Gruen and Corsten, 2008). Following this approach, out-of-stocks are most prevalently defined as the inverse of on-shelf availability (Aastrup and Kotzab, 2010), and expressed monetarily in lost sales. A lost sale occurs each time a shopper encounters an out-of-stock, i.e. a shopper

wants to buy an item that is listed for sale in the retail store, cannot find the item in its expected place or desired condition, and thus cannot purchase the item. This focus on the lost sale demonstrates the G-D perspective as it examines the manufacturers' and retailers' ability to make and distribute value-laden units of output to shoppers, who are seen as value receivers (or in the case of an out-of-stock, value not being received).

Using surveys on actual out-of-stocks and field experiments with real and hypothetical out-of-stocks, Progressive Grocer (1968a,b), Walter and Grabner (1975), Schary and Christopher (1979), and Emmelhainz et al. (1991a) identify patterns for shopper response to out-of-stocks, with later extensions by Zinn and Liu (2001, 2008): Customers may switch stores, purchase substitute items (brand switch, size switch, category switch), postpone their purchase or decide not to buy an item at all. The encounter of multiple out-of-stocks during one store visit increases the probability of walkouts without any purchases. Store switching and purchase cancellation directly lead to sales losses. All other responses to out-of-stocks dissatisfy shoppers and decrease the probability of repeat purchases at the same store. On-shelf availability is widely regarded as a key to customer service and satisfaction in retailing (Sloot et al., 2005). While earlier studies were limited in the number of stores, categories, customers, and regions under investigation, Gruen et al. (2002) find a similar distribution of shopper responses across 661 stores and 32 categories from 71,000 shoppers surveyed in 29 countries.

Shopper responses to out-of-stocks constitute undesirable counter-measures as they inflict suffering on customers to find alternatives (Chernev, 2003). From a G-D perspective, Campo et al. (2000) use a utility model with substitution cost (item switching), transaction costs (search and transport) and opportunity costs (not using an item) to illustrate this effect. Testing their model with survey data on hypothetical out-of-stocks, they show that out-of-stocks induce negative utility on shoppers. Although they differ in severity, each of the out-of-stock response options entails negative consequences for retailers and manufacturers due to immediate sales losses, as well as longer term sale losses due to decreased shopper loyalty and satisfaction (Anderson et al., 2006; Breugelmans et al., 2006; Musalem et al., 2010). This is also demonstrated by Campo et al. (2003). Analyzing sales data, they show that out-of-stocks induce customers to buy fewer products and that frequent stockouts negatively impact customer sales.

Shopper response to out-of-stocks depends mostly on issues related to space and time (Kucuk 2004; McKinnon et al., 2007). Emmelhainz et al. (1991b) find that in their field experiment with artificially induced out-of-stocks that the customer's substitution probability depends partially on situational factors, like the urgency of purchase, and habitual factors, such as the frequency of item usage. For instance, Van Woensel et al. (2007) empirically show that substitution willingness increases in urgency of demand for

freshly baked bread. Verbeke et al. (1998) present evidence that customer response to out-of-stocks depends on the availability of viable alternative purchasing locations and the kind of shopping trip (weekly grocery shopping versus additional purchases). In all of these cases, the shopper is viewed from a G-D perspective as being 'acted upon' (Vargo and Lusch, 2004).

Complementary to marketing research on shopper responses to out-of-stocks, logistical causes of out-of-stocks in the supply chain have been investigated. Starting with the Progressive Grocer (1968a,b), several studies have investigated the causal factors for stockouts within retail supply chains (e.g. McKinnon et al., 2007; Kucuk, 2008; Fernie and Grant, 2008; Grant and Fernie, 2008; Trautrimis et al., 2009; Aastrup and Kotzab, 2009). In contrast to service levels between suppliers and retail distribution centers, which are reported as close to 100%, availability is regularly reported to deteriorate on store shelves (Gruen et al., 2002; ECR Europe, 2003; McKinnon et al., 2007; Gruen and Corsten, 2008; Aastrup and Kotzab, 2009; Hofer, 2009).

The studies on the causes of out-of-stocks investigate a wide array of logistics-related errors and process deficiencies, and typically divide these errors into prestore (upstream) and instore causes. There exists a broad consensus among these studies that most out-of-stocks occur at the store level, primarily through defective ordering and shelf replenishment practices. The prestore causes for out-of-stocks include supplier problems, ordering problems regarding order sizes and specification, case pack quantities, delayed orderings, inaccurate forecasts as well as delayed deliveries from the retail distribution centers or suppliers (Emmelhainz et al., 1991b; ECR Europe, 2003; McKinnon et al., 2007; Aastrup and Kotzab, 2009).

Recently, scholars have started to looking into the instore causes for stockouts with greater detail. Instore causes include manual forecasting augmentations, poor inventory management, placement problems, staff scheduling, and shelf replenishment and return policies (Raman et al., 2001; McKinnon et al. (2007); Van Woensel et al. (2007), Grant and Fernie (2008), Curçeu et al., 2009; Hofer (2009); Trautrimis et al., 2009; van Zelst et al., 2009). Also, research has connected stockouts and category/item characteristics. Stockout rates vary greatly among categories (Gruen et al., 2002; McKinnon et al., 2007), and are particularly pronounced during promotions (Gruen and Corsten, 2008). Other instances leading to higher out-of-stock probabilities are categories with high demand uncertainty, e.g. caused by a high rate of impulse purchases, seasonality effects, and frequent price promotions, as well as special item handling requirements, such as cooling (Fernie and Grant, 2009). The underlying common element of this logistics research is the G-D perspective that improved processes can increase sales by lowering levels of out-of stocks. Table 3.1 summarizes the current knowledge on the extent, causes, shopper

responses and the financial impact of out-of-stocks.

Extent	Causes	Shopper Response	Impact
Global average: -8.3% -one in 13 items is out-of-stock	Instore causes (70-90% of out-of-stocks): -ordering practices -shelf replenishment practices -planning practices	When encountering an out-of-stock, shoppers may: -brand switch -size switch -store switch -delay purchase -cancel purchase	Global average: -4% of sales lost -results in US\$ 0.012 cent losses in earnings per share to retailing investors -shopper dissatisfaction and diminishing store and brand loyalty
Depending on: -measuring method -country and region	Prestore causes (10-30% of out-of-stocks): -delivery delay -shortage at distribution center or supplier Depending on: -store execution -data accuracy -forecast accuracy -shelf capacity -sales velocity -changes in sales velocity, (e.g. promotions) -perishability	Depending on: -brand loyalty -store loyalty -category and item characteristics (e.g. utilitarian) -shopper characteristics (e.g. price sensitivity) -situational variables (e.g. urgency) -available alternatives	Depending on: -shopper response -sales velocity -profit margin -handling cost -inventory holding cost
Sources: Aastrup and Kotzab (2010); Gruen and Corsten (2008); Gruen et al. (2002)	Aastrup and Kotzab (2009); Curçeu et al. (2009); Fernie and Grant, (2008); Grant and Fernie, (2008); Gruen and Corsten (2008); Gruen et al. (2002); Kucuk, (2008); McKinnon et al. (2007); Raman et al. (2001a,b); Trautrim et al. (2009); van Zelst et al. (2009)	Campo et al. (2000); Chernev et al. (2003); Emmelhainz et al. (1991b); Fitzsim- mons (2000); Gruen and Corsten (2008); Gruen et al. (2002); Kucuk (2008); McK- innon et al. (2007); Sloot et al. (2005); Van Woensel et al. (2007); Verbeke et al. (1998); Zinn and Liu (2001, 2008)	Anderson et al. (2006); Breugelmans et al. (2006); Gruen and Corsten (2008); Gruen et al. (2002); Musalem et al. (2010)

Table 3.1: Recent findings on retail out-of-stocks

3.2.2 Service-Dominant logic in the FMCG Supply Chain context

S-D logic, as described in Vargo and Lusch (2004a,b; 2006; 2008a,b, see also Chapter 2) sees service as the fundamental basis of exchange, and expresses the logic in a series of foundational premises (FPs), e.g., service is exchanged for service (FP1). However, the exchange of service may be masked by indirect exchange (FP2). For example, in the FMCG context, the physical product, such as a bottle of shampoo, masks the service of providing clean and healthy looking hair in the pursuit of attractiveness. Within this view, Vargo and Lusch (2008b) describe service as the application of one entity's competencies (knowledge and skills) to the benefit of another. Continuing the example, an FMCG manufacturer creates and produces a shampoo item, delivers it to a retailer who then advertises and distributes it to a shopper, who then obtains value through storage and usage of the product. As such, service is exchanged through a physical good, which acts as a vehicle (distribution mechanism) for service provision (FP3).

In S-D logic, service is viewed as collective resources that when put to use, create value. From the seller's perspective, service is the set of resources available in the offering value network. Lusch et al. (2010, p.20) describe a value network as "a spontaneously sensing and responding spatial and temporal structure of largely loosely coupled value proposing social and economic actors interacting. . . , to: (1) co-produce service offerings, (2) exchange service offerings, and (3) co-create value", of which supply chains are subsets. For value creation, the selling enterprise collates the competencies (product research and development, packaging, customer understanding, advertising, etc.) within its value network and provides these in the form of a value proposition to the customer. From the customer's perspective, the offering is complemented with her/his own value network resources and exchanged against something to the seller's benefit, e.g. money, which the seller can use to expand its resources. Continuing the shampoo example, a manufacturer combines the resources from its network to provide the promise of attractive hair through a combination of soaps, scents, packaging, distribution outlets, communications, and pricing. The customer applies her/his resources (shower, blow dryer, style from the hairdresser, comments from friends, beauty advice from magazines, and so on) with the shampoo to achieve the desired attractiveness. Sellers and customers are thus reciprocally and actively involved in a collaborative value creation process (FP6). In this process, the seller does not directly deliver value but only offers value propositions (FP7) as inputs for value creation, i.e. deliver on its promise. The various inputs are blended in with other value network's value propositions elsewhere; one entity assembles an array of resources to form an offering, which another entity puts to use together with its own resources.

Consequently, both parties act as resource integrators (FP9) and form shared ecosystems of service exchange, or markets (Vargo, 2011). Due to the unique individual specification of the service by the customer, Vargo and Lusch (2008b, p.7) regard value as “uniquely and phenomenologically determined by the beneficiary” (FP10), and therefore dependent on exchange context (Chandler and Vargo, 2011).

3.3 The Service-Dominant Logic perspective of retail on-shelf availability

3.3.1 Value-creation through on-shelf availability

Using the ‘first moment of truth’ where the shopper meets the FMCG manufacturer’s offering in a retail setting in time and space, value co-creation has the opportunity to occur. At the retail store, each resource integrator (shopper, retailer, and manufacturer) is connected with the other resource integrators. As shown in the previous shampoo example, value co-creation assumes on-shelf availability, and is depicted in Figure 3.1. Value co-creation occurs when manufacturer, retailer and shopper integrate their value networks’ resources for a certain point in time and space. The retailer takes on the role of the primary resource integrator, facilitating the exchange of service through providing on-shelf availability.

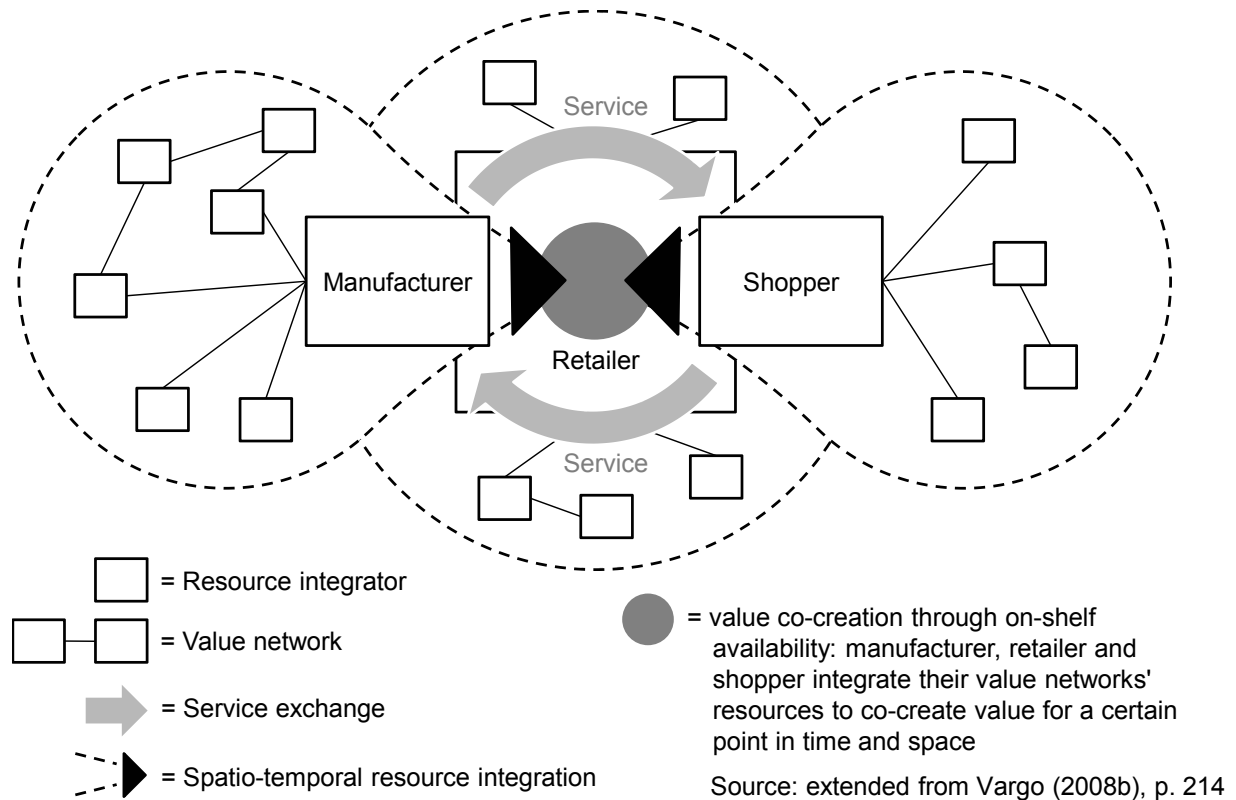


Figure 3.1: A higher-level representation of value creation through on-shelf availability

When the resources of each actor meet at an intended time and location, service exchanged and resources subsequently integrated, value is co-created. In more detail, in the context of retail on-shelf availability, four loci of value can be distinguished:

1. *Availability-to-exchange value*: The shopper has the opportunity to purchase a desired product and may have choice among products.
2. *Exchange-value*: The resources necessary for the transfer of the physical product to take place.
3. *Availability-to-use value*: The physical product provides value as it acts as a vehicle to buffer the time between exchange and use.
4. *Value-in-use*: Solution to the user's need (Vargo and Lusch, 2008a).

Each of these loci of value are determined by the beneficiary (shopper and user) and governed by their specific contexts, and is illustrated in Figure 2. Availability-to-exchange may be very important to a shopper with an urgent demand or the desire to shop around, and as a reminder on what to buy. The retailer influences this by making assortment

decisions and assuring on-shelf availability. Exchange-value is the most prominently observed, because it includes the retail price and promotions which are highly visible. The availability-to-use may be of special importance to deal with unpredictable events, such as having candles and batteries in the house. Availability-to-use value depends greatly on how the manufacturer has designed the product, e.g. storability and perishability. Value-in-use is where the individual fulfills needs through actual use. All four loci represent the value-proposition of the supply side, with the retailer proposing mainly the availability-to-exchange value, and the manufacturer proposing availability-to-use value, and value-in-use. Both retailer and manufacturer are part of the exchange-value proposition. Depending on context, each value locus as determined by the beneficiary may vary.

In that sense, with the shopper visiting a store with the intention to buy a specific product, that the offering retailer has available as the manufacturer had intended (i.e. the supply side value proposition), the shopper eventually buys and uses the product. This integrates the resources of all three parties, co-creating value at multiple loci. This is depicted in Figure 3.2.

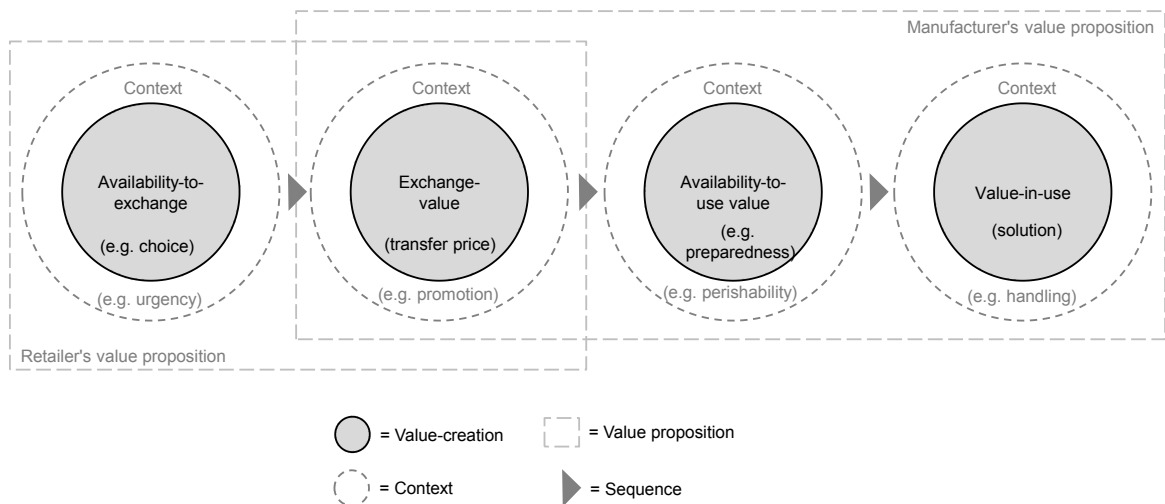


Figure 3.2: Loci of value creation

3.3.2 Value-attenuation through out-of-stocks

From the existing G-D perspective of research on out-of-stocks, examinations of the costs have typically been linked to a product or category. For example, Gruen and Corsten (2008) outline multiple measurements of out-of-stocks depending on the level the loss will be aggregated. Using the S-D perspective, the question is framed to how the out-of-stocks affect overall value creation.

When the problem of out-of-stock items is framed in S-D logic, on-shelf availability

research shows that value-creation in S-D logic depends on the spatio-temporal availability of the offering and represents a prerequisite for the exchange of service. With non-availability of physical goods, service cannot be exchanged and value not created as intended, with the exception of postponing interaction. If the offering retailer and the buying customer manage to integrate their resources to match at a certain place and time, value-creation and exchange through service can take place. Failing to do so will entail costs within the service network.

This infers that non-availability entails a variety of negative effects for shoppers that lead to value-attenuation irrespective of alternatives. For example, customers unable to substitute cannot create a desired service, and the offering counterpart incurs lost sales, which has been well researched from a G-D perspective. From the S-D logic perspective, customer response to out-of-stocks is the re-distribution of value creation, e.g. through switching a store. This changes the dynamics of value attenuation and value creation within retailing, and has several implications for distribution. As a consequence of the reciprocal and mutual nature of exchange and co-creation of value, S-D logic requires the timely interaction of at least two entities available at a certain place and a certain point in time.

However, what happens in the context of S-D logic if a physical good required for value creation is not available, i.e. out-of-stock? Value can be attenuated between any of the three actors when an out-of-stock occurs. The S-D logic perspective shows us that shoppers redistribute value and that value attenuation occurs to the overall network. In the case of the store switch (Figure 3.3, panel A), value-creation is shifted towards another store and retailer respectively. If a shopper decides to substitute brand or item size, value is shifted respectively (Figure 3.3, panel B). If the shopper delays the purchase, value-creation is shifted towards a later point in time (Figure 3.3, panel C). If the shopper cancels a purchase, no value is created (Figure 3.3, panel D). Shopper responses to out-of-stock situations shift value through the retailing ecosystem. Value is attenuated in all cases, and in the case of purchase cancellations, market size is below its potential.

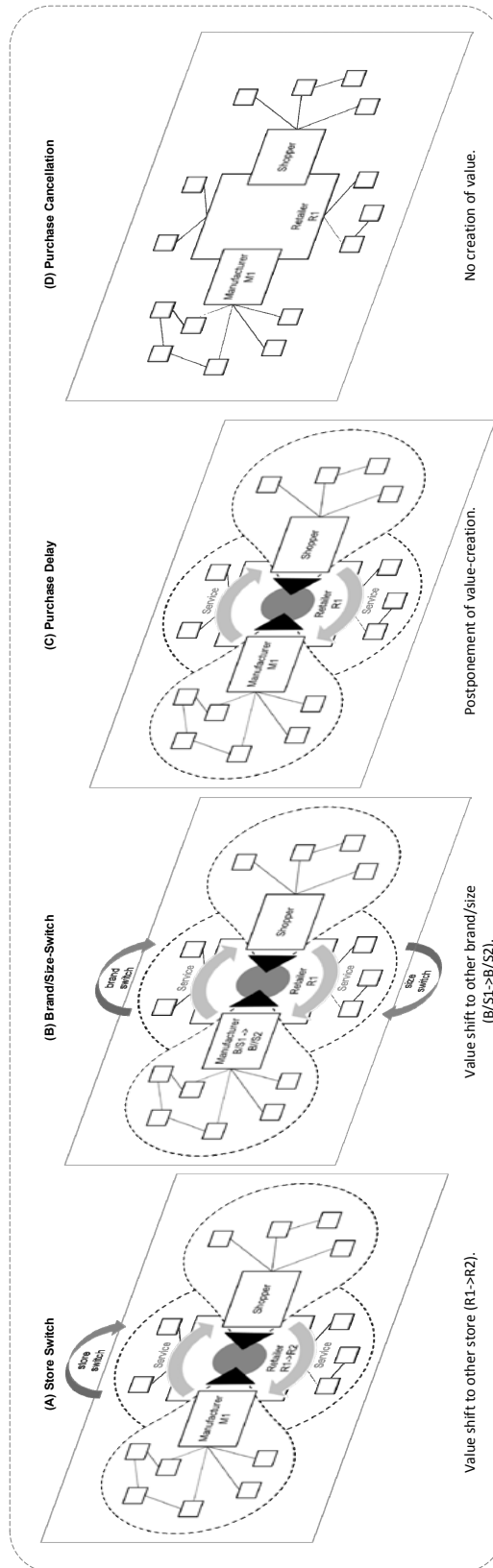


Figure 3.3: Shopper out-of-stock response and its impact on value creation

In addition to the cost of out-of-stocks due to lost sales, more recently, some researchers have added the cost of incorrect demand information ('how much') being provided to the retailer and manufacturer due to out-of-stocks. In these cases, sales data (what shoppers actually purchased) does not match demand data (what shoppers would have purchased had desired items been available), and thus increases uncertainty in retailers' ordering (Gruen and Corsten, 2008). However, little or no attention has been directed towards demand information being sent to the wrong place, thus understating the costs of out-of-stocks. Thus the view of out-of-stocks from the S-D logic perspective provides an improved way to view the broader effects of out-of-stocks.

In Figure 3.3, panel A, the case of a shopper switching stores to (indicated as 'R1→R2'), out-of-stock research has traditionally shown that the cost to the manufacturer is limited. Yet, while the manufacturer receives correct aggregate demand information, the physical distribution information ('where to and when', i.e. ordering procedures, delivery cycle times, and replenishment practices) is askew, as shopper demand is recorded for store R2, which only occurred because of an out-of-stock in store R1. In the case (Figure 3.3, panel B) of a shopper switching brand or item size (indicated as 'B/S1→B/S2'), the retailer receives correct category information, but receives an incorrect signal on the item level, which is passed upwards to the manufacturer. In Figure 3.3, Panel C, the case of a shopper delaying a purchase, both retailer and manufacturer receive incorrect demand and distribution information over time. In the case of purchase cancellation (Figure 3.3, panel D), where the shopper decides to not buy the item at all, both retailer and manufacturer are faced with wrong demand and distribution information.

3.3.3 Developing a model of value attenuation for out-of-stocks

As the previous section demonstrated, using the S-D logic perspective to view the broader costs incurred by the various actors and their networks in an out-of-stock situation, the costs reach well-beyond the sales losses examined from the G-D perspective. As shown in Figure 4 and described below, the different views present different models to recognizing the costs of out-of-stocks.

Shoppers' value attenuation

When facing an out-of stock on intended item purchase, a shopper can incur a range in costs such as extra time and money to find the item at another store, time spent deliberating on the substitutability on alternative items, they suffer personal disappointment and possible loss of face to others in their value network if they cannot deliver items as promised, they need to re-organize their own value creation processes, and are disrupted

in their habits. Combined, these costs lead to a lesser quality solution, because shoppers do not get what they intended at the desired time and place.

Retailers' value attenuation

Out-of-stocks lead to direct sales losses, shopper dissatisfaction, and encourages disloyal shopping at competing stores. Besides suffering direct sales losses and decreasing store equity, the S-D logic perspective shows that retailers incur additional costs in their operations and decreasing returns to investments in operations and sales. This is due to the incorrect demand signal induced by out-of-stocks. The demand signal can be understated on items that were out-of-stock as well as complementary items that would have been purchased in combination with an out-of-stock item. Sales forecasts are made with incomplete information, and thus tend to under-estimate demand when out-of-stocks are frequent. Substitute items have an overstated demand signal due to the desired item being out-of-stock.

This has several implications for the retailer. Incorrect distribution information leads to poor in-store execution, as replenishment staff take care of the wrong items, as inaccurate data from inventory systems provide incorrect forecasting, ordering and shelf replenishment information. In-store, this may lead to inadequate labor supply for replenishment of certain items at certain times of the day or the week, while at the same time inducing higher instore logistics costs through staff looking for out-of-stock items in back rooms, providing instant help to shoppers who cannot find an out-of-stock item, and disrupting the flow of goods in shelf replenishment with unplanned restocking activities, etc. With instore logistics being the highest logistics cost factor in retailing and corrective staff action seldom reported, item and category profitability may be negative without the retailer being able to observe this.

Frazier et al. (2009) show that no fewer than 60 types of knowledge can be shared in the supply chain, which illustrates the potential scope of value attenuation based on data distortion and its impact on physical distribution. The incorrect demand information may cause retailers to make poor assortment management choices due to demand being viewed as being equal to actual sales, tying shelf space to items with lower sales velocity. The incorrect demand signal lessens promotional effectiveness and reduces the return on investment into all systems using transactional data, such as automated store ordering. In both cases, out-of-stocks alter the demand structure in an unobserved way and lead to sustained poor data. This can lower the impact of promotions, and trade promotion budgets may remain misallocated. Moreover, the retailer sends distorted demand and distribution signals into its value network, which may be amplified or cushioned depending on the supply chain setup and data aggregation stages.

Manufacturers' value attenuation

Out-of-stocks cause manufacturers to suffer from a loss of sales, brand loyalty and brand equity. Out-of-stocks push shoppers to try competitors' brands. When out-of-stocks are frequent, shoppers may switch their primary intent to another brand, or even find another category to fulfill the underlying need.

Out-of-stocks increase the overall costs of the relationship with the retailer due to increased audit activity to monitor on-shelf availability, irregular ordering by the retailer, and inaccurate distribution information. The distorted demand also affects manufacturer planning processes, such as forecasting, production scheduling, promotions and new product development. In addition, any distortion in promotional and ordering activities increases the likelihood for billing and accounting errors, leading to increased post-audit costs (Parvatiyar et al., 2005).

Similar to the retailer's costs, the manufacturer incurs a lowered overall effectiveness of marketing efforts and investments into information and operations systems which rely on accurate data. Since manufacturers cannot directly observe out-of-stocks and to protect against a higher forecasting error caused by inaccurate demand information, their sole non-collaborative protection mechanism is to increase inventories and distribution responsiveness to retailer orders, which may lead to higher than needed inventory holding costs and waste in the supply chain. Manufacturer and retailer collaborative planning and execution are hindered, when the manufacturer receives an aggregate signal correct to the store switch, but not correct in the distribution. This hinders collaborative planning and execution, especially in promotions.

Extended out-of-stock cost model

The costs of out-of-stocks using the S-D perspective that were described in the previous section, can be summarized in an extended stock-out cost model, and that is presented in Equation 3.1. The G-D view on out-of-stock encompasses direct sales losses and the long-term sales impact of out-of-stocks on retailers and manufacturers: The costs of out-of-stocks C_{OOS} are comprised of the long-run sales losses to retailer R and manufacturer M , expressed in $s_{R,M}$ and the the long-run sales losses $l_{R,M}$ adjusted by the out of stock type ω , which captures the location, duration and sales velocity.

The S-D logic view on out-of-stocks extends this view by including value attenuation to the shopper S (c_S , depending impact severity β) and the impact of out-of-stocks on the networks of R, M, S ($v_{R,M,S}$, depending on impact severity δ), as well as interaction effects. The notation for the extended out-of-stock cost model is given in Table 3.2.

C_{OOS}	costs of out-of-stocks
ρ	Retailer
M	Manufacturer
S	Shopper (including the user)
ω	out-of-stock type (i.e. where it occurs), duration and sales velocity
$s_{\rho,M}$	the short-term sales losses s for ρ and M
$l_{\rho,M}$	the long-term sales losses l for ρ and M
c_S	the cost c of recovering from an out-of-stock to S
$v_{\rho,M,S}$	the value network impact v of out-of-stock on ρ, M, S
ι_1	impact of shopper response on $s_{\rho,M}$
ι_2	impact of shopper response on $l_{\rho,M}$
β	severity of impact of an out-of-stock on S
δ	severity of impact of an out-of-stock on the networks of ρ, M, S

Table 3.2: Notation for the extended out-of-stock cost model

$$C_{OOS} = \underbrace{\omega\{\underbrace{(\iota_1 s_{\rho,M} + \iota_2 l_{\rho,M})}_{\text{Goods-Dominant view}} + (\beta c_S + \delta v_{\rho,M,S})\}}_{\text{Service-Dominant logic view}}. \quad (3.1)$$

3.4 Implications and future research directions

This Chapter has described how the S-D perspective of out-of-stocks changes the way that out-of-stock actors and the impact of out-of-stocks are viewed as opposed to the G-D view. S-D logic frames the shopper as an active part of the entire retail ecosystem, and as the orchestrator of value redistribution within the retailing ecosystem, a role which was previously not considered from the G-D view. Shoppers' substitution behavior (either store or item within store) sends incorrect demand and distribution signals, leading to a redistribution of value within the retailing ecosystem. S-D logic also contributes new insight into the costs of out-of-stocks to manufacturers and retailers, as value propositions are altered and value is attenuated. The attenuation of value to shoppers and their network, the effects of incorrect demand and distribution information and consequential decreases in related investment and collaboration effectiveness are also uncovered through the S-D view. Table 3.3 summarizes the key extensions of the S-D logic view on out-of-stocks compared to the previous G-D view.

Perspective	Shopper	Retailer	Manufacturer
Goods-Dominant view on out-of-stocks	Role: <i>-innocent victim of supply chain service failure</i> <i>-encounters problem</i> <i>-not considered in the solution</i> Impact: <i>-suffers increased costs</i>	Role: <i>-primary perpetrator of most out-of-stocks</i> <i>-source of the problem</i> <i>-central to any solution</i> Impact: <i>-sales losses</i> <i>-operational inefficiencies</i> <i>-diminished store equity</i>	Role: <i>-supplemental and occasional perpetrator</i> <i>-affected by the problem</i> <i>-passive contributor to solution</i> Impact: <i>-sales losses</i> <i>-diminished brand loyalty</i>
Key extensions through Service-Dominant logic	Role: <i>-orchestrator of value redistribution within the retail ecosystem</i> <i>-is part of the problem</i> Impact: <i>-ultimately carries the financial burden of out-of-stocks (priced into the items purchased)</i> <i>-others in the shoppers' network face increased</i>	Role: <i>-primary resource integrator</i> <i>-central to any solution</i> Impact: <i>-retail ecosystem profits are attenuated due to direct sales losses, increased costs due to distorted demand information and distribution</i>	Role: <i>-secondary resource integrator</i> <i>-proactive contributor to solution</i> Impact: <i>-manufacturer network profits are attenuated due to direct sales losses and distorted distribution information</i>

Table 3.3: Transcending the Goods-Dominant view of out-of-stocks to a Service-Dominant view

We argue that value-creation arises from the spatio-temporal integration of value network resources. Mismatches therein may render service-exchange and the co-creation of value impossible, alter an enterprises' value proposition, and attenuate value. Based on shopper response to out-of-stocks, value becomes redistributed throughout the retailing ecosystem, impacting both retailer and manufacturer in previously understated ways.

The value of the S-D logic approach can be seen in potentially realigning the actors towards joint value creation, based on better understanding how value is attenuated.

Two promising research possibilities are opened up when adopting an S-D logic view on out-of-stocks, retailer-manufacturer misalignment and supply-demand mismatches. The first area occurs in the manufacturer-retailer dyad, where retailers' and manufacturers' incentives to reduce out-of-stocks are misaligned, leading to lost potential for value co-creation in the upstream supply chain (i.e. collaboration). The second area focuses on improving the spatio-temporal availability of items. It calls for providing items on the retail shelf in such a way that it supports the shopper's own value creation, or the user, respectively, when the shopper occurs as the new resource integrator to a user. Figure 3.4 illustrates the positioning of future research areas in the retailing ecosystem.

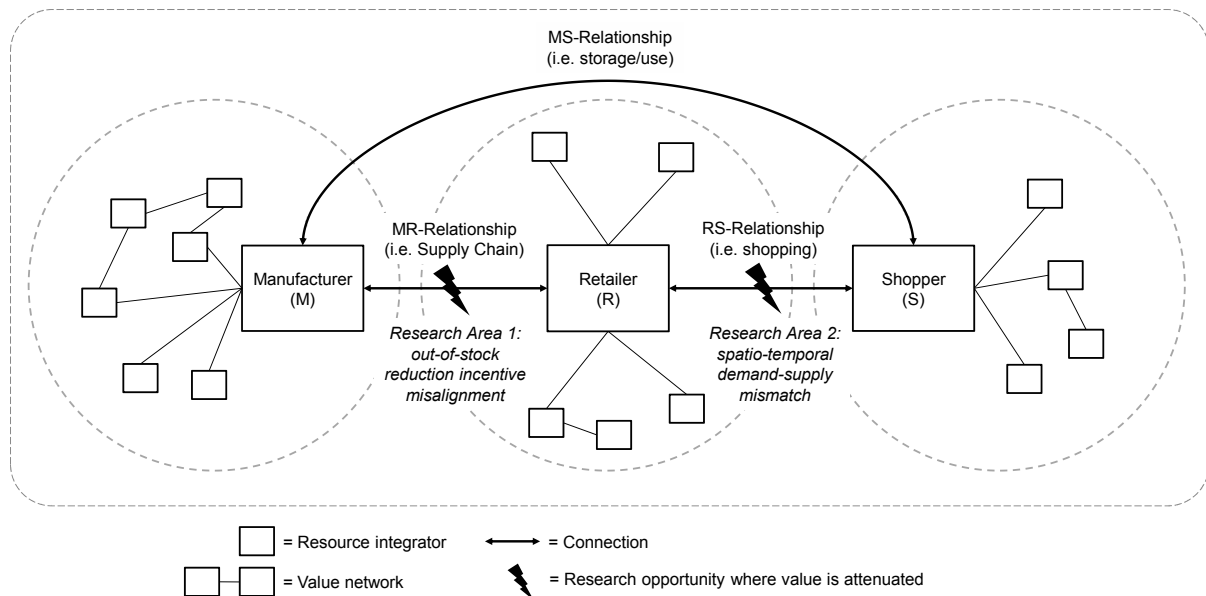


Figure 3.4: Main areas for further research on retail out-of-stocks

3.4.1 Retailer-manufacturer misalignment

As pointed out by Gruen et al. (2002), retailers and manufacturers are misaligned in their incentives to address out-of-stocks. Brand manufacturers are more concerned with losses in brand loyalty (shoppers switching brands), while retailers are more concerned with losses in store loyalty (shoppers switch stores). Viewing stockouts in the interdependent ecosystem view of S-D logic reveals more opportunities for aligning these partner's incen-

tives. Table 3.4 shows where additional common ground becomes apparent. The value attenuation mechanism depends on the shopper's transaction cost, opportunity cost, and substitution cost (Campo et al., 2000). These responses provide incentives to the various actors differently (Gruen et al., 2002). Cases where one actor is incented while the other is not incented (store switch and brand switch) can be viewed from a perspective of greater common loss (value attenuation) across all actors. This can provide a starting place to begin to co-create value through joint solutions to improving on-shelf availability.

If the opportunity cost is...	...and the substitution cost is...	...and the transaction cost is...	...the shopper will...	... value is...	... which is an incentive to improve for...
<i>high</i>	<i>high</i>	<i>low</i> →	<i>buy item at another store</i>	<i>attenuated and shifted to other store (spatial)</i>	<i>retailer</i>
<i>low</i>	<i>high</i>	<i>low</i> →	<i>delay the purchase</i>	<i>attenuated and shifted to other time (temporal)</i>	<i>retailer and manufacturer</i>
<i>high</i>	<i>high</i>	<i>high</i> →	<i>substitute (same brand)</i>	<i>attenuated and shifted to other size item</i>	<i>neither</i>
<i>high</i>	<i>low</i>	<i>high</i> →	<i>substitute (other brand)</i>	<i>attenuated and shifted to other brand</i>	<i>manufacturer</i>
<i>low</i>	<i>high</i>	<i>high</i> →	<i>not purchase item</i>	<i>attenuated and none created</i>	<i>retailer and manufacturer</i>
<i>Sources: costs developed by Campo et al. (2000), adapted from Gruen et al. (2002)</i>					

Table 3.4: Out-of-stock-based value attenuation, value shift and resulting misalignment of incentives

3.4.2 Supply-demand mismatch

Figure 3.1 and the subsequent discussion throughout this paper indicate that value creation and value attenuation are directly linked to spatio-temporal resource integration. In retailing, co-creation of value then occurs when all actors are able to integrate their resources towards a certain point in time and space. This finding has an implication for availability-to-exchange value and the other loci of value creation and presents a new perspective on how the supply side can integrate the resources necessary for service pro-

vision: towards the beneficiary's (shopper and user) own spatio-temporal value creation goals. In the G-D view of on-shelf availability, this supply chain target is absent. The focus of on-shelf availability has the role of protecting the retailer and upstream actors against uncertain demand, and lacks the necessary connection to the shopper.

The S-D logic view could help retailers in finding the ideal 'when and where' to position their offerings. For example, S-D logic may provide the underpinnings for research directed towards enhancing the co-creation of value through high-density offerings, which, drawing on Normann (2001), is "the best combination of resources . . . mobilized for a particular situation - e.g. for a customer at a given time in a given place. . . , to create the optimal value/cost result" (Normann, 2001, p.27). An example of high-density offerings and distribution is Japan's 7-Eleven, that employs an on-shelf availability strategy deliberately taking items off the shelves temporarily to offer shoppers a different assortment to suit a particular store environment's potential customers during the day (Lee, 2004). Thus, retail logistics management research could focus on the integrator role of retailers in providing optimal on-shelf availability levels that support customers in their daily lives by providing the service required at a certain place and point in time as best approximation for on-shelf availability targets in retail supply chains.

Further, separating the role of shopper and user, where the shopper is a value integrator for a particular value network is a novel solution to the value-in-exchange dilemma, and opens up paths to further investigate the S-D logic insights on value attenuation caused by out-of-stocks. Our model's severity parameter could act like an impact scaling variable, where different groups of customers (based on some behavioral preference) would be influenced differently by the presented out-of-stock consequences. This case of a new set of relations and the special case where the shopper is the user, may provide rich insights into the effects of supply-demand mismatches. Also, whether value attenuation effects increase, decrease, or cancel each other out at certain stages (e.g. due to aggregation effects) in the value networks requires further and quantitative attention.

The S-D perspective provides a broadened perspective of understanding and addressing the role of availability and the attenuation of value caused by out-of-stock items in the FMCG industry. This perspective can be generalized to other product and service categories such as replacement parts and less frequently purchased items or to defining targets for availability-based contracting industries. S-D logic can also add perspective in situations of scarcity and limited supply (either planned or due to resource limitations), as the total effects of the actors' networks collide to create value, and then see that value attenuate.

3.5 References

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Chapter 4

A retail inventory policy for cyclical demand – the value of accounting for demand seasonality

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We investigate the value of accounting for demand seasonality in inventory control. We consider a single-location, single-item periodic-review lost sales inventory problem with seasonal demand in a retail environment. Customer demand has seasonality with a known season length, the lead time is shorter than the review period, and orders are placed as multiples of a fixed batch size. The cost structure comprises of a cost per order, a fixed cost per batch, and a per unit variable cost to model retail handling costs. We consider four different settings which differ in the degree of demand seasonality that is incorporated in the model: with or without within-review period variations and with or without across-review periods variations. In each case, we calculate the policy which minimizes the long-run average cost and compute the optimality gaps of the policies which ignore part or all demand seasonality. We apply the problem to a real life setting, using Point-of-Sales data. We find that it is most beneficial to incorporate demand seasonality for high-velocity products with low batch size for which demand across-review periods varies substantially and provide recommendations on how to decrease optimality costs without significantly increasing the complexity of the retailer's store ordering system.

Keywords: Retail inventory control, Lost sales, Non-stationary demand, Seasonality.

4.1 Introduction

The main challenge in managing retail inventory is to match replenishment and demand, that is providing items on the shelf justified by an upcoming shopper demand. Economies of scale in supply, inadequate store execution and demand variation often lead to out-of-stocks and excess inventory. While store execution and retail out-of-stocks have received considerable attention in academia and business practice (see Aastrup and Kotzab, 2010), the impact of demand variation has largely been overlooked (Bijvanck and Vis, 2011).

Demand in retailing is known to vary depending on the day of the week and time of year, around important holidays such as Christmas, and the seasons. For example, ice cream is in higher demand in the summer months. Demand is also generally not evenly distributed within the day. For instance, in business districts more customers shop just after working hours on weekdays. Retailers can, to some degree, reduce demand variation, for instance by reducing promotions or offering 'everyday low prices'. However, customer buying habits, like shopping on weekends, limit a retailer's ability to completely smooth demand variation. This creates the need for retailers to account for seasonality in their inventory control and shelf inventories seasonally, in (partial) synchronization with the demand pattern (Aviv and Fedegruen, 1997).

Yet retailers lack the capabilities or skills to incorporate demand seasonality into their store ordering systems and therefore shelf replenishment. Advanced automated store ordering (ASO) systems allow for different yearly seasonality patterns for each item. However, retailers may choose to use store aggregate or chain-wide demand seasonality patterns, or to ignore demand seasonality altogether because of the added level of complexity. Less sophisticated ASO systems lack the technical ability to include seasonality effects, especially when it comes to weekly or daily seasonality. This leads to systematic mismatches in demand and supply at the item-store level, resulting in higher than needed costs. For example, Gruen and Corsten (2008) show that out-of-sync replenishment and demand lead to recurring out-of-stocks in retail stores on specific days of the week. This raises the question of the importance of incorporating demand seasonality in store ordering.

We study a setting where demand has a known seasonality pattern with two types of variations: within-review period and across-review periods (the review period is defined as the time between when two replenishment orders are placed). We apply our findings to real-life examples where demand follows a seasonality cycle over the days of the week and the times of the day. Figure 4.1 illustrates the seasonality patterns under investigation. It shows the sales of a specific cigarette product (global brand, single box of 10 cigarettes) at a European retail store for two months in 2010. Demand varies depending on the day

of the week: weekly sales peak on Saturday and Sunday. Demand is also not evenly distributed within a day: on Saturday, most of the sales occur before 5pm while on Sunday most of the sales occur after 5pm. In essence, the demand rate varies across days of the week and within the day, but displays the same periodic pattern every week.

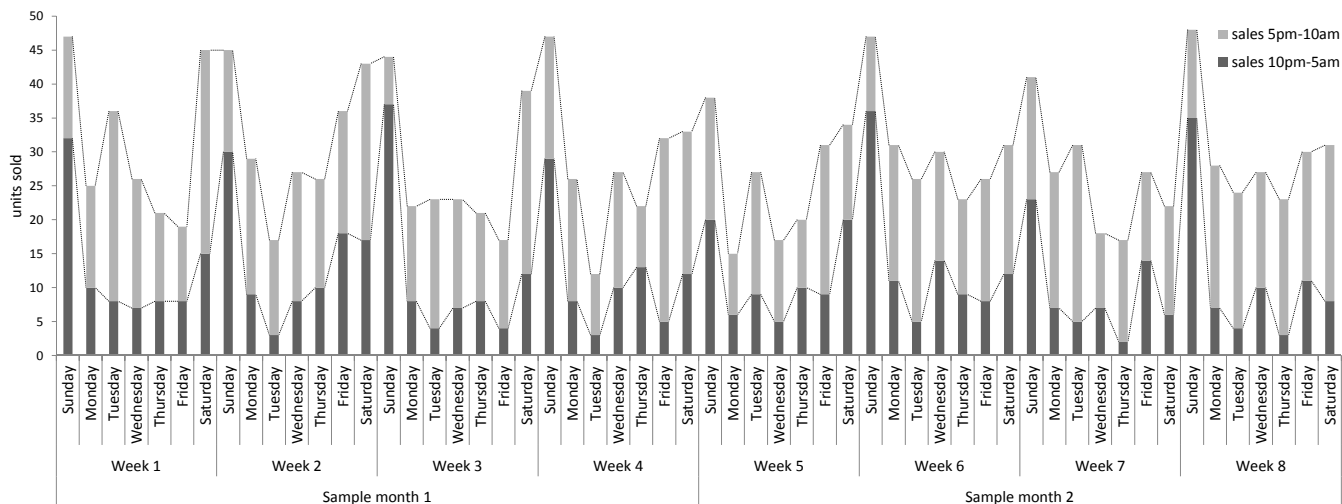


Figure 4.1: Sales seasonality in cigarette sales during a two-month period in 2010

Given seasonal customer demand, we research the following questions: (1) What is the cost of neglecting demand seasonality in retail inventory control? (2) For which type of products is this cost significant? (3) How much can be gained by partially incorporating demand seasonality into an ASO system and what is the best way to do so? We answer these questions in a setting which is suitable for retail environments: we consider a single location, single item, lost sales inventory problem with handling costs where the lead time is shorter than the review period, and orders are placed as multiples of a fixed batch size. Further, we assume that demand is non-stationary and seasonal. We first calculate the optimal inventory policy using the long-run average cost criterion and show how it varies with key parameters of the model. Second, we consider three alternate settings, in which the retailer accounts for varying degrees of seasonality. In the first setting, the retailer only accounts for across-review periods variations. In the second setting, the retailer only accounts for within-review periods variations. In the third setting, the retailer ignores all form of seasonality, which often corresponds to current retail practice. We calculate the performance of the inventory policies for all three settings using the true distribution of demand and compute optimality gaps. We discuss when it is most important to incorporate within- and across-review periods variations into the ASO system. Third, we apply the problem to a real-life setting, using Point-of-Sales data from a European retailer and replenishment information. We also explore simplified policies of only distinguishing between weekday and weekend sales.

We find that it is most important to include seasonal variations for product categories with high sales velocity, large across-review period variations, and small case pack size. Ideally, a retailer should include both within- and across-review periods variations. However, if this is too difficult or costly to implement, we show that in most cases, the next best alternative is to take only across-review periods variations into account. In our real-life application, we further find that the retailer can achieve notable cost decreases by carefully defining the weekend and distinguishing between weekend and weekday demand. We also discuss some special cases where we found that ‘less information is better’, meaning that incorporating only one type of demand seasonality, e.g., accounting for within-review period variations but not across-review periods variations, can lead to worse performance than completely ignoring all levels of demand seasonality.

The closest paper to ours is a recent study by Tunc et al. (2011), who investigate the best stationary policy given that demand is non-stationary. They find that a stationary policy may be a good approximation only if demand uncertainty is high, setup costs are high and penalty costs are low. Our papers have fundamentally different approaches. Tunc et al. (2011) search for the best stationary (s, S) policy given non-stationary demand: the retailer knows that demand is non-stationary but restricts himself to a stationary policy because it is easier to implement. In contrast, this paper considers the best non-stationary inventory policy given a demand pattern that is missing some seasonality information. The retailer incorporates parts of the seasonality in its ASO, for example by using weekly demand estimates. Further, Tunc et al. (2011) use a model with backorders, no lead time, a batch size of one, no handling costs and finite horizon, which limits its applicability to the retail industry. In contrast, we consider an infinite-horizon average cost, lost-sales inventory model, with batch sizes and handling costs.

Our study contributes to the literature in several ways. First, we are, to the best of our knowledge, the first authors to consider the impact of ignoring demand seasonality in a model tailored for retailing, i.e., a model with lost sales, lead times, batch sizes, and handling costs. In our analysis we calculate the optimal policy for each possible demand setting, using dynamic programming. Second, we give insights on the tradeoff between the complexity of an ASO system and the cost benefits of incorporating demand seasonality to various degrees. Third, we include a study based on real-life sales data.

The remainder of this study is organized as follows: Section 4.2 gives a brief review of related single-item retail inventory models with lost sales and inventory models considering non-stationary demand. Our model is presented in Section 4.3. We solve the problem given the true distribution of demand in Section 4.4 then study the costs of ignoring non-stationarity in Section 4.5. Section 4.6 applies the model to a real-life situation. Section 4.7 presents the conclusions and points towards further research.

4.2 Literature

In their comprehensive review on lost sales inventory modeling, Bijvanck and Vis (2011) identify integrating non-stationary demand as a key concern for research. They argue that little is known about the non-stationary setting, despite the importance of understanding non-stationary demand for modeling real life phenomena. In this section, we review the literature on lost-sales inventory models and inventory models with non-stationary demand in reference to retail inventory management.

4.2.1 Lost-sales inventory models

In contrast to inventory models with backordering, where unmet demand is satisfied at a later time, lost-sales inventory models assume that customers are unwilling to wait for their order. Such behavior is frequent for retail out-of-stocks (Campo et al., 2000). Lost-sales models penalize unmet demand to capture the negative effects of out-of-stocks. These include diminished customer loyalty and increased in-store logistics costs through staff attending shoppers and looking for out-of-stock items in back rooms (Gruen et al., 2002).

Compared to the backordering problem, the inventory replenishment problem with lost-sales has been considered far less frequently in the literature due to its more complex structure (Bijvanck and Vis, 2011). Recent developments related to our research include incorporation of fractional lead time. Sezen (2006) uses dynamic programming to show the long-run average cost is rather insensitive to the choice of the period length. Sezen (2006) simulates the impact of the review period length on on-hand inventory for the case of fractional lead times. He finds shorter review periods to be suitable for products with variable demand, and longer review periods suitable for products with less variable demand.

Also recently, handling costs have been added to lost-sales inventory modeling. Curşeu et al. (2011) include store handling cost into the single-item inventory problem in a retail setting. This reflects Van Zelst et al. (2009)’s finding that item handling (e.g. receipt of goods, shelf replenishment) accounts for 75% of store logistics costs, while inventory accounts for the remaining 25% (see also Saghir and Jönson, 2001). Curşeu et al. (2011) examine the optimal policy under the long-run average cost criterion using parameter values typical for grocery retailing. They show that retailers can achieve substantial cost reductions by including handling costs in their inventory decisions.

Non-stationary demand, however, has received very little attention in lost-sales inventory modeling. Reviewing lost-sales inventory models, Bijvanck and Vis (2011, p.11), conclude that it is necessary “to focus more research on non-stationary situations. Even

though steady-state conditions are more analytically traceable, they become less relevant in practical situations due to non-stationary demand. . . . Consequently, the methodology to analyze lost-sales inventory systems should change accordingly.” To fill this gap, we seek to explore a lost-sales inventory problem under non-stationary demand and review the corresponding literature.

4.2.2 Inventory models with non-stationary demand

Compared to models assuming stationary demand, studies on non-stationary demand inventory models are scarce (Tunc et al., 2011). Previous work on non-stationary demand settings includes Karlin (1960a,b), who treats the discounted version of the non-stationary demand problem, assuming stationary costs and variable demand. Karlin (1960b) gives an algorithm to calculate the optimal policy. Morton (1978) studies similar problems in a non-stationary setting (not necessarily periodic) and proposes that myopic and nearly myopic policies are optimal in most cases where excess stock can be discharged at low cost. Later, Zipkin (1989) considers an (uncapacitated) infinite-horizon inventory problem with stochastic demands where demand varies periodically. He introduces cycle-adjusted costs and provides a proof that a base-stock reorder policy is optimal under the average cost criterion. Aviv and Fedegruen (1997) show that in a capacitated setting, a periodically modified base-stock policy is optimal under the discounted and long-run average cost criteria. Other problem sets, such as the finite-horizon case, have also been studied (e.g. Morton and Pentico, 1995; Kapuściński and Tayur, 1998). Table 4.2.2 summarizes key approaches to modeling inventories with non-stationary demand. Note that none of these models include handling costs in their formulation.

	<i>lost sales</i>	<i>backorders</i>	<i>capacitated</i>	<i>fixed cost</i>	<i>lead time</i>	<i>demand seasonality</i>	<i>capacity seasonality</i>	<i>cost seasonality</i>	<i>finite horizon</i>	<i>infinite horizon</i>	<i>discounted cost</i>	<i>average cost</i>
Karlin (1960a)	✓	✓	×	×	×	×	×	×	×	✓	✓	×
Karlin (1960b)	✓	✓	×	×	✓	×	×	×	×	✓	✓	×
Morton (1978)	✓	×	×	×	×	×	×	×	×	✓	×	✓
Zipkin (1989)	✓	✓	×	×	×	✓	×	✓	×	✓	✓	✓
Morton and Pentico (1995)	✓	×	×	×	×	×	×	×	✓	×	×	×
Aviv and Fedegruen (1997)	×	✓	✓	×	✓	✓	✓	✓	✓	✓	✓	✓
Kapuściński and Tayur (1998)	×	✓	✓	×	×	✓	×	×	✓	✓	✓	✓
Tunc et al. (2011)	×	✓	×	✓	×	✓	×	×	✓	×	×	×
This paper	✓	×	×	✓	✓	✓	×	×	×	✓	×	✓

Table 4.1: Related research on non-stationary demand inventory problems

To extend the knowledge on lost-sales inventory problems under non-stationary demand, we propose a single-location, single-item periodic-review lost sales inventory problem with non-stationary demand, orders as multiples of fixed batch sizes, and a cost structure to comprise costs per order, per batch and per unit. We describe the model mathematically in Section 4.3.

4.3 The mathematical model

We consider a periodic review inventory replenishment system with lost sales, batch ordering and inventory handling costs, similar to that of Curşeu et al. (2011). The review cycle length R , i.e. the time between when two successive orders are placed, is exogenous to the model and set as the time unit. The lead time L is fixed and shorter than the review period length. Hence, each review period is divided into two parts: a period of length L before order is received, and a period of length $R - L$ after the order is received and before the next order is placed. Demands in these two parts are independent discrete random variables which exhibit a seasonal pattern with a fixed period of $\bar{d}$, that is, the demand during the lead time in review period t has the same distribution as demand during the lead time in review period $t + \bar{d}$. Similarly, demand after the order is received in review period t has the same distribution as demand after the order is received in review

period $t + \bar{d}$. Let $D_{d,L}$ and $D_{d,R-L}$ denote the demand in the d -th review period within a season respectively before and after the order is received, for $d = 1, \dots, \bar{d}$. Without loss of generality, we assume that review period 1 is the start of a new season so that the *season index* associated with review period t is a value between 1 and $\bar{d}$ that indicates which period within the season review period t corresponds to: $d_t = \text{mod}(t-1, \bar{d}) + 1$.³ Table 4.2 gives the notation used in this paper.

R	Review period
L	Lead time ($0 \leq L \leq R$)
t	Period index, $t = 0, 1, 2, \dots$
d_t	Season index for period t , $d_t = 1, 2, \dots, \bar{d}$
I_t	Inventory on hand at the beginning of period $t = 0, 1, 2, \dots$
a_t	Quantity ordered in period $t = 0, 1, 2, \dots$
$D_{d,L}$	Demand during lead time in d -th review period within a season
$D_{d,R-L}$	Demand after the receipt of the order in d -th review period within a season
$D_{d,R}$	Total demand during the d -th review period, $D_{d,R} = D_{d,L} + D_{d,R-L}$
q	Fixed (exogenously determined) batch size, $q = 1, 2, \dots$
K	Fixed cost per order
K_1	Handling cost per batch
K_2	Handling cost per unit
h	Holding cost per unit of inventory (charged at the end of the period)
p	Penalty cost for each unit of sales lost during a period (charged at the end of the period)

Table 4.2: Notation

At the beginning of the review period, the on-hand inventory I_t and season index d_t are observed and an order a_t is placed. The order arrives L time units later within the same review cycle. The order a_t is a nonnegative integer multiple of a fixed batch size q , i.e. $a_t \in \{0, q, 2q, \dots\}$. Next, the demand during the lead time $D_{d_t,L}$ is realized and, if possible, satisfied from on-hand inventory. All demand not immediately satisfied is lost. Then, after the order placed at the beginning of the period arrives, demand $D_{d_t,R-L}$ occurs until the beginning of the next review period. Again, all demand not directly satisfied from on-hand inventory is lost. Figure 4.2 depicts the sequence of events for each period.

³ $\text{mod}(x, y)$ is the remainder of the division of x by y . For example $d_9 = \text{mod}(9-1, 7) + 1 = 2$.

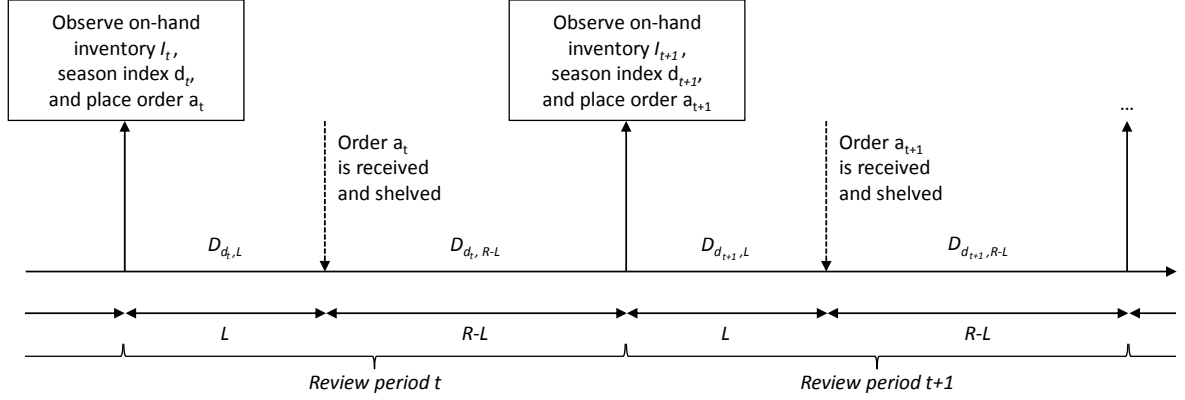


Figure 4.2: Sequence of events

The decision epoch is the beginning of each review period. The season index and the inventory on-hand at the beginning of a review period characterize the system state, so a state is (d_t, I_t) and the state space is $SS = \{(1, 0), (1, 1), \dots, (2, 0), (2, 1), \dots, (\bar{d}, 0), (\bar{d}, 1), \dots\}$. At each review moment, a decision is made regarding the ordering quantity limited to the set $A(i) = \{0, q, 2q, \dots\}$, for every $i \in SS$. The expected transition times from one decision epoch to the next are deterministic and equal to R . The evolution of on-hand inventory from one decision epoch to the next is given by the following recursive relation:

$$I_{t+1} = ((I_t - D_{d_t, L})^+ + a_t - D_{d_t, R-L})^+, \quad d = 1, \dots, \bar{d}; t = 0, 1, 2, \dots,$$

where $(x)^+ = \max\{0, x\}$ for any $x \in \mathbb{R}$.

The probability $p_{d,i,j}(a)$ of a transition from state (d, i) to state $(\text{mod}(d, \bar{d}) + 1, j)$, given the ordering decision a is:

$$p_{d,i,j}(a) = P(j = ((i - D_{d,L})^+ + a - D_{d,R-L})^+), \quad d = 1, \dots, \bar{d}; i, j = 0, 1, \dots, \quad a = 0, q, 2q, \dots,$$

When no order is placed in a given review period, i.e., $a = 0$, we have:

$$\begin{aligned} p_{d,i,0}(0) &= P(D_{d,R} \geq i), d = 1, \dots, \bar{d}; i = 1, 2, \dots, \\ p_{d,i,j}(0) &= P(D_{d,R} = i - j), d = 1, \dots, \bar{d}; i = 0, 1, \dots, j = 1, 2, \dots, i, \\ p_{0,0,0}(0) &= 1, \end{aligned}$$

When the order amounts to $a = nq > 0$, we have:

$$\begin{aligned}
p_{d,i,0}(a) &= \sum_{k=0}^{i-1} \mathbf{P}(D_{d,L} = k) \mathbf{P}(D_{d,R-L} \geq i + a - k) + \mathbf{P}(D_{d,L} \geq i) \mathbf{P}(D_{d,R-L} \geq a), \\
&\quad d = 1, \dots, \bar{d}; i = 1, 2, \dots, \\
p_{d,i,j}(a) &= \sum_{k=0}^{i-1} \mathbf{P}(D_{d,L} = k) \mathbf{P}(D_{d,R-L} = i + a - j - k) + \mathbf{P}(D_{d,L} \geq i) \mathbf{P}(D_{d,R-L} = a - (j - i)), \\
&\quad d = 1, \dots, \bar{d}; i = 1, 2, \dots; j = 1, 2, \dots, a, \\
p_{d,i,j}(a) &= \sum_{k=0}^{i+a-j} \mathbf{P}(D_{d,L} = k) \mathbf{P}(D_{d,R-L} = i + a - j - k), \\
&\quad d = 1, \dots, \bar{d}; i = 1, 2, \dots, j = a + 1, \dots, a + i, \\
p_{0,0,0}(a) &= \mathbf{P}(D_{d,R-L} \geq a), \\
p_{d,0,j}(a) &= \mathbf{P}(D_{d,R-L} = a - j), \quad d = 1, \dots, \bar{d}; j = 1, 2, \dots, a, \\
p_{d,i,j}(a) &= 0, \quad \text{otherwise.}
\end{aligned} \tag{4.2}$$

The total expected cost from one decision epoch to the next (i.e. the one-period transition cost), given state (d, i) and order $a = nq$, is defined as:

$$c_{d,i}(a) = c_{d,i}^r(a) + c_{d,i}^h(a) + c_{d,i}^p(a), \quad a \in A(i), \quad (d, i) \in SS, \tag{4.3}$$

where the expected replenishment cost $c_{d,i}^r$ and the expected holding $c_{d,i}^h$ and penalty costs $c_{d,i}^p$ are given by:

$$\begin{aligned}
c_{d,i}^r(0) &= 0, \\
c_{d,i}^r(a) &= K + K_1 n + K_2 nq, \quad a = nq > 0
\end{aligned} \tag{4.4}$$

and

$$\begin{aligned}
c_{d,i}^h(0) + c_{d,i}^p(0) &= h \mathbf{E} [(i - D_{d,R})^+] + p \mathbf{E} [(i - D_{d,R})^-], \\
c_{d,i}^h(a) + c_{d,i}^p(a) &= h \mathbf{E} [(i - D_{d,L})^+ + a - D_{d,R-L}]^+ \\
&\quad + p \{ \mathbf{E} [(D_{d,L} - i)^+] + \mathbf{E} [(D_{d,R-L} - a - (i - D_{d,L})^+)^+] \} \\
&= h \left\{ \sum_{k=0}^{i-1} \mathbf{P}(D_{d,L} = k) \mathbf{E} [(i - k + a - D_{d,R-L})^+] + \mathbf{P}(D_{d,L} \geq i) \mathbf{E} [(a - D_{d,R-L})^+] \right\} \\
&\quad + p \left\{ \mathbf{E} [(D_{d,L} - i)^+] + \sum_{k=0}^{i-1} \mathbf{P}(D_{d,L} = k) \mathbf{E} [(D_{d,R-L} - a - i + k)^+] \right\} \\
&\quad + p \mathbf{P}(D_{d,L} \geq i) \mathbf{E} [(D_{d,R-L} - a)^+],
\end{aligned}$$

for $a > 0$, respectively, where $(x)^- = \max\{0, -x\} = -\min\{0, x\}$ for any $x \in \mathbb{R}$. The replenishment cost include a fixed component (K), a variable component which depend on the number of batches (K_1) and a variable component that varies with the number of units in the order (K_2). For more details on the calculation of handling costs, we refer to Curşeu et al. (2009). The holding cost captures the cost of excess inventory, such as financial cost of carriage and write-offs for waste. The penalty cost for unmet demand accounts for the negative effects on the retailer such as lost customer loyalty.

We aim to determine the inventory policy U^* , solving the following optimization problem:

$$\min_U C(U) = \frac{1}{R} \sum_{i \in SS} \pi_i c_i(a)$$

where $C(U)$ denotes the long-run expected average cost under policy U , and $(\pi_i)_{i \in SS}$ represents the steady-state distribution of the inventory on hand, provided it exists.

$C(U)$ is generally a complex function of U and it may not be possible to determine the steady-state distribution in closed form. For the conditions under which an optimal policy exists under the long-run average-cost criterion, see Puterman (2005). For instance. If an optimal policy exists, then there exist relative values $(v_i)_{i \in SS}$ and the long-run average cost g , to satisfy the average-cost optimality equation:

$$v_i = \min_{a \in A(i)} \{c_i(a) - g + \sum_{j \in SS} p_{ij}(a)v_j\}, \quad i \in SS. \quad (4.5)$$

The unique relative values $(v_i)_{i \in SS}$ are obtained by providing an intimal condition, such as $v_0 = 0$. As is common in this type of inventory problem, we use a value iteration algorithm to solve the optimality equations and to determine the optimal policy (Puterman, 2005). In our numerical computations, the state space is truncated to a size sufficiently large to ensure a global optimum. The state space size is obtained by testing larger and larger sizes until the results are insensitive to the increments.

4.4 The WA setting

For notational convenience, we assume from now on that $D_{d,L}$ and $D_{d,R-L}$ have a Poisson distribution with mean $\lambda_{d,L}$ and $\lambda_{d,R-L}$ respectively, where d is the with season index. Our model can also be implemented with any discrete distribution. Let $\mathbf{\lambda}_{WA}$ be the vector that summarizes the demand distribution parameters used by the retailer when

calculating its inventory policy:

$$\boldsymbol{\lambda}_{WA} = \begin{pmatrix} \lambda_{1,L} & \lambda_{2,L} & \dots & \lambda_{\bar{d},L} \\ \lambda_{1,R-L} & \lambda_{2,R-L} & \dots & \lambda_{\bar{d},R-L} \end{pmatrix} \quad (4.6)$$

where the first row contains the mean values of demand during the lead time for the $\bar{d}$ periods in a season and the second row contains the mean values of demand after the order is received for the $\bar{d}$ periods in a season.

If the retailer uses vector $\boldsymbol{\lambda}_{WA}$ to compute the transition probabilities $p_{d,i,j}(a)$ and cost vector $c_{d,i}(a)$, he is taking into account both the *within*-review-period variations and the *across*-review-periods variations. We refer to this setting as the *WA* setting, where *W* stands for *Within* and *A* for *Across*. In practice, this means that the retailer creates a separate bookkeeping of demand for each period within the season before and after the order is received; hence the retailer uses $2\bar{d}$ input variables in its ASO system. Let U_{WA} denote the corresponding optimal policy.

4.4.1 Structure of the *WA* policy

Figure 4.3 depicts the structure of the optimal policy *WA* as a function of the on-hand inventory for each period within a season (as well as three other policies which will be defined in Section 4.5). We used $K = K_1 = K_2 = 0$, $h = 1$, $p = 50$, $q = 1$, $\bar{d} = 7$ and the following $\boldsymbol{\lambda}_{WA}$. This $\boldsymbol{\lambda}_{WA}$ vector was generated using equations (4.7) and (4.8) with $\bar{\lambda} = 5$, $\delta_W = 0.2$ and $\delta_A = 1.162$ (Details in Section 4.4.2):

$$\boldsymbol{\lambda}_{WA} = \begin{pmatrix} 6.79 & 1.21 & 2.14 & 3.07 & 4.00 & 4.93 & 5.86 \\ 0.30 & 0.54 & 0.77 & 1.00 & 1.23 & 1.46 & 1.70 \end{pmatrix}$$

Note that in the $\boldsymbol{\lambda}_{WA}$ vector above, demand increases across review periods within a season. In particular, more demand needs to be satisfied with the order placed in review period $d + 1$ compared to d for $d = \{1, \dots, 6\}$.

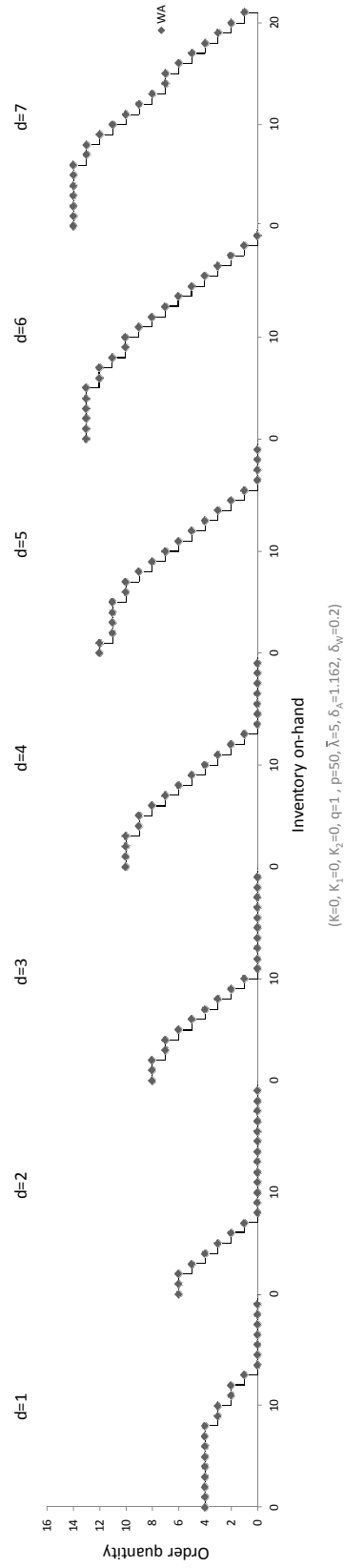


Figure 4.3: Example of optimal policy for the *WA* setting

Figure 4.3 shows that the structure of the optimal policy differs from an (s, S, nq) policy as for low levels of inventory on-hand, the advice is to order the same quantity. It also shows the optimal order quantity to vary across periods within a season.

To characterize an inventory policy, we define the optimal reorder point $s_d = \max\{i : (i, d) \in SS \text{ and } a_{(i,d)} > 0\}$ for season index d below which it is always optimal to place an order and above which it is never optimal to do so and the maximum reachable stock level after the order is received in season index d : $I_d^{max} = \max\{i + a_{(i,d)} : (i, d) \in SS \text{ and } a_{(i,d)} > 0\}$. For example, in Figure 4.7, we have $(s_1, \dots, s_7) = (13, 7, 10, 13, 16, 19, 21)$ and $(I_1^{max}, \dots, I_7^{max}) = (14, 8, 11, 14, 17, 20, 22)$.

Figure 4.3 also shows that the order quantities have a tendency to increase with the season index. This is due to our choice of λ_{WA} vector where most of the demand occurs at the end of the season. Also s_d and I_d^{max} are monotone for periods $d = 2, \dots, 7$. The first period is a transition period between the high demand at the end of the season and the low demand at the start of the season; the order quantity is low because the demand to be served with the new order is low but the values of s_1 and I_1^{max} are still high because high demand will deplete the existing inventory until the order is received.

4.4.2 Sensitivity analysis on the WA policy

In this section, we study how the long-run average costs and the structure of the WA policy vary with the model parameters.

For the cost parameters, we use $K = \{0, 10, 20\}$, $K_1 = \{0, 5, 10\}$, $K_2 = \{0, 1, 2\}$, $p = \{25, 50, 75\}$ and $h = 1$. The value of the cost parameters are thus set relative to the unit holding cost. For the case pack size, we use $q \in \{1, 3, 6, 12\}$. We vary the λ_{WA} by setting $\bar{d} = 7$ and using the following formulas for $d \in \{1, \dots, 7\}$:

$$\lambda_{d,L} = (1 - \delta_W) [\bar{\lambda} + \delta_A(\text{mod}(d - 2, \bar{d}) - 3)], \quad (4.7)$$

$$\lambda_{d,R-L} = \delta_W [\bar{\lambda} + \delta_A(d - 4)]. \quad (4.8)$$

In these formulas $\bar{\lambda}$ is the average demand per review period, δ_W is a parameter that allows for the proportion of demand within a review period to vary in a systematic way and δ_A is a parameter that allows the demand in each period within a season to vary in a systematic way. Increasing δ_W leads to more demand after the lead time (within each review period) compared to during the lead time. Increasing δ_A leads to more demand at the end rather than the start of the season. Our choice of values for $\lambda_{d,L}$ and $\lambda_{d,R-L}$ implies that more demand needs to be satisfied with the order placed in review period $d+1$ compared to d for $d = 1, \dots, 6$. Note that the order placed at the start of review period d has to cover the $R - L$ portion of review period d plus the L portion of review period

$d + 1$. Our choice of values for $\lambda_{d,L}$ and $\lambda_{d,R-L}$ imply that $\lambda_{d,R-L} + \lambda_{d+1,L}$ is increasing in d . Note also that in order for all the mean demand values to be positive, we need $\delta_A \leq \frac{\bar{\lambda}}{3}$. We use $\bar{\lambda} = \{0.1, 1, 5, 10\}$, $\delta_W \in \{0, 0.1, \dots, 0.9, 1\}$ and $\delta_A \in \left\{0, \frac{\bar{\lambda}}{30}, \frac{2\bar{\lambda}}{30}, \dots, \frac{\bar{\lambda}}{3}\right\}$. Figure 4.4 illustrates how the λ_{WA} vector varies with δ_W and δ_A . Based on these parameters, we generated 17,424 problem instances in our sensitivity analysis, resulting in 69,696 policy and average cost calculations.

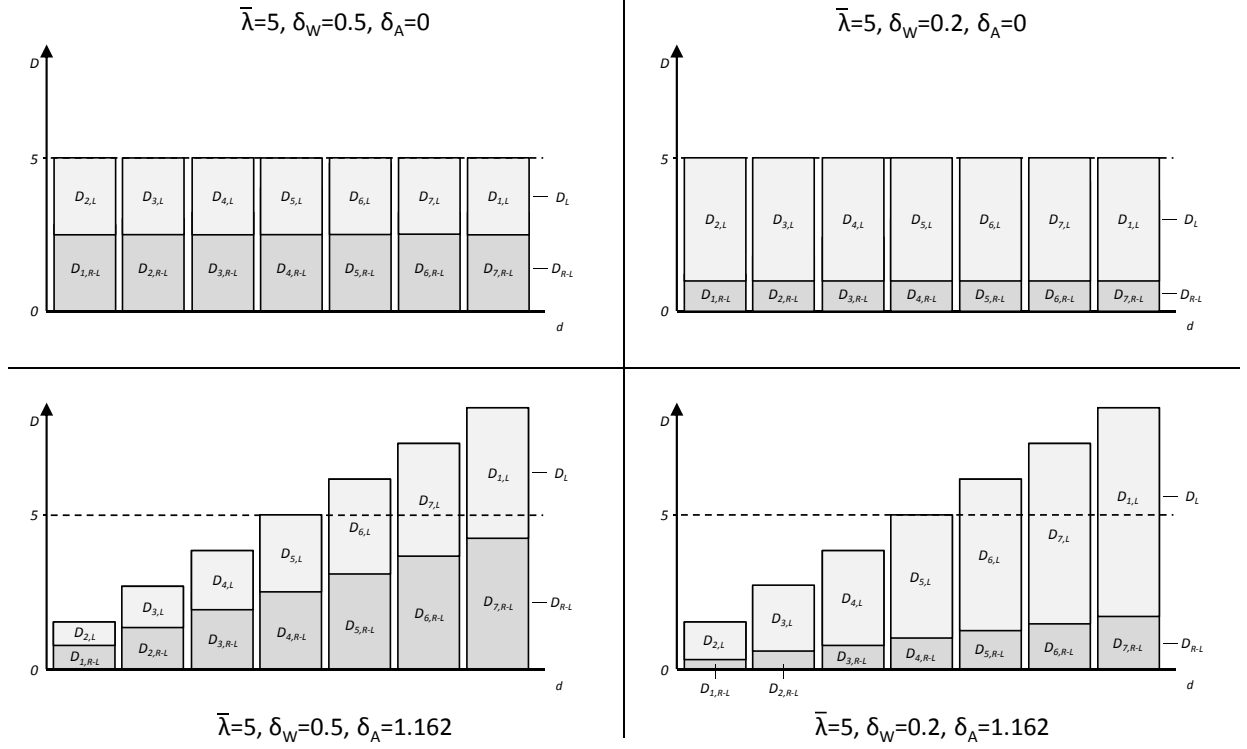


Figure 4.4: Construction of the λ_{WA} vector as a function of $\bar{\lambda}$, δ_W and δ_A .

We find that the optimal reorder points $s_1, \dots, s_{\bar{d}}$ are increasing in p and $\bar{\lambda}$ and decreasing in K and q . Also, the maximum reachable inventory values $I_1^{max}, \dots, I_{\bar{d}}^{max}$ are increasing in p , $\bar{\lambda}$, K and q . These results are consistent with the findings of Curşeu et al. (2011) in a model without demand seasonality. We also find that both s_d and I_d^{max} values are decreasing in δ_W for $d = 1, \dots, \bar{d}$. This is because there is less demand uncertainty when a smaller proportion of the demand occurs during the lead time as opposed to after the order is received. Finally, an increase in δ_A , which has the effect of switching more of the demand towards the end of the season, creates more variance in the vectors $(s_1, \dots, s_{\bar{d}})$ and $(I_1^{max}, \dots, I_{\bar{d}}^{max})$, with generally higher values at the end of the season.

Figure 4.5 shows the results of the sensitivity analysis on the long-run average cost $C(U_{WA})$. As expected, we find that the long-run average cost increases in K , K_1 , K_2 and p (keeping all other parameters constant). We also find that the average cost increases with the case pack size q . This is because the case pack size represents a minimal order

quantity, which limits the retailer's flexibility in terms of order quantities. We find that the long-run average cost increases with average demand $\bar{\lambda}$, but more interestingly, it decreases with δ_W . This is because increasing δ_W means that less of the review period demand occurs during the lead time, leading to fewer mid-period stock-outs. Finally, we find that the impact of δ_A on the average cost is much less pronounced than that of δ_W . Though it is not perfectly monotone, it seems that increasing δ_A , which has the effect of switching more of the demand towards the end of the season, eventually leads to a slight increase in costs. This is due to the fact that demand becomes more asymmetric, leading to more opportunities for stock-outs at the end of the season.

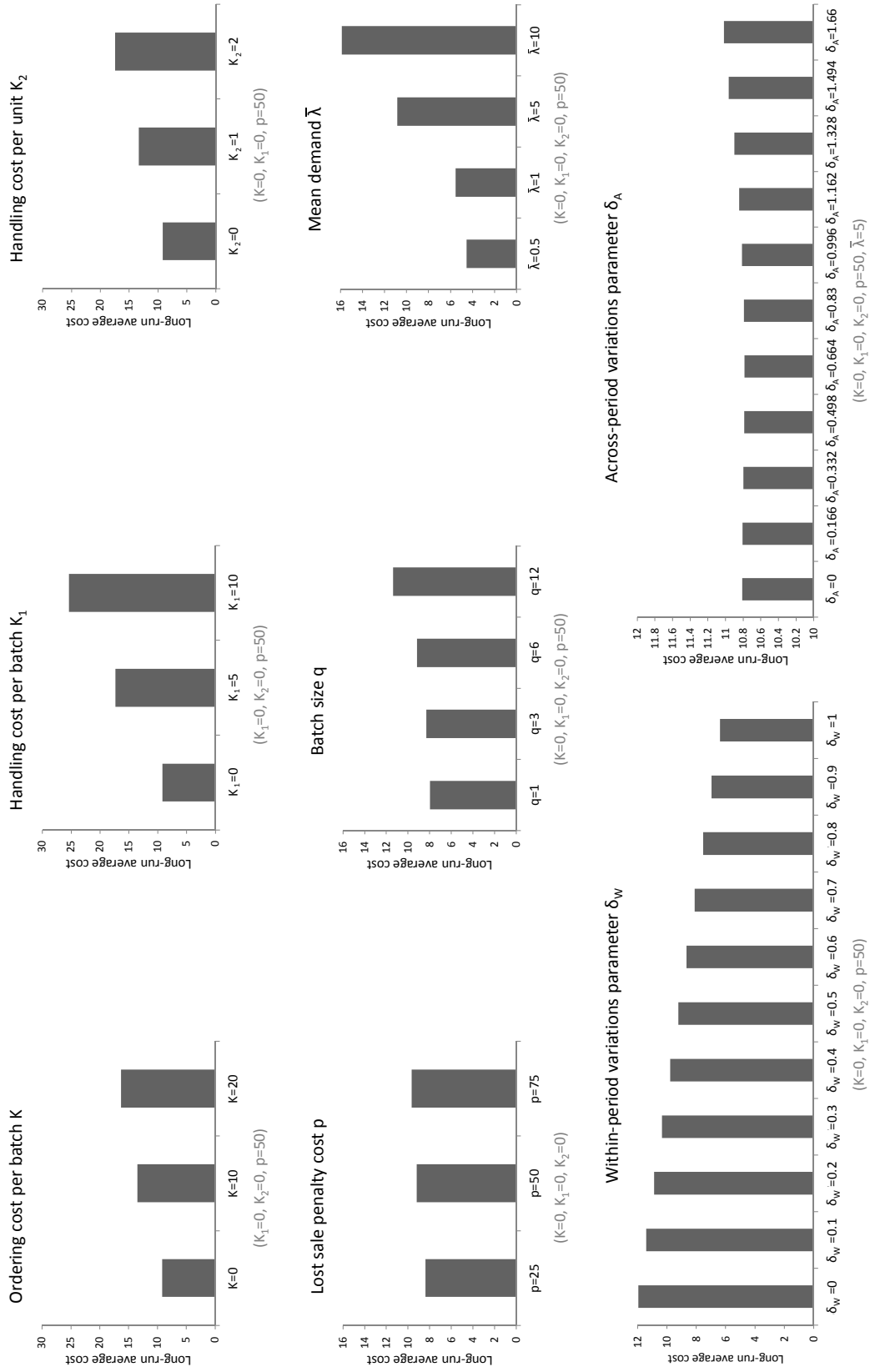


Figure 4.5: Sensitivity analysis on the long-run average cost for the WA setting

4.5 The value of accounting for demand seasonality

As outlined in the introduction, retailers may not track down demand data as finely as in what is required to compute the WA policy ($2\bar{d}$ input variables). In particular, a retailer may ignore within-review-period or across-review-periods variations or both. We consider three ways in which the retailer may ignore some of the relevant seasonality information.

First, we consider the case of a company which keeps a record of the demand it observes for each period of a season but, in its bookkeeping, does not distinguish between before and after the order is received. The retailer uses only $\bar{d}$ input variables in its ASO system: one for each period in a season. This retailer finds that demand in the d -th review period within a season has a Poisson distribution with mean $\lambda_{d,L} + \lambda_{d,R-L}$ for $d = 1, \dots, \bar{d}$. He then assumes that demand is evenly distributed during the review period, that is, he finds that $D_{d,L}$ has a Poisson distribution with mean $\frac{L}{R}(\lambda_{d,L} + \lambda_{d,R-L})$ and $D_{d,R-L}$ has a Poisson distribution with mean $\frac{R-L}{R}(\lambda_{d,L} + \lambda_{d,R-L})$ for $d = 1, \dots, \bar{d}$. We refer to this case as the $\overline{W}A$ setting since it ignores within-review period variations but still acknowledges across-review periods variations. We use the following notation: $\overline{W}$ when the retailer ignores within-review period variations and W when the retailer accounts for within-review period variations. Similarly $\overline{A}$ when the retailer ignores across-review periods variations and A when the retailer accounts for across-review periods variations.

Let $\lambda_{\overline{W}A}$ be the vector that summarizes the demand distribution parameters used by the retailer when calculating its inventory policy:

$$\lambda_{\overline{W}A} = \begin{pmatrix} \frac{L}{R}(\lambda_{1,L} + \lambda_{1,R-L}) & \frac{L}{R}(\lambda_{2,L} + \lambda_{2,R-L}) & \dots & \frac{L}{R}(\lambda_{\bar{d},L} + \lambda_{\bar{d},R-L}) \\ \frac{R-L}{R}(\lambda_{1,L} + \lambda_{1,R-L}) & \frac{R-L}{R}(\lambda_{2,L} + \lambda_{2,R-L}) & \dots & \frac{R-L}{R}(\lambda_{\bar{d},L} + \lambda_{\bar{d},R-L}) \end{pmatrix}$$

Second, we also examine the situation where the retailer acknowledges that the demand distribution before and after receiving the order in a review period is different, but does not recognize the seasonality across review periods. In this case, the retailer uses only two input variables in its ASO system: one for each part of the review period (before and after the order is shelved). This retailer finds that $D_{d,L}$ has a Poisson distribution with mean $\frac{1}{\bar{d}} \sum_{d=1}^{\bar{d}} \lambda_{d,L}$ and $D_{d,R-L}$ has a Poisson distribution with mean $\frac{1}{\bar{d}} \sum_{d=1}^{\bar{d}} \lambda_{d,R-L}$ for $d = 1, \dots, \bar{d}$. We refer to this case as the $W\overline{A}$ setting, since the retailer sees within-review-period variations but does not account for across-review-periods variations. Let $\lambda_{W\overline{A}}$ be the vector that summarizes the demand distribution parameters used by the retailer when calculating its inventory policy:

$$\lambda_{W\overline{A}} = \begin{pmatrix} \frac{1}{\bar{d}} \sum_{d=1}^{\bar{d}} \lambda_{d,L} & \frac{1}{\bar{d}} \sum_{d=1}^{\bar{d}} \lambda_{d,L} & \dots & \frac{1}{\bar{d}} \sum_{d=1}^{\bar{d}} \lambda_{d,L} \\ \frac{1}{\bar{d}} \sum_{d=1}^{\bar{d}} \lambda_{d,R-L} & \frac{1}{\bar{d}} \sum_{d=1}^{\bar{d}} \lambda_{d,R-L} & \dots & \frac{1}{\bar{d}} \sum_{d=1}^{\bar{d}} \lambda_{d,R-L} \end{pmatrix}$$

Third, we consider the case of a retailer which neither accounts for within-review-period nor across-review-periods variations. In this case, the retailer uses only one input variable in its ASO system: the total demand over one review period. This retailer finds that this demand has a Poisson distribution with mean $\frac{1}{\bar{d}} \sum_{d=1}^{\bar{d}} (\lambda_{d,L} + \lambda_{d,R-L})$. He then assumes that demand is evenly distributed within each review period, that is, he finds that $D_{d,L}$ has a Poisson distribution with mean $\frac{L}{R} \frac{1}{\bar{d}} \sum_{d=1}^{\bar{d}} (\lambda_{d,L} + \lambda_{d,R-L})$ and $D_{d,R-L}$ has a Poisson distribution with mean $\frac{R-L}{R} \frac{1}{\bar{d}} \sum_{d=1}^{\bar{d}} (\lambda_{d,L} + \lambda_{d,R-L})$. We refer to this case as the $\overline{WA}$ setting since the retailer ignores both within-review-period and across-review-periods variations. Let $\boldsymbol{\lambda}_{\overline{WA}}$ be the vector that summarizes the demand distribution parameters used by the retailer when calculating its inventory policy:

$$\boldsymbol{\lambda}_{\overline{WA}} = \begin{pmatrix} \frac{L}{R} \frac{1}{\bar{d}} \sum_{d=1}^{\bar{d}} (\lambda_{d,L} + \lambda_{d,R-L}) & \frac{L}{R} \frac{1}{\bar{d}} \sum_{d=1}^{\bar{d}} (\lambda_{d,L} + \lambda_{d,R-L}) & \dots & \frac{L}{R} \frac{1}{\bar{d}} \sum_{d=1}^{\bar{d}} (\lambda_{d,L} + \lambda_{d,R}) \\ \frac{R-L}{R} \frac{1}{\bar{d}} \sum_{d=1}^{\bar{d}} (\lambda_{d,L} + \lambda_{d,R-L}) & \frac{R-L}{R} \frac{1}{\bar{d}} \sum_{d=1}^{\bar{d}} (\lambda_{d,L} + \lambda_{d,R-L}) & \dots & \frac{R-L}{R} \frac{1}{\bar{d}} \sum_{d=1}^{\bar{d}} (\lambda_{d,L} + \lambda_{d,R-L}) \end{pmatrix}$$

The $\overline{WA}$ setting is the same as discussed in Curşeu et al. (2011) since the authors ignore any type of demand seasonality.

Table 4.3 summarizes the information requirements, that is the number of input variables used by the retailer in his ASO system for each setting. Example 1 illustrates the calculation of the $\boldsymbol{\lambda}$ vectors.

Setting	Number of input variables
WA	$2\bar{d}$
$\overline{WA}$	$\bar{d}$
$W\overline{A}$	2
$\overline{W\overline{A}}$	1

Table 4.3: Demand information requirements (input variables) in the four settings

Example 1. Let $\bar{d} = 7$ and

$$\boldsymbol{\lambda}_{WA} = \begin{pmatrix} 0.4 & 0.6 & 0.8 & 1.0 & 1.2 & 1.4 & 1.6 \\ 1.6 & 2.4 & 3.2 & 4.0 & 4.8 & 5.6 & 6.4 \end{pmatrix}$$

If $R = 1$ and $L = 0.4$, we have:

$$\begin{aligned}\lambda_{\overline{WA}} &= \begin{pmatrix} 0.8 & 1.2 & 1.6 & 2 & 2.4 & 2.8 & 3.2 \\ 1.2 & 1.8 & 2.4 & 3 & 3.6 & 4.2 & 4.8 \end{pmatrix} \\ \lambda_{W\overline{A}} &= \begin{pmatrix} 1 & 1 & 1 & 1 & 1 & 1 & 1 \\ 4 & 4 & 4 & 4 & 4 & 4 & 4 \end{pmatrix} \\ \lambda_{\overline{WA}} &= \begin{pmatrix} 2 & 2 & 2 & 2 & 2 & 2 & 2 \\ 3 & 3 & 3 & 3 & 3 & 3 & 3 \end{pmatrix}\end{aligned}$$

Figure 4.6 illustrates the demand vectors as used in the four policies WA , $\overline{WA}$, $W\overline{A}$, and $\overline{WA}$ as given in Example 1.

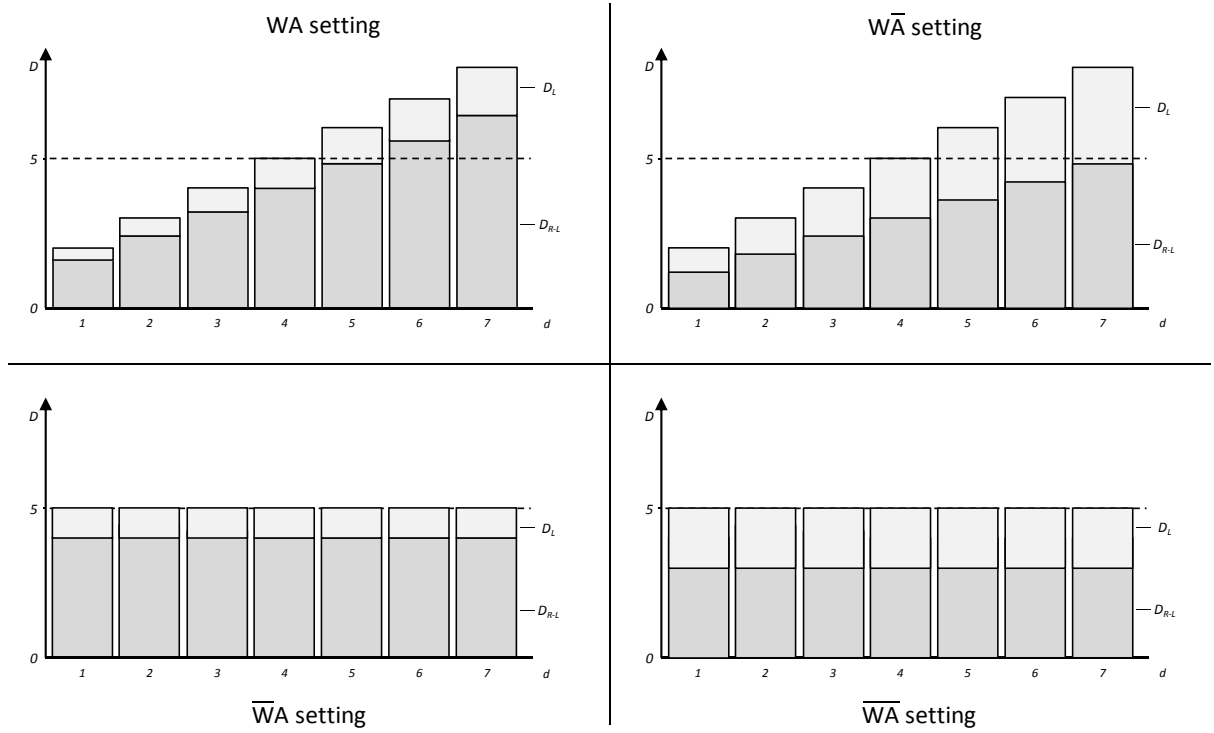


Figure 4.6: Illustration of the λ vector in all four settings

In the $\overline{WA}$, $W\overline{A}$ and $\overline{WA}$ settings, we solve for the optimal inventory policy given the corresponding λ vector using the method described in Section 4.3. Note that the dynamic program can be simplified in the $W\overline{A}$ and $\overline{WA}$ cases because the retailer does not account for across-review-periods variations so it suffices to use I_t as a state variable. Let $U_{\overline{WA}}$, $U_{W\overline{A}}$ and $U_{\overline{WA}}$ denote the inventory policy in the $\overline{WA}$, $W\overline{A}$ and $\overline{WA}$ settings respectively.

We calculate the long-run expected average cost of each policy using the probability transition matrix and cost vector calculated based on $\boldsymbol{\lambda}_{WA}$ in (4.6), which embraces within- and across-periods demand variations. We calculate the performance gap of each policy with respect to the optimal long-run average cost, i.e. the cost associated with the WA policy, as:

$$100 \times \frac{C(U) - C(U_{WA})}{C(U_{WA})}$$

where $C(U)$ denotes the long-run average cost of policy U , for $U = U_{\overline{WA}}, U_{W\overline{A}}$ and $U_{\overline{WA}}$.

4.5.1 Comparison of the policies

In this section, we compare the structure of the $U_{WA}, U_{\overline{WA}}, U_{W\overline{A}}$ and $U_{\overline{WA}}$ inventory policies. Figure 4.7 shows the optimal order quantities as a function of on-hand inventory for all four settings when $K = K_1 = K_2 = 0$, $p = 50$, $\bar{\lambda} = 5$, $\delta_W = 0.2$, $\delta_W = 1.162$, and $\bar{d} = 7$, i.e., in the same setup as in Section 4.4.2.

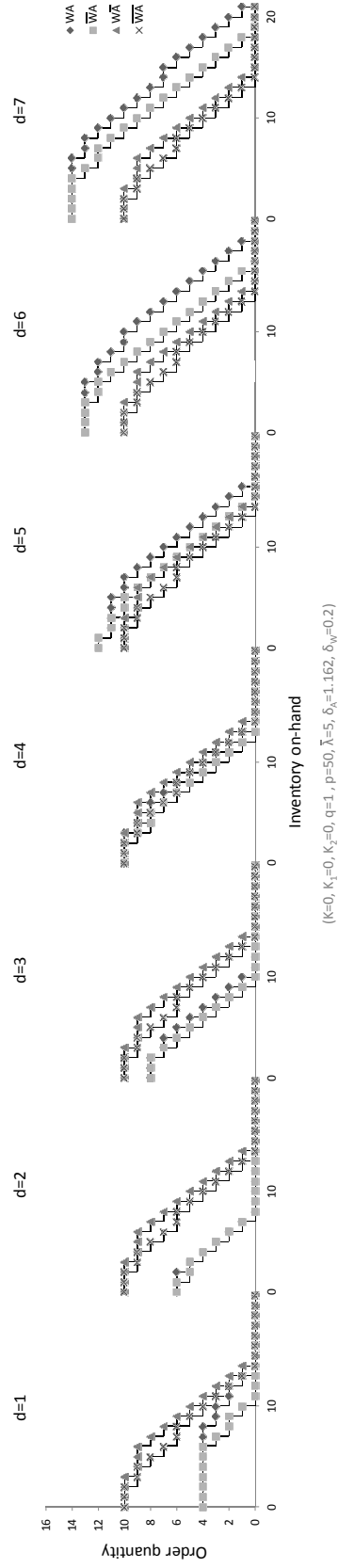


Figure 4.7: Example of the optimal policy in all four settings

From Figure 4.7 we see that the inventory policy in the $W\bar{A}$ and $\bar{W}\bar{A}$ settings is the same for each period within the season while it tends to increase with the season index in the other two settings. This is because the retailer ignores across-review-periods variations in the $W\bar{A}$ and $\bar{W}\bar{A}$ settings and therefore treats every review period as identical. This means to the retailer in the $W\bar{A}$ and $\bar{W}\bar{A}$ orders too much at the start of the season when demand is low and too little at the end of the season when demand is high. Further, a pairwise comparison of the policies in the WA and $\bar{W}\bar{A}$ settings and the policies in the $W\bar{A}$ and $\bar{W}\bar{A}$ settings reveals that ignoring within review-period variations leads to lower-than-optimal order quantities. This is because most of the demand occurs during the lead time (since $\delta_W = 0.2$), therefore the retailer tends to underestimate demand uncertainty when it assumes that demand is evenly distributed during the review period as is the case in the $\bar{W}A$ and $\bar{W}\bar{A}$ settings.

4.5.2 Performance of the three policies

In this section, we study the performance of the policies which minimize the long run average cost in the $\bar{W}A$, $W\bar{A}$ and $\bar{W}\bar{A}$ settings by varying the model parameters. To do so, we use the same problem instances as in Section 4.4.2.

Figure 4.8 shows how the average optimality gaps of the three policies vary with each parameter.

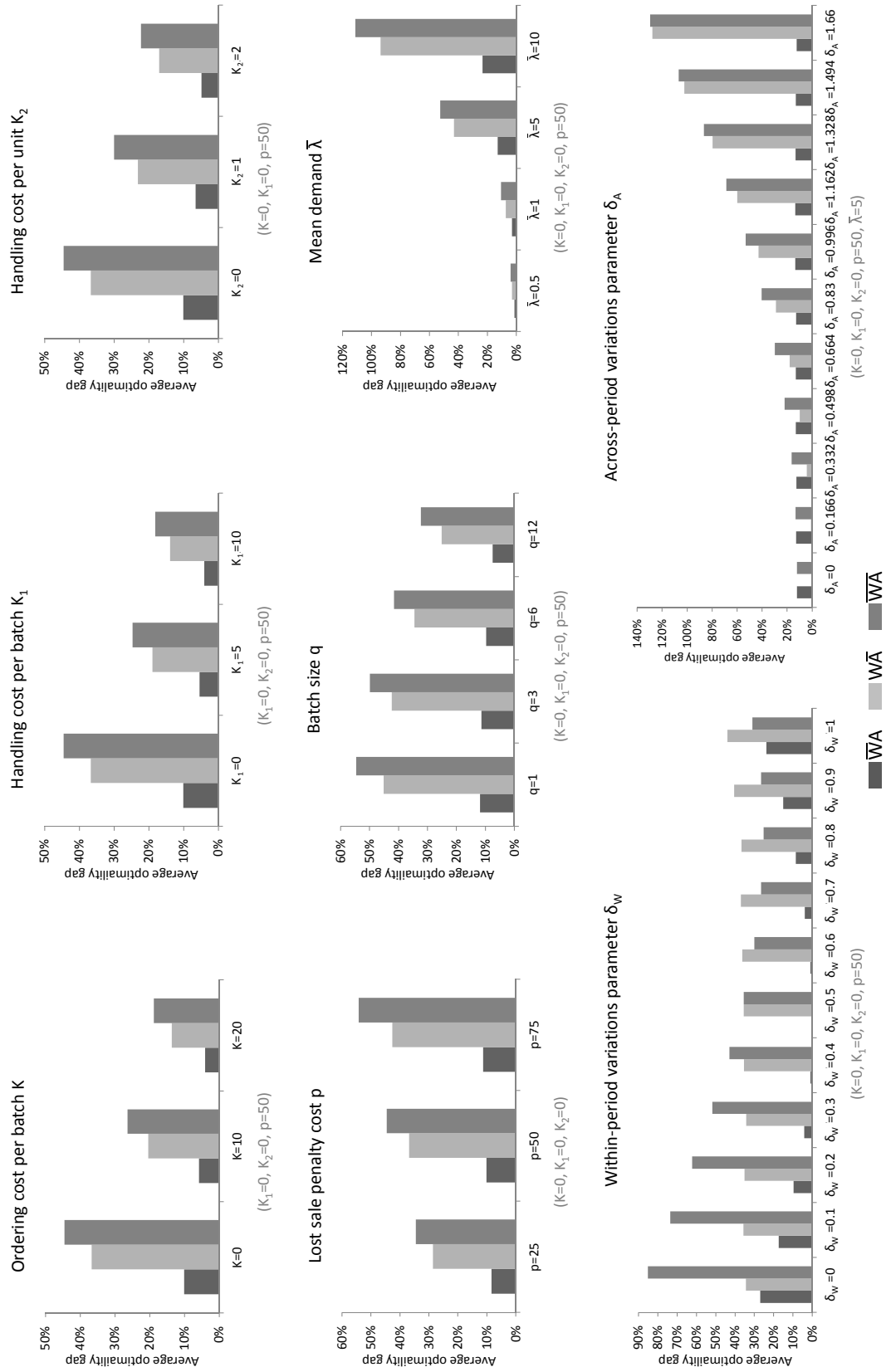


Figure 4.8: Results of the sensitivity analysis

Figure 4.8 shows how the average optimality gaps of the three policies vary with each parameter. In most cases, the average optimality gap of the $\overline{WA}$ policy is the largest, followed by the $W\overline{A}$ policy, and then by the $\overline{W}A$ policy. This means that using more input variables in the ASO system generally leads to better decisions and lower average cost. However, this is not always the case. When δ_A is low, so there is little variation across periods in a season, the optimality gap of the $\overline{W}A$ policy can be higher than that of the $W\overline{A}$ policy. This is because there is more to gain by realizing that demand is not evenly spread across the review period. Also, when δ_W is high, so that little demand occurs during the lead time, the retailer benefits from ignoring both types of variations rather than accounting for within-review-period variations only. In other words, less information is better! This is because the retailer who ignores both types of seasonality benefits from two effects running in opposite directions. Not seeing that most of the demand occurs after the lead time results in higher than optimal order quantities. Not seeing that most of the demand occurs at the end of the season leads to lower than optimal order quantities in periods with higher season indices. Combined, the two effects partially offset each other. In contrast, the retailer who only ignores across-review periods variations but accounts for within-periods variations will order too little at the start of the season, resulting in higher stock-out penalties.

Figure 4.8 shows that the optimality gaps decrease in K , K_1 , K_2 and q . This can be explained by the fact that larger fixed costs (per order or per batch) and larger case pack sizes lead to larger optimal order quantities (measured by I_d^{max} for $d = 1, \dots, \bar{d}$) as shown in Section 4.4.2. As a result it becomes less important to observe across- and within-review periods variations because the inventory ordered is used to cover multiple periods of demand. Moreover, the optimality gaps of the three policies are increasing in the penalty cost p . This is because a higher penalty cost makes the under-stocking associated with ignoring seasonality more costly. Further, an increase in the average demand $\bar{\lambda}$ leads to an increase in optimality gaps since more demand to satisfy means more opportunity for errors when seasonality is ignored.

An increase in δ_A , which has the effect of shifting more of the demand to the end of the season, leads to worse performance of the policies in the $W\overline{A}$ and $\overline{WA}$ settings. This is in line with expectations, since the retailer ignores across-review periods variations in these settings. Varying δ_W away from 0.5 means that the demand within a review period is distributed less evenly between the two sub periods (before and after the order is received). As a result the $\overline{WA}$ policy, which assumes demand is evenly distributed within the review period, performs worse. The impact on the optimality gaps of the $\overline{WA}$ setting is more difficult to analyze because of the two opposite effects offsetting each other as discussed above.

4.6 Application to a real-life setting

In this section we evaluate the value of accounting for demand seasonality using item-store level Point of Sales data collected at a European retailer for a single store in the entire year of 2010. The store stocks about 10.000 items (i.e. stock-keeping units) and is located at a major intersection, with two competitors' stores nearby. It is open 7 days a week from 6am to 10pm.

The retailer records sales by the second and stores this data by the hour. So it is possible to observe monthly, weekly, daily and intraday demand variation. Following Van Donselaar et al. (2010), we conducted several observations on replenishment (after shelving) and on-shelf availability (before store closing) to ensure that tasks are executed as planned and sales data are not distorted by out-of-stocks. These observations were carried out unannounced and hidden observations in order to prevent pre-observation and post-observation changes in store ordering and replenishment as Gruen and Corsten (2008) suggest. We did not find frequent or systematic out-of-stocks and therefore assume historical sales data to be a reasonable representation of shopper demand. In what follows we use the terms *sales* and *demand* interchangeably.

We analyze sales data at the item-level and find that demand during the week follows specific patterns. These patterns vary among items and are distinct from store sales patterns (see also the example of cigarette sales in Section 4.1, Figure 4.1). We focus our analysis on a sample of 10 items from 10 different product categories. All of these items are included in the ASO system. The ASO system does not include fresh produce and several bakery items which we therefore excluded from the analysis.

For each of the items, shelf replenishment is structured as follows. Every evening at 5pm, the ASO system observes on-hand inventory and calculates the order quantities. The store manager either approves or overwrites the orders and sends a confirmation to the distribution center. All orders are processed in the same regional distribution center which the retailer owns and operates. There are no direct deliveries from suppliers. The order placed every evening at 5pm arrives by truck from the distribution center the next morning. Until 10am, store staff shelves all items according to the planograms. The replenishment staff is well trained in shelf replenishment. The store has a small backroom for organizing items for shelf replenishment, e.g. to dispose of excess packaging, and to organize returns of roll cages and recycling materials. Items left over from shelf replenishment (one jar of jam, two deodorants etc.) are organized in backroom bins until the next scheduled shelf replenishment.

Based on our discussion with the store managers (specifically, we talked to the store head manager, replenishment and checkout staff, the corporate heads of logistics and sales

as well as the forecasting and ASO team in the retailer's headquarters), it appears there is no systematic practice of overwriting the ASO's order quantities. In particular, we believe that the store manager does not advance orders to balance workload as discussed in Van Donselaar et al. (2010). Overwriting the ASO occurs on rare occasions when store manager expects demand to deviate from the order suggestion based on her personal experience.

The ASO system generates orders in three steps. First, the system calculates an average of the past 52 weeks of sales data, excluding promotions and special events, for example the national day. Second, it divides the resulting weekly demand estimate by seven in order to obtain the daily demand estimate. Third, the system compares the demand estimate to on-hand inventory and calculates the daily order quantities according to a formula accounting for case pack size and shelf space. It follows that the current ASO system neither accounts for intra-week sales variations nor intra-day variations. To provide examples, it ignores if an item typically sells more on Saturdays than on Mondays. Also, the ASO system ignores if an item sells more at night (after the 5pm order placement) than before lunch (after the 10am replenishment of the last order).

We witnessed that the retailer is concerned by this inadequacy and currently considers refining the ASO system. The team in charge of ASO is thinking of incorporating intra-week sales variations to a certain degree by calculating two daily demand estimates: one for weekday sales (e.g. Monday-Friday) and one for weekend sales (e.g. Saturday and Sunday). However, they are unsure about the benefits of this refinement to the ASO system and unclear about whether to treat Friday sales as weekday or weekend.

4.6.1 Modeling

As mentioned earlier, the 10 items we study can be ordered every day at 5pm and the store is open every day from 6am to 10pm. Hence, we use $R = 16$ hours = 1 (business) day for the length of the review period. Given that the new order is on the shelves by 10am, we use $(10 - 5) + (10 - 6) = 9$ hours = $9/16$ day for our estimate of the lead time L . Therefore, in this section, within-review-period variations mean intra-day variations while across-review periods correspond to across-days variations. Figure 4.9 depicts the sequence of events observed in practice. Note that the days of the week do not fully correspond to the review periods. For example, review period t in Figure 4.9 includes Saturday from 5pm to 10pm and Sunday from 6am to 10am. However, for simplicity, we call each review period by the day of the week where there is the most overlap. For instance, review period t is referred to as Sunday, review period $t + 1$ as Monday, etc. Also let day 1 in a week be Sunday, day 2 be Monday, etc.

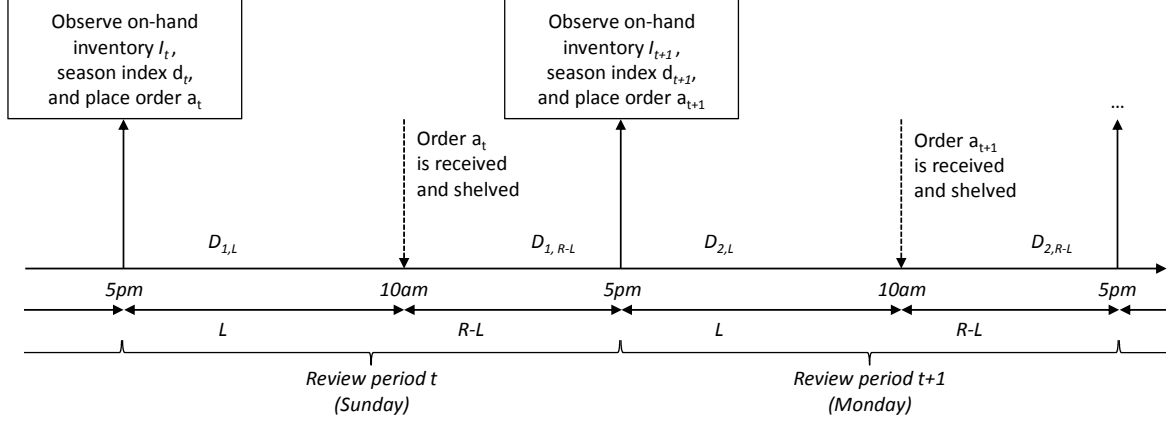


Figure 4.9: Sequence of events as observed in practice

For each item, the sales data exhibit a clear seasonality pattern with a period of one week, i.e., $\bar{d} = 7$ days. Figure 4.1 in Section 4.1 gives an example of the observed seasonality patterns. We model the demand using a Poisson distribution; Figure 4.12 in the Appendix is an example of a histogram for one of the items we used.

For each item, the sales data exhibit a clear seasonality pattern with a period of one week, i.e., $\bar{d} = 7$ days. Figure 4.1 in Section 4.1 gives an example of the observed seasonality patterns. We model the demand using a Poisson distribution; Figure 4.12 in the Appendix is an example of a histogram for one of the items we used.

The 10 items we selected cover a broad range of sales velocity, weekly and daily sales patterns, case-packs sizes, and other attributes, including global brands, national brands, regional brands, and private labels; hedonic and utilitarian items; items for immediate consumption and home storage; as well as varying degrees of shelf life. This product selection approach is common in on-shelf availability research (see, for instance, Campo et al., 2000; Gruen and Corsten, 2008). Note that utilitarian items are primarily instrumental and functional, whereas hedonic items provide more experiential value, fun, excitement, and pleasure (see Sloot et al., 2005). Weeks during which there was a promotion or a special event (specifically Easter, Christmas, and the national day) were ignored in our analysis. Table 4.4 lists the 10 items and their attributes.

Item	Sales velocity	Attributes				Case pack size
		<i>brand</i>	<i>hedonic level</i>	<i>shelf life</i>	<i>purchased for</i>	
Energy drink (25ml can)	ultra high	global	hedonic	very long	immediate use and storage	24
Caffeinated soda (1.5l bottle)	high	global	hedonic	very long	immediate use and storage	4
Milk (1l tetra pack)	high	private	utilitarian	short	immediate use and storage	6
Croissants (single bun)	medium	private label	hedonic	short	immediate use and storage	1
Lettuce (single head)	medium	regional	utilitarian	short	immediate use and storage	1
Cigarettes (single box of 10)	medium	global	hedonic	very long	immediate use and storage	10
Sausage (double pack)	medium	regional	hedonic	medium	immediate use and storage	1
Potato chips (300gr pack)	slow	national	hedonic	long	immediate use and storage	4
Eggs (pack of six)	slow	regional	utilitarian	short	immediate use and storage	1
Orange juice (4x1l tetra pack)	slow	private	utilitarian	long	immediate use and storage	1

Table 4.4: Main product attributes for the 10 items.

Table 4.5 gives the average sales values during the lead time L , after the shelving of the new order $R - L$ for each day of the week as well as average weekly demand. We also include two measures, denoted V_W and V_A which respectively measure the extent of within-review periods variations and across-review periods variations. They are calculated as follows:

$$\begin{aligned}
V_W &= \frac{1}{7} \sum_{d=1}^7 \left| \frac{9}{16} - \frac{\lambda_{d,L}}{\lambda_{d,L} + \lambda_{d,R-L}} \right| \\
V_A &= CV(\lambda_{d,L} + \lambda_{d,R-L})_{d=1,\dots,7},
\end{aligned}$$

where $9/16$ is the percentage of time that corresponds to the lead time within a review period and CV stands for coefficient of variation.

		Average demand							Avg. wk. demand	V_W	V_A
Item		Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday			
Energy drink	<i>L</i>	9.58	8.69	8.5	8.09	9.28	10.19	8.11	126.52	0.06	0.22
(2.5dl can)	<i>R-L</i>	16.75	7.36	6.24	7.13	7.4	7.25	11.95			
Caffeinated soda	<i>L</i>	6.8	1.83	2.78	4.36	4.2	3.27	4.82	58.83	0.08	0.42
(1.5l bottle)	<i>R-L</i>	6.78	1.97	2.89	3.78	4.4	3.49	7.46			
Milk	<i>L</i>	2.86	1.59	3.51	2.95	3.21	3.33	3.12	51.58	0.16	0.16
(1l tetra pack)	<i>R-L</i>	3.57	4.19	4.33	4.41	3.84	4.26	6.41			
Croissants	<i>L</i>	1.07	2.51	2.32	2.44	2.60	2.82	1.93	30.68	0.07	0.06
(single bun)	<i>R-L</i>	3.33	1.80	1.90	1.97	1.85	2.09	2.05			
Lettuce	<i>L</i>	1.27	1.50	1.46	1.62	1.53	1.21	3.28	26.86	0.15	0.19
(single head)	<i>R-L</i>	3.11	1.93	1.87	2.05	2.01	2.03	2.01			
Cigarettes	<i>L</i>	1.24	1.57	1.68	1.57	1.67	1.61	1.83	22.36	0.06	0.21
(single box of 10)	<i>R-L</i>	3.39	1.32	1.09	1.25	1.13	1.40	1.61			
Sausage	<i>L</i>	0.73	0.32	0.64	0.71	0.77	0.73	1.08	14.67	0.20	0.45
(double pack)	<i>R-L</i>	0.67	0.54	1.19	1.44	1.48	1.58	2.79			
Potato chips	<i>L</i>	1.71	0.64	0.56	0.54	0.59	0.7	1.02	11.17	0.06	0.58
(300gr pack)	<i>R-L</i>	1.6	0.5	0.25	0.54	0.46	0.62	1.44			
Eggs	<i>L</i>	0.34	0.24	0.37	0.29	0.42	0.37	0.34	5.30	0.12	0.17
(pack of six)	<i>R-L</i>	0.57	0.34	0.33	0.37	0.29	0.47	0.56			
Orange juice	<i>L</i>	0.4	0.22	0.26	0.24	0.23	0.19	0.26	4.82	0.18	0.29
(4x1l tetra pack)	<i>R-L</i>	0.59	0.17	0.44	0.52	0.44	0.3	0.56			

Table 4.5: Demand information for the 10 selected items.

Since the current replenishment policy in the retailer's ASO system neither accounts for intra-day nor across-days variations, we choose to model it using the $\overline{WA}$ policy introduced in Section 4.5. Note that this is not an exact representation of the retailer's ASO system for two main reasons: (1) the policy used by the ASO system is a simpler policy which resembles an (s, S, nq) policy (2) the order quantity chosen by the ASO system is not explicitly based on a minimization of the costs involved. In terms of costs, the $\overline{WA}$ policy is therefore a lower bound on the performance of the policy used by the ASO system, which implies that our results on the impact of incorporating seasonality are on the conservative side.

We compare this policy to the WA policy which takes into account both within-day and across-days variations, the $\overline{WA}$ policy which incorporates across-days but not within-day variations and the $W\overline{A}$ policy which considers within-day but not across-days

variations. The first four rows in Table 4.6 show the value of the vector λ in each of the four settings for the energy drink item as an example.

No. of input variables		λ vectors for the energy drink
λ_{WA}	14	$\begin{pmatrix} 9.58 & 8.69 & 8.50 & 8.09 & 9.28 & 10.19 & 8.11 \\ 16.75 & 7.36 & 6.24 & 7.13 & 7.40 & 7.25 & 11.95 \end{pmatrix}$
$\lambda_{\overline{WA}}$	1	$\begin{pmatrix} 10.17 & 10.17 & 10.17 & 10.17 & 10.17 & 10.17 & 10.17 \\ 7.91 & 7.91 & 7.91 & 7.91 & 7.91 & 7.91 & 7.91 \end{pmatrix}$
$\lambda_{\overline{WA}}$	7	$\begin{pmatrix} 14.81 & 9.03 & 8.29 & 8.56 & 9.38 & 9.81 & 11.28 \\ 11.52 & 7.02 & 6.45 & 6.66 & 7.30 & 7.63 & 8.78 \end{pmatrix}$
$\lambda_{W\overline{A}}$	2	$\begin{pmatrix} 8.92 & 8.92 & 8.92 & 8.92 & 8.92 & 8.92 & 8.92 \\ 9.15 & 9.15 & 9.15 & 9.15 & 9.15 & 9.15 & 9.15 \end{pmatrix}$
$\lambda_{\overline{W}(FS)}$	2	$\begin{pmatrix} 10.01 & 10.01 & 10.01 & 10.01 & 10.01 & 10.55 & 10.55 \\ 7.79 & 7.79 & 7.79 & 7.79 & 7.79 & 8.20 & 8.20 \end{pmatrix}$
$\lambda_{\overline{W}(SS)}$	2	$\begin{pmatrix} 13.05 & 9.02 & 9.02 & 9.02 & 9.02 & 9.02 & 13.05 \\ 10.15 & 7.01 & 7.01 & 7.01 & 7.01 & 7.01 & 10.15 \end{pmatrix}$
$\lambda_{\overline{W}(FSS)}$	2	$\begin{pmatrix} 11.97 & 8.82 & 8.82 & 8.82 & 8.82 & 11.97 & 11.97 \\ 9.31 & 6.86 & 6.86 & 6.86 & 6.86 & 9.31 & 9.31 \end{pmatrix}$
$\lambda_{W(FS)}$	4	$\begin{pmatrix} 9.15 & 9.15 & 9.15 & 9.15 & 9.15 & 9.27 & 9.27 \\ 8.65 & 8.65 & 8.65 & 8.65 & 8.65 & 9.49 & 9.49 \end{pmatrix}$
$\lambda_{W(SS)}$	4	$\begin{pmatrix} 8.91 & 8.95 & 8.95 & 8.95 & 8.95 & 8.95 & 8.91 \\ 14.29 & 7.08 & 7.08 & 7.08 & 7.08 & 7.08 & 14.29 \end{pmatrix}$
$\lambda_{W(FSS)}$	4	$\begin{pmatrix} 9.59 & 8.65 & 8.65 & 8.65 & 8.65 & 9.59 & 9.59 \\ 11.69 & 7.03 & 7.03 & 7.03 & 7.03 & 11.69 & 11.69 \end{pmatrix}$

Table 4.6: Demand vectors for the different settings for the energy drink

Calculating the minimum long-run average cost under each setting requires an estimate of the cost parameters, which in practice is a very difficult task. For instance, Zipkin (2000) notes this difficulty as an obstacle for practical implementation. Only partial solution approaches to this problem exist in research, such as observational studies on store handling cost (e.g. Curşeu et al., 2009) and estimations on stockout penalty costs (e.g. Anderson et al., 2006; Olivares et al., 2010). For this reason, we decided to vary the cost parameters in a way similar to the approach in Sections 4.4.2 and 4.5.2. We use $p \in \{25, 50, 75\}$, $K \in \{0, 5, 10, 15, 20, 25\}$, $K_1 \in \{0, 5, 10\}$, $K_2 \in \{0, 1, 2\}$, $h = 1$, leading to 162 problem instances per item. This way, we are able to calculate the value of incorporating seasonality under a wide range of cost treatments. The value of the case pack size q was set equal to the actual value observed in practice for each item (see Table 4.4, first column from right).

4.6.2 Results

Figure 4.10 gives the results of our analysis. For each item, we report the minimum, average, and maximum optimality gaps for the policies $\overline{W}A$, $W\overline{A}$ and $\overline{W}\overline{A}$ compared to the performance of the WA policy across all 162 problem instances.

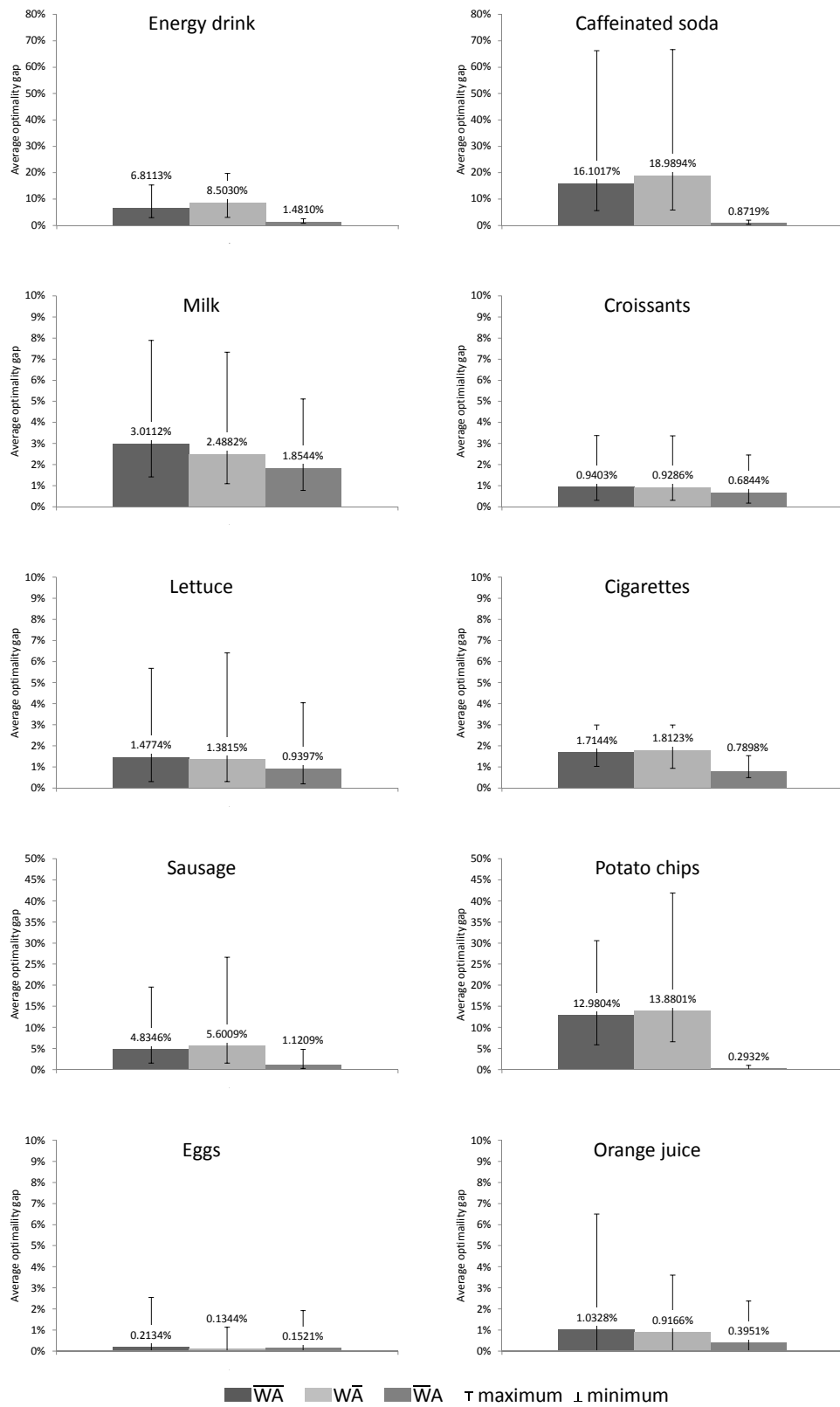


Figure 4.10: Average optimality gaps of the three policies for all 10 items

We see that the optimality gaps of the $\overline{WA}$ policy can be substantial. The maximum value is equal to 66.27% and is achieved for the caffeinated soda. This means that the retailer's costs can be 66.27% higher than optimal when he ignores all forms of demand seasonality. Overall the gaps are largest for the caffeinated soda, the potato chips and the energy drink and lowest for eggs, croissants and the orange juice. In order to determine what makes the optimality gaps high or low, we regressed the optimality gaps of the $\overline{WA}$ policy on the following independent variables: average weekly demand, case pack size, V_W and V_A as defined in Table 4.5. The results are shown in Table 4.7. For the most part, we are able to confirm the results obtained in Section 4.5.1 based on our small sample of 10 items: the optimality gaps are increasing in the average weekly demand, and the extent of across-days variations (as measured by V_A) and decreasing in the case pack size. Surprisingly we find that they are decreasing in the extent of intra-day variations (as measured by V_W); we believe that this is due to our small sample size of 10 items. The results also suggest that intra-day variations are less important than across-days variations as the rest of our analysis confirms.

<i>Variable</i>	<i>Coefficients</i>	<i>Standard Error</i>
<i>Intercept</i>	-0.005	0.019
<i>Case pack</i>	-0.006*	0.001
<i>Avg. wk. demand</i>	0.001**	0.000
V_W	-0.413*	0.106
V_A	0.296***	0.033
R^2	0.957	
<i>Adjusted R^2</i>	0.922	
<i>Statistical significance at * $p \leq 0.05$, ** $p \leq 0.01$, *** $p \leq 0.001$.</i>		

Table 4.7: Regression analysis

Figure 4.10 shows that for all 10 items, switching from the $\overline{WA}$ to the $\overline{WA}$ policy would lead to a decrease in the average optimality gaps. This is especially notable with the energy drink (from 6.81% to 1.48%), the caffeinated soda (from 16.10% to 0.87%), the sausage (from 4.83% to 1.12%) and the potato chips (from 12.98% to 0.29%). This means that the retailer has a lot to gain from incorporating across-days variations. In fact doing so alone brings the retailer within 1.85% of optimality for all items and within 1% for seven of them. Switching from the $\overline{WA}$ policy to the WA policy does not always lead to an reduction in the average optimality gaps. In particular, the retailer would be worse off if it was to incorporate intra-day variations without taking into account across-days variations for the energy drink, caffeinated soda, sausage, potato chips and cigarettes.

This is another example of ‘less information is better’ as discussed in Section 4.5.1.

Switching to the $\overline{W}A$ policy may lead to almost optimal performance as measured by the WA policy, but doing so requires using 7 input variables in the inventory replenishment system, which may be too complex for some companies or their ASO system. In what follows we therefore consider a middle-ground setting in which the retailer groups the days of the week into weekdays versus weekend days and calculates a separate average daily demand for each group. As mentioned before, the retailer we spoke to considered implementing a similar idea.

We construct six new settings. These six settings differ with respect to the definition of weekend (either Friday-Saturday, Saturday-Sunday or Friday-Saturday-Sunday) and whether or not they account for intra-day variations. In settings where the retailer does not account for intra-day variations, the retailer assumes that the demand is evenly distributed throughout the review period. In his book-keeping, he keeps track of only two values of demand: the daily weekday demand and daily weekend demand. We refer to these cases as the $\overline{W}(FS)$, $\overline{W}(SS)$ and $\overline{W}(FSS)$ settings when the weekend is defined respectively as Friday-Saturday, Saturday-Sunday and Friday-Saturday-Sunday. The corresponding λ vectors are calculated as follows:

$$\lambda_{\overline{W}(FS)} = \begin{pmatrix} \frac{9}{16}\overline{\lambda}^d & \frac{9}{16}\overline{\lambda}^d & \frac{9}{16}\overline{\lambda}^d & \frac{9}{16}\overline{\lambda}^d & \frac{9}{16}\overline{\lambda}^d & \frac{9}{16}\overline{\lambda}^e & \frac{9}{16}\overline{\lambda}^e \\ \frac{7}{16}\overline{\lambda}^d & \frac{7}{16}\overline{\lambda}^d & \frac{7}{16}\overline{\lambda}^d & \frac{7}{16}\overline{\lambda}^d & \frac{7}{16}\overline{\lambda}^d & \frac{7}{16}\overline{\lambda}^e & \frac{7}{16}\overline{\lambda}^e \end{pmatrix}$$

where $\overline{\lambda}_d = \frac{1}{5} \sum_{d=1}^5 (\lambda_{d,L} + \lambda_{d,R-L})$ and $\overline{\lambda}^e = \frac{1}{2} \sum_{d=6}^7 (\lambda_{d,L} + \lambda_{d,R-L})$.

$$\lambda_{\overline{W}(SS)} = \begin{pmatrix} \frac{9}{16}\overline{\lambda}^e & \frac{9}{16}\overline{\lambda}^d & \frac{9}{16}\overline{\lambda}^d & \frac{9}{16}\overline{\lambda}^d & \frac{9}{16}\overline{\lambda}^d & \frac{9}{16}\overline{\lambda}^d & \frac{9}{16}\overline{\lambda}^e \\ \frac{7}{16}\overline{\lambda}^e & \frac{7}{16}\overline{\lambda}^d & \frac{7}{16}\overline{\lambda}^d & \frac{7}{16}\overline{\lambda}^d & \frac{7}{16}\overline{\lambda}^d & \frac{7}{16}\overline{\lambda}^d & \frac{7}{16}\overline{\lambda}^e \end{pmatrix}$$

where $\overline{\lambda}_d = \frac{1}{5} \sum_{d=2}^6 (\lambda_{d,L} + \lambda_{d,R-L})$ and $\overline{\lambda}^e = \frac{1}{2} \sum_{d=1,7} (\lambda_{d,L} + \lambda_{d,R-L})$.

$$\lambda_{\overline{W}(FSS)} = \begin{pmatrix} \frac{9}{16}\overline{\lambda}^e & \frac{9}{16}\overline{\lambda}^d & \frac{9}{16}\overline{\lambda}^d & \frac{9}{16}\overline{\lambda}^d & \frac{9}{16}\overline{\lambda}^d & \frac{9}{16}\overline{\lambda}^e & \frac{9}{16}\overline{\lambda}^e \\ \frac{7}{16}\overline{\lambda}^e & \frac{7}{16}\overline{\lambda}^d & \frac{7}{16}\overline{\lambda}^d & \frac{7}{16}\overline{\lambda}^d & \frac{7}{16}\overline{\lambda}^d & \frac{7}{16}\overline{\lambda}^e & \frac{7}{16}\overline{\lambda}^e \end{pmatrix}$$

where $\overline{\lambda}_d = \frac{1}{4} \sum_{d=2}^5 (\lambda_{d,L} + \lambda_{d,R-L})$ and $\overline{\lambda}^e = \frac{1}{3} \sum_{d=1,6,7} (\lambda_{d,L} + \lambda_{d,R-L})$.

In settings where the retailer accounts for intra-day variations, it keeps track of four quantities: weekday demand before the leadtime, weekday demand after the leadtime, weekend demand before the leadtime and weekend demand after the leadtime. We refer to these as the $W(FS)$, $W(SS)$ and $W(FSS)$ settings when the weekend is defined respectively as Friday-Saturday, Saturday-Sunday and Friday-Saturday-Sunday. The cor-

responding λ vectors are calculated as follows:

$$\lambda_{\overline{W}(FS)} = \begin{pmatrix} \delta^e \bar{\lambda}^e & \delta^d \bar{\lambda}^d & \delta^d \bar{\lambda}^d & \delta^d \bar{\lambda}^d & \delta^d \bar{\lambda}^d & \delta^d \bar{\lambda}^d & \delta^e \bar{\lambda}^e \\ (1 - \delta^e) \bar{\lambda}^e & (1 - \delta^d) \bar{\lambda}^d & (1 - \delta^d) \bar{\lambda}^d & (1 - \delta^d) \bar{\lambda}^d & (1 - \delta^d) \bar{\lambda}^d & (1 - \delta^d) \bar{\lambda}^d & (1 - \delta^e) \bar{\lambda}^e \end{pmatrix}$$

where $\bar{\lambda}_d = \frac{1}{5} \sum_{d=1}^5 (\lambda_{d,L} + \lambda_{d,R-L})$, $\bar{\lambda}^e = \frac{1}{2} \sum_{d=6}^7 (\lambda_{d,L} + \lambda_{d,R-L})$, $\delta^d = \frac{\sum_{d=1}^5 \lambda_{d,L}}{\sum_{d=1}^5 (\lambda_{d,L} + \lambda_{d,R-L})}$
and $\delta^e = \frac{\sum_{d=6}^7 \lambda_{d,L}}{\sum_{d=6}^7 (\lambda_{d,L} + \lambda_{d,R-L})}$.

$$\lambda_{\overline{W}(SS)} = \begin{pmatrix} \delta^d \bar{\lambda}^d & \delta^d \bar{\lambda}^d & \delta^d \bar{\lambda}^d & \delta^d \bar{\lambda}^d & \delta^d \bar{\lambda}^d & \delta^e \bar{\lambda}^e & \delta^e \bar{\lambda}^e \\ (1 - \delta^d) \bar{\lambda}^d & (1 - \delta^d) \bar{\lambda}^d & (1 - \delta^d) \bar{\lambda}^d & (1 - \delta^d) \bar{\lambda}^d & (1 - \delta^d) \bar{\lambda}^d & (1 - \delta^e) \bar{\lambda}^e & (1 - \delta^e) \bar{\lambda}^e \end{pmatrix}$$

where $\bar{\lambda}_d = \frac{1}{5} \sum_{d=2}^6 (\lambda_{d,L} + \lambda_{d,R-L})$, $\bar{\lambda}^e = \frac{1}{2} \sum_{d=1,7} (\lambda_{d,L} + \lambda_{d,R-L})$, $\delta^d = \frac{\sum_{d=2}^6 \lambda_{d,L}}{\sum_{d=2}^6 (\lambda_{d,L} + \lambda_{d,R-L})}$
and $\delta^e = \frac{\sum_{d=1,7} \lambda_{d,L}}{\sum_{d=1,7} (\lambda_{d,L} + \lambda_{d,R-L})}$.

$$\lambda_{\overline{W}(FSS)} = \begin{pmatrix} \delta^e \bar{\lambda}^e & \delta^d \bar{\lambda}^d & \delta^d \bar{\lambda}^d & \delta^d \bar{\lambda}^d & \delta^d \bar{\lambda}^d & \delta^e \bar{\lambda}^e & \delta^e \bar{\lambda}^e \\ (1 - \delta^e) \bar{\lambda}^e & (1 - \delta^d) \bar{\lambda}^d & (1 - \delta^d) \bar{\lambda}^d & (1 - \delta^d) \bar{\lambda}^d & (1 - \delta^d) \bar{\lambda}^d & (1 - \delta^e) \bar{\lambda}^e & (1 - \delta^e) \bar{\lambda}^e \end{pmatrix}$$

where $\bar{\lambda}_d = \frac{1}{4} \sum_{d=2}^5 (\lambda_{d,L} + \lambda_{d,R-L})$, $\bar{\lambda}^e = \frac{1}{3} \sum_{d=1,6,7} (\lambda_{d,L} + \lambda_{d,R-L})$, $\delta^d = \frac{\sum_{d=2}^5 \lambda_{d,L}}{\sum_{d=2}^5 (\lambda_{d,L} + \lambda_{d,R-L})}$
and $\delta^e = \frac{\sum_{d=1,6,7} \lambda_{d,L}}{\sum_{d=1,6,7} (\lambda_{d,L} + \lambda_{d,R-L})}$.

Rows 5 to 10 in Table 4.6 show the value of the vector λ in each of the six settings for the energy drink example.

We now repeat the optimality gap analysis with these six new settings using the same 162 problem instances outlined earlier. Figure 4.11 gives the results of our analysis.

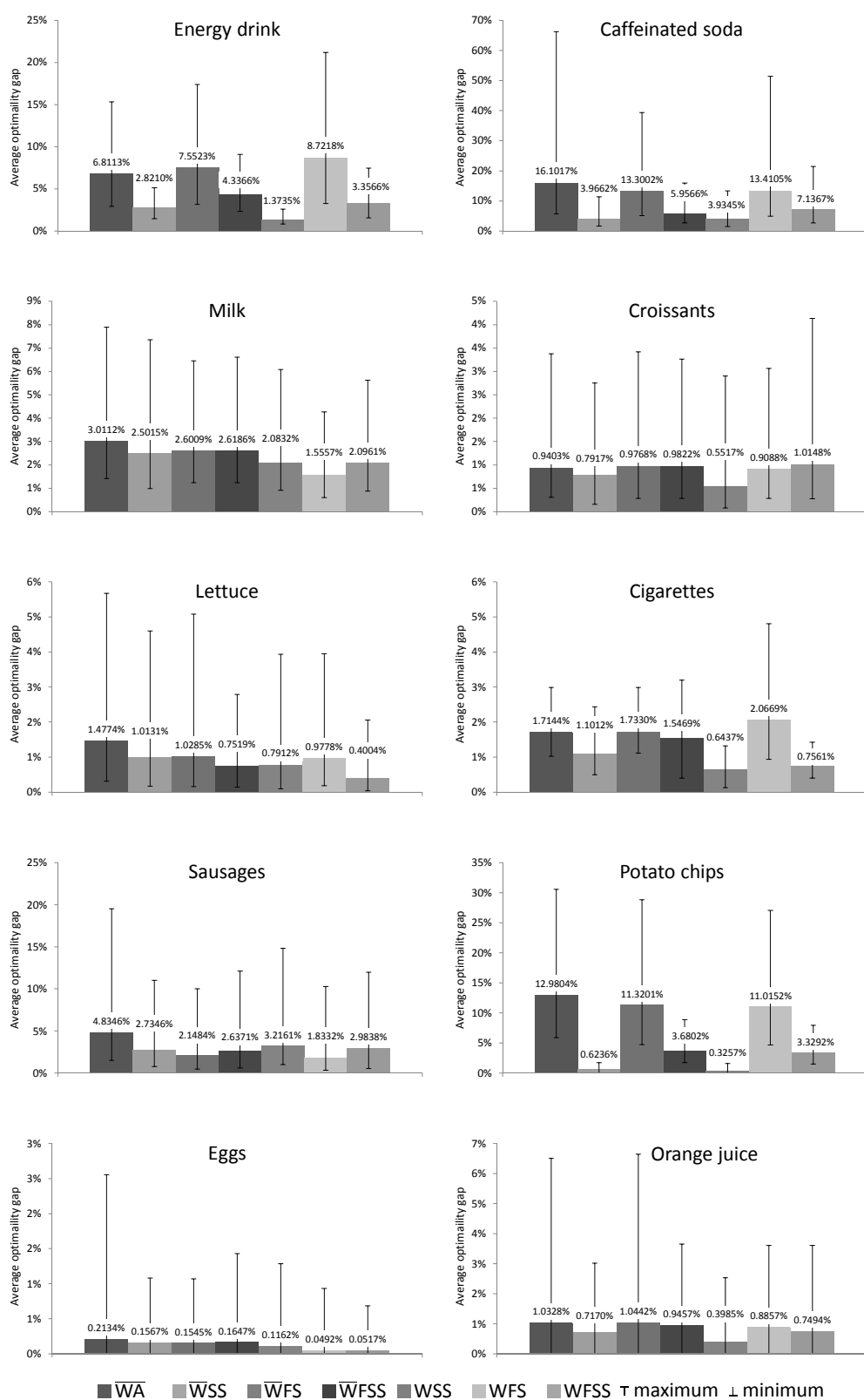


Figure 4.11: Average optimality gaps of the new policies for all 10 items

We now repeat the optimality gap analysis with these six new settings using the same 162 problem instances outlined earlier. Figure 4.11 gives the results of our analysis. It shows that it is possible to achieve a significant reduction in costs by distinguishing between weekdays and weekend days. In some cases however, it is important to use the appropriate definition for the weekend. For example, the weekend should clearly be defined as Saturday-Sunday for the energy drink, caffeinated soda, croissant and potato chips items, as Friday-Saturday for sausage and as Friday-Saturday-Sunday for lettuce. Not defining the weekend properly can lead to worse performance than the $\overline{WA}$ policy (e.g., for the energy drink, croissants, cigarettes and orange juice). Incorporating intra-day variations generally leads to a further reduction in costs but this improvement is not as important compared to the cost decrease that comes with the weekday-weekend distinction.

In summary, if the retailer has limited resources or limited capabilities for incorporating seasonal variations into its ASO system, it should mostly focus on categories of high velocity products with large across-days variations (as measured by the coefficient of variation V_A) and small case pack size, where the savings can be the highest. The first best option is to incorporate intra-day as well as across-days variations (14 input variables) but if this proves to be too difficult, the second best option is to take only across-days variations into account (7 input variables). If this is still too complicated – and our discussions with retailers suggest this may be the case – the retailer can still achieve considerable reductions in costs by carefully defining the weekend and distinguishing between weekend and weekday demand (i.e. using only 2 input variables for the ASO system).

4.7 Conclusions and future research

We have analyzed the optimal inventory decision for a retailer when its demand is non-stationary and in particular, seasonal. By comparing the results of the optimal policy with policies accounting for seasonality to a lesser degree, we have obtained insights into the cost of ignoring demand seasonality in inventory management.

Our paper yields some important insights for retail management. By accounting for non-stationary demand in inventory management, retailers can reduce inventory holding, handling and stock-out cost substantially. Cost savings are higher for fast-moving items with high demand variability across review periods and low case pack size. Our numerical analysis with real life data indicates potential cost savings that are considerable for the retailing industry with its tight margins and rigorous focus on cost-efficiency (a reduction of up to 66.27% in optimality gaps). Large cost savings can be already achieved with

a simple distinction between weekday and weekend sales, provided that the weekend is defined appropriately for each item (the optimality gap goes down to an average of 1.60%). Doing so improves the return on investment in automated store ordering systems that are equipped with the capabilities of accounting for non-stationary demand.

As our model is not specific to a particular demand pattern, it may also be employed in ultra-high selling retail outlets with multiple deliveries per day, for instance. The smaller the review period, the more accurate the information for shelf replenishment. Moreover, albeit the focus of this research was the retailing industry, we believe the insights to be of interest to similar settings, where product values are low compared to handling costs, demand is non-stationary and non-availability is penalized by customers.

In order to limit the complexity of the inventory problem at hand, we excluded minimum shelf inventory requirements, shelf space restrictions (we assume shelf space to be sufficient for demand during lead time), and perishability concerns in our analysis. Incorporating minimum stock requirements and shelf space restrictions into the model may provide interesting insights under non-stationary demand (see also Curşeu et al., 2011). Also, we investigate a single-item, single-location problem. Future research could work towards building multi-item and/or multi-echelon models and investigate workload scheduling and balancing in the retail supply chain (such as adjustments to delivery times as well as seasonal capacity constraints and cost) and at the store level (see Hübner et al., 2010). Lastly, we do not consider promotional events. Future research could work towards understanding promotional non-stationarity, e.g. the item-level intraday and across-days effects of various types of promotions. Combining the insights of promotional demand variation with our non-stationary demand inventory model accounting for ordering and handling costs may provide additional insights to retail marketers and logistics managers for increasing the return on promotions. Finally, another possible avenue for future research is the study of easy-to-implement heuristic policies which incorporate demand seasonality. For example, it would be interesting to study how well a (s_d, S_d, nq) policy, with d being the season index, would perform compared to the optimal policy used in this paper.

4.8 Acknowledgments

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4.10 Appendix

This section gives the rationale for the use of the Poisson distribution for our real life examples in Section 4.6. Figure 4.12 shows the observed and (Poisson) expected frequency of cigarette sales (global brand, box of 10) during the lead time in 2010. For a discussion on supermarket sales distributions and issues in supermarket sales forecasting, see Taylor (2007).

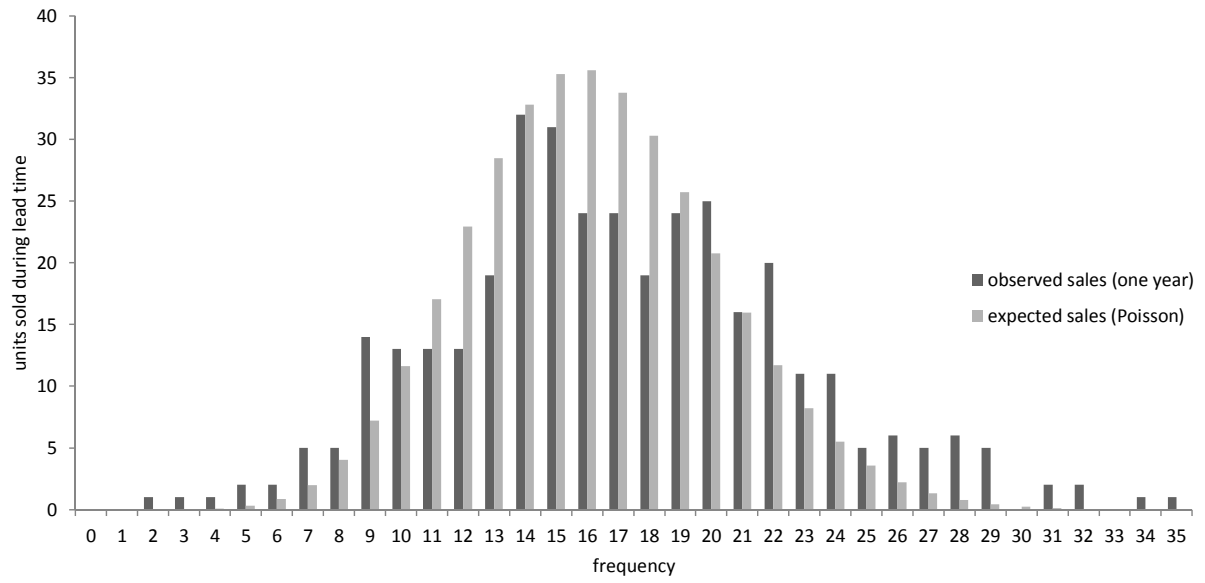


Figure 4.12: Frequency of cigarette sales during lead time in 2010

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