

**How companies turn connected products into product-service systems –
Insights from the discrete manufacturing industry**

DISSERTATION
of the University of St. Gallen,
School of Management,
Economics, Law, Social Sciences,
International Affairs and Computer Science,
to obtain the title of
Doctor of Philosophy in Management

submitted by

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Dissertation no. 5229

Difo-Druck GmbH, Untersiemaun 2022

The University of St.Gallen, School of Management, Economics, Law, Social Sciences, International Affairs and Computer Science, hereby consents to the printing of the present dissertation, without hereby expressing any opinion on the views herein expressed.

St.Gallen, May 24, 2022

The President:

Prof. Dr. Bernhard Ehrenzeller

Acknowledgments

This thesis is the result of my research at the Institute of Technology Management (ITEM) at the University of St. Gallen (HSG), where I was part of the Bosch IoT Lab, a collaboration between the HSG, ETH Zürich, and the Bosch Group. It has been a privilege to be part of this collaboration. This thesis would not have been possible without the tremendous support of the Bosch Group, many colleagues, and mentors.

Above all, I would like to thank my supervisor, Prof. Dr. Elgar Fleisch, for the unique opportunity to conduct research at the intersection of theory and practice. I am particularly grateful for his unlimited trust and for being a mentor to me beyond my doctoral studies. I would also like to thank my co-supervisor, Prof. Dr. Oliver Gassmann, for his support, guidance, and feedback.

Furthermore, special appreciation belongs to Prof. Dr. Felix Wortmann, Scientific Director of the Bosch IoT Lab, for getting the best out of me. Your leadership and support were essential for my personal and professional development – thank you! I would like to thank Timo Gessmann and Dr. Wolfgang Bronner, representatives of the Bosch Group, who both supported me in maximizing the impact we are having in the Bosch Group. I would also like to thank Prof. Dr. Heiko Gebauer for his support and for “teaching” me how to publish scientific research. In addition, I would like to thank Elisabeth Vetsch-Keller, who is the good soul of this chair.

I would like to thank all my colleagues and friends at the chairs of Prof. Elgar Fleisch. A big thank you goes to my colleagues at the Bosch IoT Lab, Dr. Dominik Bilgeri, Dr. Mathieu Chanson, Simon Föll, Dr. Bernhard Gahr, Sven Jung, Kevin Koch, Shu Liu, Martin Maritsch, Dr. Arne Meeuw, Fabian Schäfer, and Eva van Weenen for making my journey enjoyable and for many “near-death experiences” in our team events. And of course, I want to thank all the amazing people that were around, either in St. Gallen or in Zurich. Thank you – you are arguably the smartest people I know.

Finally, my family deserves my deepest gratitude. My parents, Cornelia and Roland, who taught me everything I know and who made me the person I am, and my sisters, Corinne and Eileen, who inspire me every day with their dedication. Most especially, I would like to thank my partner Verena for her unconditional love and encouragement.

Zurich, January 2022

Claudio Lamprecht

Abstract

Manufacturing firms are increasingly moving beyond merely selling products to offering product-service systems (PSSs) – integrated bundles of hardware, services, and software designed to address customer needs. While PSSs are not new, they have recently gained considerable momentum owing to the rise of the Internet of Things (IoT). In the past, service was all about sending people to customer sites. Today, connected products enable remote monitoring, predictive maintenance, remote updates, and more. In essence, companies can digitize essential PSS services while keeping their marginal costs close to zero. However, many manufacturers struggle to successfully develop and commercialize PSSs.

The increasing interest in PSSs has resulted in a rapidly growing body of literature. Thus far, however, knowledge about how manufacturers can implement PSSs is limited. The extant research fails to provide the knowledge, tools, and guidelines needed to support manufacturers in this transition. In order to address this research gap, this thesis uses three original studies to investigate how companies can transition connected products to sustainable PSSs. All three studies apply an inductive multiple case study approach to derive meaningful insights into a complex, real-world phenomenon.

The first study investigates misconceptions about PSSs to provide practitioners with a clear understanding of these systems. The results reveal six misconceptions that prevent manufacturers from transitioning towards PSSs. The misconceptions relate to when PSSs are relevant, what they are, and how firms should approach them. The second study explores PSS business model patterns with the aim of supporting the design of sustainable PSS business models. In an analysis of 199 PSSs, the study reveals 58 patterns that characterize value proposition, value capture, and value creation elements. The patterns represent the building blocks of existing PSS business models that can be reused, reassembled, and recombined in new PSS business models. The third study examines how manufacturers can measure PSS performance. It uncovers a key performance indicator set that can be used to comprehensively measure PSS performance, thereby allowing manufacturers to manage the progress and outcomes of their PSS transformations. The findings of this thesis contribute new theoretical knowledge and serve practitioners by helping them generate a business impact.

Zusammenfassung

Produzierende Unternehmen verkaufen zunehmend nicht mehr nur Produkte, sondern Produkt-Service-Systeme (PSS) - ein integriertes Bündel aus Hardware-, Service- und Softwareelementen, um Kundenprobleme zu lösen. PSS sind zwar nichts Neues, haben aber erst in jüngster Zeit durch das Aufkommen des Internets der Dinge (IoT) erheblich an Dynamik gewonnen. In der Vergangenheit bestand "Service" vor allem darin, Servicemitarbeiter zum Kunden zu schicken. Heute ermöglichen vernetzte Produkte beispielsweise Fernüberwachung, vorausschauende Wartung und Fernaktualisierungen. Im Grunde können Unternehmen wesentliche PSS-Serviceelemente mit Grenzkosten nahe Null digitalisieren. Viele Unternehmen tun sich jedoch schwer, PSS erfolgreich zu entwickeln und zu vermarkten/umzusetzen.

Das zunehmende Interesse an PSS hat zu einem rasch wachsenden Forschungsfeld geführt. Jedoch ist das Wissen darüber, wie Unternehmen PSS einführen können noch begrenzt. Es mangelt an Erkenntnissen, Werkzeugen, und Leitlinien, die Unternehmen bei der Transformation unterstützen. Um diese Forschungslücke zu adressieren, untersucht die vorliegende Dissertation anhand von drei Studien, wie Unternehmen vernetzte Produkte in nachhaltige PSS umwandeln können. Die Studien basieren dabei auf einem induktivem Fallstudienansatz, um aussagekräftige Erkenntnisse über ein komplexes, reales Phänomen zu gewinnen.

Die erste Studie untersucht PSS-Irrtümer, um Praktikern ein klares Verständnis über PSS zu vermitteln. Die Ergebnisse offenbaren sechs PSS-Irrtümer, die Unternehmen daran hindern PSS einzuführen. Die Irrtümer beziehen sich auf die Themen: wann PSS relevant sind, was PSS sind, und wie Unternehmen an PSS herangehen sollten. Die zweite Studie untersucht Geschäftsmodellmuster bei PSS, um die Entwicklung von PSS Geschäftsmodellen zu unterstützen. Die Analyse von 199 PSS führt zu 58 Muster, die das Wertangebot, die Wertschöpfungskette, und die Ertragsmechanik von PSS Geschäftsmodellen charakterisieren. In der dritten Studie wird schließlich untersucht, wie Unternehmen die Performance von PSS messen können. Aus der Studie resultiert ein Kennzahlensystem, das Unternehmen zur Messung und Steuerung von PSS verwenden können. Die Ergebnisse dieser Dissertation führen zu neuen theoretischen Erkenntnissen und sollen Praktikern helfen PSS zu kommerzialisieren.

Previous Publications

This dissertation contains material that has already been published or was/will be submitted for publication as scientific articles in peer-reviewed journals, articles in practitioner outlets, or books.

The core findings of this thesis build upon four manuscripts. Although I am not the first author of all the manuscripts, I hereby declare that I wrote most of the content of the four manuscripts that constitute the core findings of this thesis. Of course, my co-authors contributed substantially to these manuscripts with their feedback, reviews, and suggestions. As all my co-authors for these four manuscripts are professors, the findings have not been considered for other PhD dissertations. Accordingly, parts of this dissertation can bear a strong resemblance or correspond literally to my own previously published work. This dissertation builds upon the following manuscripts:

Lamprecht, C., Gebauer, H., Fleisch, E., & Wortmann, F. (2022a). A KPI set for steering the IoT business in product companies. *Research-Technology Management*, 65(2), 53-63. <https://doi.org/10.1080/08956308.2022.2015951>

Lamprecht, C., Gebauer, H., Fleisch, E., & Wortmann, F. (2022b). *Der IoT Profit Cycle - ein Kennzahlensystem für das IoT Geschäft*. Manuscript submitted for publication, University of St. Gallen.

Lamprecht, C., Wortmann, F., Gebauer, H., & Fleisch, E. (2021). *Six myths about product as a service*. Unpublished manuscript, University of St. Gallen.

Wortmann, F., **Lamprecht, C.**, Gebauer, H., & Fleisch, E. (2021). The St. Gallen EaaS navigator: 66 pattern cards to guide the development of customer-centric product-service systems. www.amazon.de/dp/B09422FN8B

In addition, I also contributed to the following publications during my PhD research, which are outside of this thesis main scope:

Bronner, W., Gebauer, H., **Lamprecht, C.**, & Wortmann, F. (2021). Sustainable AIoT: How artificial intelligence and the internet of things affect profit, people, and planet. In O. Gassmann & F. Ferrandina (Eds.), *Connected Business: Create Value in a Networked Economy* (pp. 137-154). Springer. https://doi.org/10.1007/978-3-030-76897-3_8

- Gebauer, H., Arzt, A., Kohtamäki, M., **Lamprecht, C.**, Parida, V., Witell, L., & Wortmann, F. (2020). How to convert digital offerings into revenue enhancement – Conceptualizing business model dynamics through explorative case studies. *Industrial Marketing Management*, 91, 429-441. <https://doi.org/10.1016/j.indmarman.2020.10.006>
- Gebauer, H., Fleisch, E., **Lamprecht, C.**, & Wortmann, F. (2020). Growth paths for overcoming the digitalization paradox. *Business Horizons*, 63(3), 313-323. <https://doi.org/10.1016/j.bushor.2020.01.005>
- Knapp, J., **Lamprecht, C.**, Gebauer, H., & Wortmann, F. (2020). From selling assets to delivering equipment-as-a-service. *Proceedings of the Spring Servitization Conference 2020*, 278-280.
- Lamprecht, C.**, Gebauer, H., Fleisch, E., Wortmann, F., & Gessmann, T. (2019). Steering manufacturing firms towards IoT enabled service and product business. *Proceedings of the Spring Servitization Conference 2019*, 259-260.
- Wortmann, F., Bilgeri, D., Gebauer, H., **Lamprecht, C.**, & Fleisch, E. (2019). Geld verdienen im IoT – aber wie? *HMD Praxis der Wirtschaftsinformatik*, 56, 1094–1112. <https://doi.org/10.1365/s40702-019-00561-2>
- Wortmann, F., Bilgeri, D., Gebauer, H., **Lamprecht, C.**, & Fleisch, E. (2021). Der lange Weg im IoT – Von der Vernetzung zur Profitabilität. In S. Meinhardt & F. Wortmann (Eds.), *IoT – Best Practices: Internet der Dinge, Geschäftsmodellinnovationen, IoT-Plattformen, IoT in Fertigung und Logistik* (pp. 3-21). Springer. https://doi.org/10.1007/978-3-658-32439-1_1

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List of Abbreviations

ARR	Annual Recurring Revenue
BMI	Business Model Innovation
BSC	Balanced Scorecard
CAPEX	Capital Expenditures
CFO	Chief Financial Officer
CRM	Customer Relationship Management
CSAT	Customer Satisfaction Score
DAU	Daily Active Users
EBITDA	Earnings Before Interest, Taxes, Depreciation
ERP	Enterprise Resource Planning
EV	Enterprise Value
GE	General Electric
IoT	Internet of Things
KPIs	Key Performance Indicators
MAU	Monthly Active Users
MRR	Monthly Recurring Revenue
NAICS	North American Industry Classification System
NFC	Near Field Communication
NPS	Net Promoter Score
OEE	Overall Equipment Effectiveness

OPEX	Operating Expenditures
PMS	Performance Measurement Systems
PSS	Product-Service System
P&L	Profit and Loss Statement
RFID	Radio-Frequency Identification
ROI	Return on Investment
RQ	Research Question
SaaS	Software as a Service
SRQ	Sub-Research Question
SUV	Sport Utility Vehicle
TCO	Total Cost of Ownership
WLAN	Wireless LAN

Chapter 1

Introduction

“People don’t want to buy a quarter-inch drill. They want a quarter-inch hole!”

Theodore Levitt

1.1 Motivation

Manufacturing firms are increasingly shifting away from merely selling products towards offering integrated product-service systems (PSSs) (Grove et al., 2018; Kowalkowski et al., 2017). Offering only products is often no longer sufficient for manufacturers to differentiate themselves from competitors (Connerty et al., 2016) and customers do not want products, per se, but rather solutions to their problems (Bertini & Koenigsberg, 2020a, 2020b). As revealed by the quote above, from Harvard Business School professor Theodore Levitt, customers do not want quarter-inch drills (product); what they want is quarter-inch holes (solution). Consequently, many manufacturers are moving away from product-centric offerings to solutions by providing an integrated bundle of hardware, service, and software elements. These bundles are widely known as PSSs (Berkovich et al., 2011; Tukker, 2004). A well-known example of a PSS is Rolls-Royce’s “power-by-the-hour” offering: Rolls-Royce does not sell the turbine engine itself, but rather bundles it with spares and maintenance services to sell airlines flying hours at a defined price (Baines & Lightfoot, 2013b).

While PSSs are nothing new – Rolls-Royce’s “power-by-the-hour” offer dates back to the early 1960s (Baines et al., 2007) – they have only recently gained considerable momentum among manufacturers due to the rise of the Internet of Things (IoT) (Bertini

& Koenigsberg, 2020a; Lerch & Gotsch, 2015). The IoT represents a technological vision where any product can be connected to the internet. Manufacturers equip products with intelligent systems (e.g., sensors, actuators, software, etc.) and connectivity components that allow products to sense their environment, transmit and receive information, as well as to act upon that information (Fleisch et al., 2014; Wortmann & Flüchter, 2015). These so-called smart, connected products (hereafter connected products) empower manufacturers to create entirely new (digital) services (Porter & Heppelmann, 2014). In the past, service was all about sending technicians to customer sites. Now, connected products enable remote monitoring, predictive maintenance, remote updates, etc., allowing manufacturers to increase service efficiency and launch new (digital) services with marginal costs that are close to zero (Iansiti & Lakhani, 2014; Porter & Heppelmann, 2014; Vendrell-Herrero et al., 2017). These new opportunities spanning the physical and digital worlds enable PSSs that were previously inconceivable (Lerch & Gotsch, 2015; Porter & Heppelmann, 2014, 2015). The ability to remotely monitor bearings, for instance, paved the way for SKF – a bearings manufacturer – to sell “reliable rotations” instead of selling bearings (Brown, 2018).

In addition to solving customer problems and exploiting the business opportunities offered by connected products, PSSs generate recurring revenues, which is another reason that manufacturing firms invest in them (Oliva & Kallenberg, 2003; Towers-Clark, 2020). While product sales usually generate one-off (non-recurring) revenues, PSSs generate recurring revenue streams as customers pay a monthly or yearly fee for access, usage, performance, or functions (Bertini & Koenigsberg, 2020a; Gaiardelli et al., 2014). One example is the PSS “BlueMovement”, a home appliance subscription from Bosch, where customers pay a monthly fee to have access to household appliances. Bosch, a large German conglomerate, whose business sectors span mobility to household appliances and industrial technology, plans to increase its share of recurring revenues from its current 1% to 10% in 2026 with PSSs such as the BlueMovement home appliance subscription (BSH Hausgeräte, 2021). Generating recurring revenues allows manufacturers to increase the predictability of their business and lower the respective volatility (Tzuo & Weisert, 2018). This results in a more sustainable business and a higher company valuation (Helo et al., 2017; Hui, 2014; Korkeamäki et al., 2021). Figure 1 exemplarily illustrates the company value (EV/EBITDA) vs. recurring revenue share for a handful of selected companies. The figure shows that companies with a higher recurring revenue share tend to be valued higher (cf. Hui, 2014).

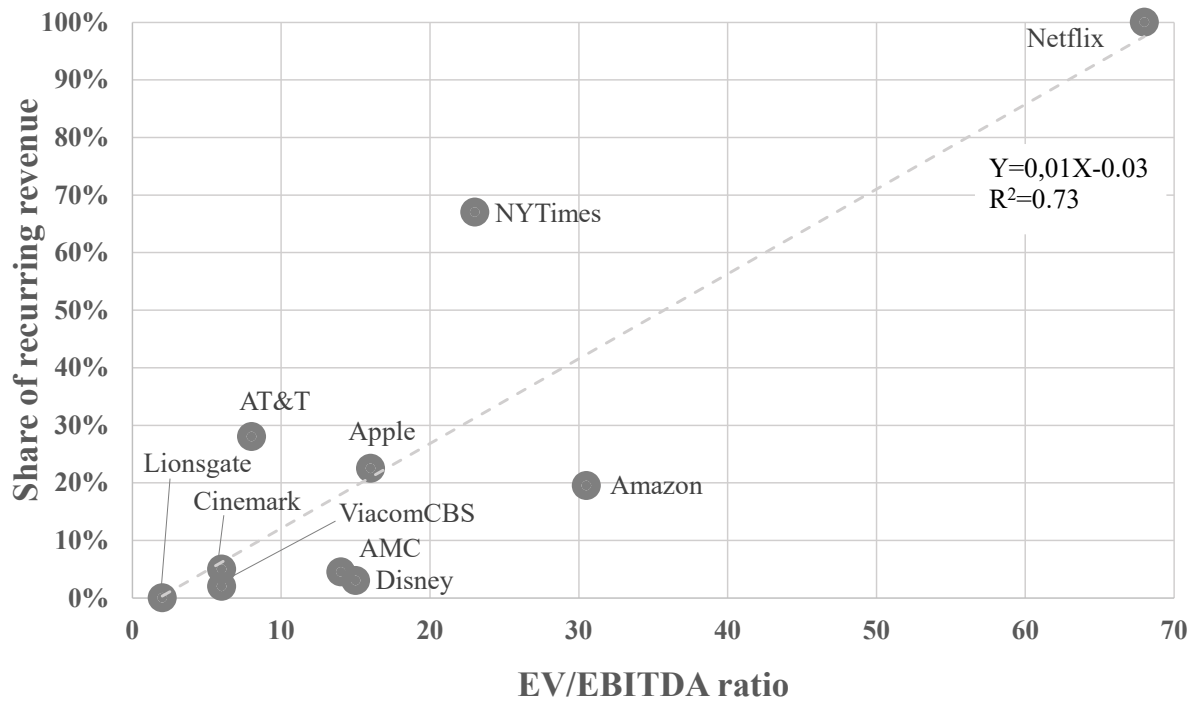


Figure 1: Company value (EV/EBITDA) vs. recurring revenue share (based on Galloway (2020))

However, selling PSSs is not the same as selling products or services (Barquet et al., 2013; Parida et al., 2014). Offering PSSs requires companies to adopt a business model that delivers solutions rather than delivering the product or services used to achieve them (Bertini & Koenigsberg, 2020b; Sjödin et al., 2020). This new way of doing business is often associated with organizational change (Baines et al., 2017) as well as with a need for a more service-oriented culture (Neely, 2008). Recent research indicates that despite manufacturers' large investments into PSSs, the generated turnover is still low (Gebauer, Fleisch, et al., 2020; Kohtamäki et al., 2020). Even manufacturers with proven track records of product excellence, such as the conglomerate General Electric (GE), have struggled to commercialize PSSs (Crooks, 2017; Davenport & Westerman, 2018). Hence, despite being a new imperative for future success for many manufacturers (Connerty et al., 2016; Lerch & Gotsch, 2015), PSSs are not yet a mature phenomenon in manufacturing (Grove et al., 2018; Kohtamäki et al., 2020; Wortmann, Bilgeri, et al., 2021). In other words, many firms are still figuring out the art and science of PSSs.

1.2 Research Objectives

Research on PSSs is rapidly emerging, driven by manufacturers' increasing interest in these systems (Paschou et al., 2020; Pirola et al., 2020). However, studies of PSS implementation remain limited (Reim et al., 2015). Although the extant research suggests that manufacturers struggle with their PSS transformations, it fails to provide the knowledge, tools, and guidelines needed to support them in this transition (Adrodegari & Saccani, 2020; Adrodegari et al., 2017; Barquet et al., 2013). This thesis aims to contribute to this emerging research field by shedding light on how manufacturing firms can transition connected products to sustainable PSSs. To this end, we¹ conducted three studies. The objective of the first study is to provide an understanding of PSSs by identifying common PSS misconceptions that prevent manufacturing firms from effectively transitioning towards PSSs. The second study aims to extend our knowledge of how manufacturers can design PSSs by identifying business model patterns that can support the design of PSS business models. The third study's objective is to contribute to the research on effectively managing PSSs by investigating how manufacturers can measure PSS performance. As such, the findings presented in this thesis contribute to theory and practice in several ways.

First, the thesis strives to contribute new theoretical knowledge. For instance, the findings on PSS misconceptions advance the extant literature indicating theory-practice disparities by identifying PSS misconceptions among practitioners. In addition, the findings on business model patterns extend the research on PSSs from a business model perspective. While the business model concept is inherently associated with manufacturers' transitions towards PSSs, research characterizing business models for PSSs is scarce (Adrodegari & Saccani, 2017). The insights from the three studies provide a detailed understanding and description of PSS-related business model components and their sub-elements, and offer new theoretical knowledge about the business model characteristics of PSSs. Furthermore, the findings on measuring PSS performance confirm the need for new performance measurement systems and provide

¹ I conducted the three studies as part of a larger research effort in the Bosch IoT Lab. To acknowledge my colleagues and co-authors who contributed to these studies with feedback, reviews, and suggestions, I use the term "we" throughout this thesis (see also the *Previous Publications* chapter).

new knowledge regarding key performance indicators (KPIs) relevant for measuring PSS performance.

Second, the findings of this thesis can help practitioners generate a business impact. We derived the results of the three studies in close cooperation with manufacturers active in various industries and sectors. The examples provided, along with the theoretical knowledge we derived and the frameworks and tools (e.g., business model patterns, KPI set) we developed, will enable practitioners to better understand, design, and manage PSSs.

1.3 Thesis Outline

The remainder of this thesis is structured as follows. Chapter 2 outlines the existing research and relevant concepts that informed the research. In particular, this includes research and core concepts regarding the “Internet of Things” and “Product-Service Systems”. Subsequently, chapter 3 outlines the applied methodological approach, including the underlying research questions, as well as the means of data collection and analysis. Next, chapters 4 to 6 present the core findings, which are the main contributions of this thesis. Each chapter is dedicated to a specific individual topic to answer the overall research question. Finally, chapter 7 summarizes the key findings, outlines the general implications, and concludes by indicating future research directions.

Chapter 2

Background and Related Work

This chapter outlines existing research that informs the present thesis research. First, the chapter describes the technological background by introducing the Internet of Things. Second, we outline the product-service systems concept leveraging the Internet of Things. Third, we describe product-service systems in the empirical context of manufacturing companies. In addition, the presented research provides definitions for the core theoretical concepts used in the empirical studies that make up the thesis. Table 18 in the appendix provides an overview of the concepts used throughout this thesis.

2.1 Internet of Things

The Internet of Things (IoT) is a technological vision that any product can be connected to the internet (Iansiti & Lakhani, 2014; Lee & Lee, 2015). Companies increasingly equip what were previously mere physical products with “smart” components (e.g., sensors, software, actuators, microprocessors) and connectivity components (e.g., antennas, RFID, WLAN, NFC). This enables products to sense their environment, transmit and receive information, as well as to act upon that information (Fleisch et al., 2015; Mattern & Floerkemeier, 2010; Ng & Wakenshaw, 2017; Wortmann & Flüchter, 2015). “Digitally upgrading” physical products in this way merges the previously separate physical and digital worlds, thereby substantially enhancing the physical product value by adding the capabilities of the digital world (Mattern & Floerkemeier, 2010). One example for this upgrading is Nest’s surveillance cameras, where an internet connection enables a convenient online video history service (Nest, 2021).

As illustrated in Figure 2, this merger of the physical and the digital worlds is usually composed of five core value layers. Fleisch et al. (2015) outline that the physical thing represents the first layer, which supplies the direct and physical benefit to the user. In the case of surveillance cameras, this takes the form of surveillance videos. However, the cameras are now equipped with “smart” components, such as sensors and actuators (layer 2). Motion sensors in the camera, for example, measure whether people are in a room. At the same time, actuators switch cameras on or off to film when people are actually in the room. With layer three, the previous layers are connected to the internet and thus become globally accessible. In the example of the surveillance cameras, by connecting a camera to the household Wi-Fi, it can transmit and receive data (e.g., users can access live videos captured by the camera from anywhere). In layer four, data is collected, stored, and analyzed (layer 4) – typically in a cloud backend system. Lastly, building upon layers one to four, digital services extend the physical product’s value – e.g., by creating an online video history for the surveillance cameras. Hence, the value experienced by customers is a combination of the physical product (layer 1) and the digital services (layer 5), meaning that this solution as a whole is more than the sum of the single components (Fleisch et al., 2015; Porter & Heppelmann, 2014, 2015; Saarikko et al., 2017).

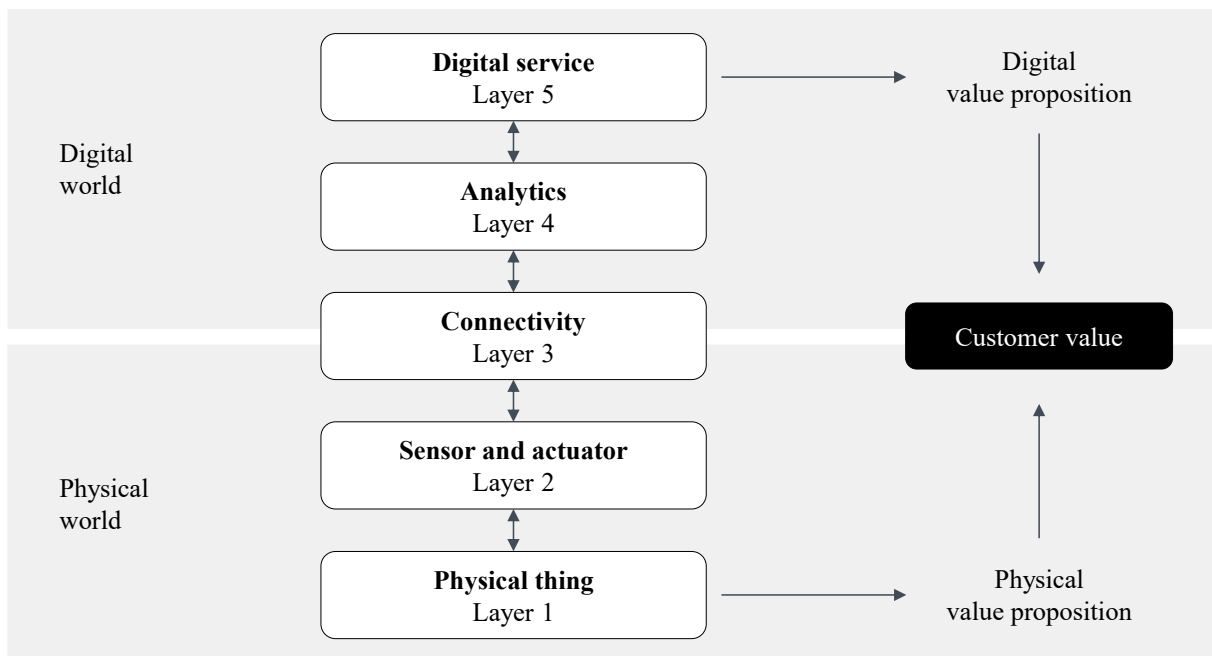


Figure 2: IoT value stack (adapted from Fleisch et al. (2015))

2.1.1 Connected Products

Connected products represent companies' physical access points to the digital world (Mattern & Floerkemeier, 2010) – layers 1 through 3 in the previously outlined IoT value stack. Hence, companies invest in making their products “smart” and “connected” to participate in the digital world (Wortmann et al., 2019). However, despite considerable attention from practitioners and researchers, no common definition for connected products exists (Raff et al., 2020). For instance, Porter and Heppelmann (2014) define connected products through three types of components: the physical components that comprise a product's electrical and mechanical parts, the smart components that amplify the value of the physical parts, and the connectivity components that enable information exchange with and between products (Porter & Heppelmann, 2014). On the other hand, Raff et al. (2020) identified 16 criteria to define connected products. They extracted a conceptual framework comprising four archetypes (digital, connected, responsive, and intelligent) to conceptualize connected products. This dissertation uses the definition by Porter and Heppelmann (2014) for connected products, as it is frequently used in the fields of IoT and product-service systems (e.g., Fleisch et al., 2015; Rymaszewska et al., 2017; Wortmann & Flüchter, 2015).

2.1.2 Creating and Capturing Value in the IoT

Connected products have become a tangible reality, with connected cars, intelligent machines, or smart home appliances as a few well-known examples (Jankowski, 2014; Lee & Lee, 2015). However, a connected product, per se, does not deliver added value (Fleisch et al., 2015). The extant literature characterizes two fundamental ways that companies can create and capture value with networked products: product/service-centric innovation and process-centric innovation (Wortmann et al., 2019). On the one hand, companies can innovate beyond their physical product and service offering by adding digital services to better address their customers' needs (Rymaszewska et al., 2017; Saarikko et al., 2017). On the other hand, companies can use the data from connected products to optimize internal processes to achieve cost reductions and ultimately higher margins (Bilgeri et al., 2019).

Looking first at product/service-centric innovation, it is clear that companies no longer only offer combinations of physical products and services to their customers. Connected products enable companies to augment their traditional physical products with digital

services² that provide added value to customers (Ardolino et al., 2017; Gebauer, Arzt, et al., 2020; Iansiti & Lakhani, 2014). In addition to selling a product-based physical function – e.g., a towing vehicle in the case of a tractor – companies can also create and capture value through IoT-based services – e.g., predictive maintenance to reduce unplanned downtime for customers (Fischer et al., 2012; Wortmann & Flüchter, 2015). Fleisch et al. (2015) reduce this logic to a simple formula. As outlined in Figure 3, the formula states that the value of adding IoT to physical things lies in hybrid solutions that represent the thing-based function plus the IoT-based service. Companies increasingly need to offer hybrid value propositions that merge the physical and digital worlds to remain viable in today's economy (Iansiti & Lakhani, 2014; Porter & Heppelmann, 2014; Ross et al., 2019).

Thing (Physical product)	+	IoT	=	Thing-based function	+	IoT-based service
Surveillance camera		IoT stack	→	Surveillance		Online video history, emergency call, etc.
E-bike		IoT stack	→	Ride		Navigation, theft protection, etc.
Tractor		IoT stack	→	Towing vehicle		Predictive maintenance, optimization, etc.
Everything		IoT stack	→	Whatever the thing can		Remote monitoring, predictive maintenance, remote support, etc.

Figure 3: Product-service logic of IoT (adapted from Fleisch et al. (2015))

In addition to creating and capturing value through new hybrid solutions, companies can leverage the data generated from connected products to optimize internal processes (Bilgeri et al., 2019; Porter & Heppelmann, 2015). For instance, a connected product can collect and provide product data on application, performance, wear and tear, etc. These data points can serve as invaluable inputs for optimizing existing products and services, and can improve the product development process by relying on “hard” data (Saarikko et al., 2017). For example, engineers at Konecranes, an industrial crane manufacturer, use data collected from their cranes to build a digital twin that allows

² The terms digital service, IoT-enabled service, IoT-based service, software, or digital product are synonyms and are used interchangeably in this thesis.

them to test new developments and reduce the need for physical prototypes, ultimately speeding up the whole product development process (Bilgeri et al., 2019).

In summary, companies possess two fundamental ways to create and capture value in the IoT: product/service-centric innovation or realizing benefits from process-centric innovation. This thesis primarily contributes insights to the former kind of innovation. If companies want their customers to share data from connected products, they must offer their customers products and services that provide customer value (Ramaswamy, 2016). Customers will only agree to share data if they see a benefit for themselves, and yet this data sharing is necessary for both product/service-centric innovation and process-centric innovation. Despite unprecedented opportunities and huge investments, recent research provides evidence that many companies are struggling to realize the expected benefits of the IoT. Literature refers to this phenomenon as the digitalization paradox (Gebauer, Fleisch, et al., 2020; Kohtamäki et al., 2020), which we will describe below.

2.1.3 Digitalization Paradox

With its connected products, the IoT offers unprecedented business opportunities that expand existing industry boundaries and have the potential to rewrite the competitive dynamics of industries (Porter & Heppelmann, 2014, 2015). Nearly every industry will be affected, from mobility to energy, home, industrial and retail, to only mention a few (Jankowski, 2014). Research institutes and management consultancies have outdone each other with their predictions and forecasts about the future economic impact of IoT. Many reports ground their predictions on the installed base of connected products. The research institute Statista, for instance, predicts that the number of connected products will almost triple from 8.74 billion connected IoT devices in 2020 to 25.4 billion in 2030 (Statista, 2021b). Similarly, a study by IoT Analytics predicts that connected IoT devices will reach 30.9 billion in 2025, up from 11.7 billion in 2020 (IoT Analytics, 2020). Additionally, other reports forecast that the IoT market revenue will grow from 212 billion U.S. dollars in 2019 to around 1.6 trillion U.S. dollars in 2025 (Statista, 2021a). More conservative estimates predict IoT revenues of 1.1 trillion U.S. dollars IoT in 2025 (GSMA Intelligence, 2018). While these forecasts from research institutes and management consultancies often do not meet rigorous scientific standards with respect

to data collection and validation of academic publications, they indicate the market potential of the IoT.

Despite these opportunities, many companies struggle to achieve the expected benefits from their IoT investments (Kohtamäki et al., 2020; Kranz, 2017). Recent empirical evidence has pointed out that companies face a so-called “digitalization paradox” (in short: digital paradox), which means that they invest in the IoT but fail to generate the expected revenue growth (Gebauer, Fleisch, et al., 2020). Further evidence of the digital paradox comes from well-known cases of leading companies whose IoT initiatives have struggled to meet their expectations (Davenport & Westerman, 2018). A typical example is General Electric (GE), which is striving to be a “digital industrial” company via huge investments in an IoT platform and by digitally transforming its product and services offerings. However, performance issues and other challenges have resulted in a stock price meltdown and various IoT advocates have left the company (Crooks, 2017; Geoff, 2018). Extant literature has identified inadequate business models and the inability of many companies to consistently modify their existing business models as primary reasons for the digital paradox (Gebauer, Arzt, et al., 2020; Gebauer, Fleisch, et al., 2020; Linde et al., 2021). Due to the highlighting of inadequate business models for the IoT, product-service systems (PSSs) – which we will describe below – have gained considerable attention from scholars and practitioners alike (Adrodegari et al., 2017; Lerch & Gotsch, 2015).

2.2 Product-Service Systems

2.2.1 Product-Service Systems as a Business Model Perspective

In general, a business model describes the holistic logic of doing business (Gassmann et al., 2020; Teece, 2010; Zott et al., 2011). For instance, Teece (2010, p. 173) defines a business model as a conceptual model that describes how a company “creates and delivers value to customers and then converts payments received to profits”. Although no general definition of what elements constitute a business model has emerged (Nenonen & Storbacka, 2010), research generally agrees to three higher-level elements: value proposition (*what?*), value capture (*why?*), and value creation (*how?*) (Clauss, 2017; Gassmann et al., 2020; Schneider & Spieth, 2014; Zott et al., 2011). Thereby, the

value proposition refers to what value companies create for customers. Value capture defines the monetary viability of the business model, describing how the company monetizes the value proposition. And value creation outlines how companies create and deliver the value proposition relating to the processes, activities, and resources required (Chesbrough & Rosenbloom, 2002; Gassmann et al., 2020; Teece, 2010; Zott et al., 2011). Product-service systems (PSSs), as a business model perspective, describe how a company creates and captures value by offering integrated “bundles” or “systems” of products and services to solve customer problems (Baines et al., 2009). Despite considerable research attention, there is no universally accepted PSS definition. Table 1 provides an overview of relevant PSS definitions. The overview highlights that, in essence, a PSS is about combining products and services into a single solution to satisfy customers’ needs (Goedkoop et al., 1999; Tukker, 2004). Berkovich et al. (2011) also include software in their PSS definition. Considering the increasing importance of software in today’s economy (Humphrey, 2002), this thesis defines a PSS accordingly as an “integrated bundle of hardware, software, and service elements” to solve customer problems (Berkovich et al., 2011, p. 369). For instance, Rolls-Royce bundles the turbine engine (product) with the spares and maintenance services (service and software) to sell flying hours at a defined price with their “power-by-the-hour” offering, thereby eliminating customer uncertainty regarding costs for unscheduled maintenance and repair events (Baines et al., 2007).

Author	PSS definitions
Goedkoop et al. (1999, p. 18)	<i>“A product-service system [...] is a marketable set of products and services capable of jointly fulfilling a user’s need”.</i>
Mont (2002a, p. 239)	<i>A PSS is “a system of products, services, supporting networks and infrastructure that is designed to be: competitive, satisfy customer needs and have a lower environmental impact than traditional business models”.</i>
Manzini and Vezzoli (2003, p. 851)	<i>“An innovation strategy, shifting the business focus from designing (and selling) physical products only, to designing (and selling) a system of products and services which are jointly capable of fulfilling specific client demands”.</i>
Tukker and Tischner (2006b, p. 1552)	<i>A “PSS consists of a mix of tangible products and intangible services designed and combined so that they jointly are capable of fulfilling final customer needs”.</i>
Berkovich et al. (2011, p. 369)	<i>A PSS is defined as an “integrated bundle of hardware, software, and service elements”, to solve customers’ problems.</i>
Zhang et al. (2012, p. 1579)	<i>“PSS is a systematic package in which intangible services are attached to tangible products to finish various industrial activities in the whole product life cycle”.</i>

Table 1: Relevant definitions of PSS

Research distinguishes between different PSS types. The most common classification identifies three PSS types along the spectrum from pure product to pure service (see Figure 4): (1) product-oriented, (2) use-oriented, and (3) result-oriented (Tukker, 2004). With product-oriented PSSs, the business model primarily relies on product sales, but some extra services are added, such as insurance or maintenance contracts. With use-oriented PSSs, the business model is no longer geared towards the sale of products. The ownership of the product remains with the manufacturer, and customers buy access to the product. Typical examples are car leasing, sharing, or renting. With the last type, result-oriented PSSs, intangible services primarily generate value. The providing company and customer agree on a result or performance, and no predetermined tangible product is involved. Typical examples are pay-per-outcome or pay-per-performance offerings (e.g., pay-per-landing in an airplane tire management service) (Tukker, 2015).

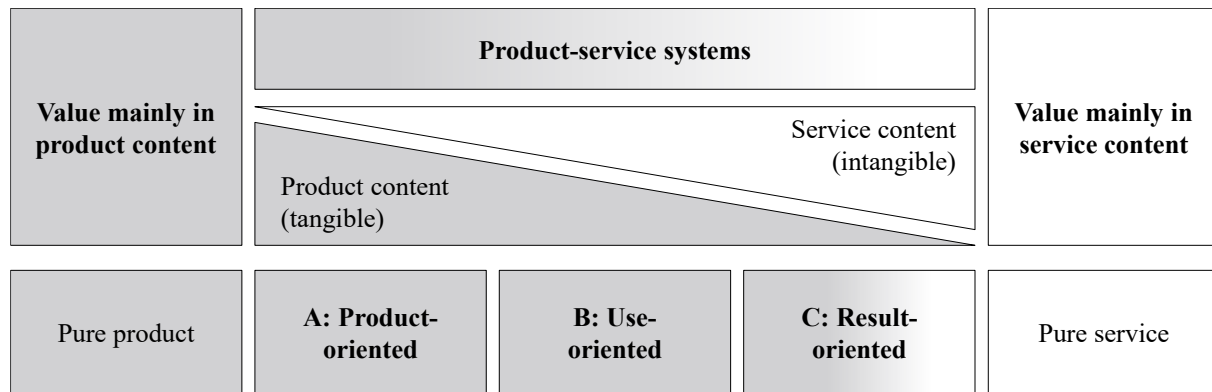


Figure 4: PSS types (adapted from Tukker (2004))

2.2.2 IoT-enabled Product-Service Systems

Software as a service (SaaS) is one of the most widespread PSSs (Berkovich et al., 2011). In the 1980s and 1990s, software (a digital product) was sold and locally installed by the customer. The growth of the internet has fundamentally changed the software industry's business model, and today software companies – such as Microsoft with Office 365 or Salesforce with its CRM (customer relationship management) software – generally host the software centrally and make it accessible to customers via the internet for a monthly or yearly fee (Berkovich et al., 2011; Wasserman, 2011). While the rise of the internet has enabled PSSs for digital products in the software industry, the emergence of the IoT is a key enabler and driver of PSSs for physical products (Pirola et al., 2020; Rymaszewska et al., 2017; Zheng et al., 2018; Zheng et al., 2019). The

convergence of the physical and digital worlds offers product companies the opportunity to create entirely new (digital) services (see Chapter 2.1) that enable PSSs that were previously inconceivable (Frank et al., 2019; Kohtamäki et al., 2020; Lerch & Gotsch, 2015; Paschou et al., 2020). For instance, Toyota and General Motors have leveraged the IoT for new PSSs, such as luxury cars that have an integrated roadside assistance service that provides help with accidents and car breakdowns 24/7 (Chowdhury et al., 2018; Howser & McMillin, 2012). Similarly, Rolls-Royce uses the IoT for its “power-by-the-hour” offering to remotely monitor jet engine data in real-time to efficiently provide maintenance when needed (Smith, 2013).

The logic of IoT-enabled PSSs can be illustrated by a two-by-two matrix (Gebauer, Arzt, et al., 2020; Gebauer, Fleisch, et al., 2020). As outlined in Figure 5, the horizontal axis of the two-by-two matrix distinguishes between products and services, whereas the vertical axis depicts the physical and digital worlds. Traditionally, companies combined physical products and services into customer solutions (horizontal axis). However, the emergence of the IoT allows companies to extend their physical offerings through digital products and digital services – i.e., software (vertical axis). Hence, companies today can combine products and services across the physical and digital worlds into PSSs to solve or contribute to solving customer problems (Gebauer, Arzt, et al., 2020; Gebauer, Fleisch, et al., 2020; Gebauer, Paiola, et al., 2020). As depicted in Figure 5, the PSS represents the company’s solution contribution to the customer’s problem.

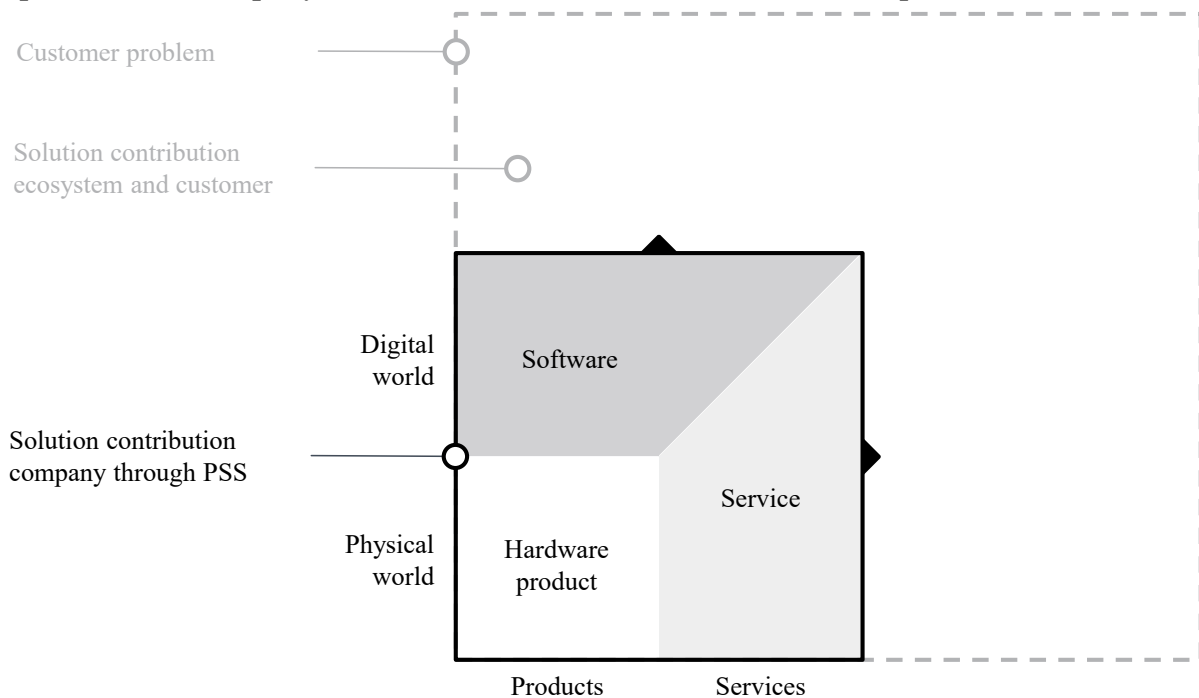


Figure 5: Two-by-two matrix (adapted from Gebauer, Fleisch, et al. (2020))

Literature refers to PSSs leveraging IoT technologies in several ways: cyber-physical PSSs (Wiesner & Thoben, 2017), smart PSSs (Zheng et al., 2019), or digitalized PSSs (Lerch & Gotsch, 2015). The latter, for instance, is defined by Lerch and Gotsch (2015, p. 47): “*as an integrated bundle of physical products, intangible services, and digital architectures designed to fulfill individual customer needs*”. This is in line with the proposed PSS definition of this thesis, where software represents the digital components.

2.2.3 Benefits and Challenges

Research has highlighted various benefits associated with PSSs (Beuren et al., 2013). For the customers, PSSs provide value-in-use, eliminate capital expenditures (CAPEX), result in higher quality, more customization (e.g., higher machine availability), and deliver new functions that better address customer needs (Cook et al., 2006; Helo et al., 2017; Tukker, 2004). For the company providing the PSS, a PSS can provide value for the triple bottom line: economic, environmental, and social (Norman & MacDonald, 2004; Reim et al., 2015; Van Halen et al., 2005). In terms of economic benefits, providing PSSs offers companies a chance to extend both their service revenues (Vandermerwe & Rada, 1988) and the recurring revenues (Helo et al., 2017). These are typically associated with higher margins and are more stable in economic downturns than product sales (Korkeamäki et al., 2021; Oliva & Kallenberg, 2003). Furthermore, as parts of a PSS rely on tacit knowledge, they are difficult to imitate and increase companies' competitiveness (Chesbrough, 2011; Lerch & Gotsch, 2015). Regarding environmental impact, PSSs allow products to be shared, upgraded, repaired, reused, optimized, or recycled. Hence, PSSs can increase resource efficiency by breaking with the linear model of take-make-dispose (Bressanelli et al., 2017; Frishammar & Parida, 2021; Tukker, 2015). Lastly, from a social perspective, PSSs can increase social sustainability by making more affordable products available (de Jesus Pacheco et al., 2019).

While the promises of PSSs are great, transitioning to PSSs does not come without challenges (Baines et al., 2007; Parida et al., 2014). Selling PSSs requires an entirely different way of doing business than selling a product or a service (Sjödin et al., 2020). A good example is Rolls-Royce, which used to make money on turbines, maintenance, and spare parts. With their “power-by-the-hour” offering (as outlined above), these

items now represent costs, with revenues entirely dependent on delivering flying hours (Baines et al., 2007; Sjödin et al., 2020). Academic literature points out that manufacturing companies accustomed to selling products and services often struggle to redesign their business models for PSSs (Baines et al., 2007; Barquet et al., 2013; Bertini & Koenigsberg, 2020a; Zancul et al., 2016).

2.3 Product-Service Systems in Manufacturing

The North American Industry Classification System (NAICS) defines manufacturing companies as those “*engaged in the mechanical, physical, or chemical transformation of materials, substances, or components into new products*” (CENSUS, 2017, p. 143). This thesis focuses on discrete manufacturing – i.e., manufacturers producing distinct products, such as automobiles, gearboxes, laundry machines, or jet engines (Wikner & Noroozi, 2016). Traditionally most of these companies earn money by selling products. However, these companies increasingly shift from simply selling products to offering integrated PSSs (Beuren et al., 2013; Cohen et al., 2006; Kowalkowski et al., 2017; Wise & Baumgartner, 1999). They make this shift for two reasons: to exploit the opportunities offered by the IoT, and to build a sustainable competitive advantage in a market of ever-faster commoditization (Forkmann et al., 2017; Iansiti & Lakhani, 2014). This shift from selling products to service-oriented business models has received substantial research attention, and not only within the PSS literature. Concepts such as “servitization” (Baines et al., 2009; Vandermerwe & Rada, 1988), “hybrid offerings” (Ulaga & Reinartz, 2011), “service infusion” (Brax, 2005), “integrated solutions” (Davies, 2004), “transition from products to services” (Oliva & Kallenberg, 2003), and “service-dominant logic” (Vargo & Lusch, 2004) also capture this transition. The work on servitization, for example, describes the shift of “*moving from the old and outdated focus on goods or services to integrated ‘bundles’ or systems [...] with services in the lead role*” (Vandermerwe & Rada, 1988, p. 314). Baines et al. (2009) point out that the concepts are closely related, have many identical principles, and the central idea is the same. Differences mainly stem from the geographical origin and motivation of the respective research streams.

Despite different theoretical approaches, the studies agree that the shift from selling products to PSSs requires fundamental changes to a manufacturer’s business model

(Barquet et al., 2013; Sjödin et al., 2020; Zancul et al., 2016). First, value is created closer and customized to customers' operations since manufacturers can leverage data from connected products to identify customers' actual needs and preferences (Rymaszewska et al., 2017). For example, manufacturers can use the data to provide maintenance when it is actually required rather than according to a specific pre-determined maintenance schedule (Saarikko et al., 2017). Second, delivering PSS value propositions often requires capabilities that surpass manufacturers' existing core competencies. These can include competencies such as data processing, partnering competence, or a service-oriented culture (Gebauer, Saul, et al., 2017; Parida et al., 2014). Third, PSSs often imply a shift from delivering value-in-exchange, in which customers purchase products, add-on maintenance, and repair services, to value-in-use (Adrodegari et al., 2017; Grubic & Jennions, 2018). Customers pay for usage, performance, or outcomes with a value-in-use model. For example, airlines pay a fee for every hour flown with Rolls-Royce's "power-by-the-hour" offering (Paschou et al., 2020). Hence, the transition requires fundamental changes to a manufacturer's business model, which presents a considerable challenge. The result is that many manufacturers struggle and fail to achieve the expected benefits of their PSSs transformation despite high investments (Gebauer, Fleisch, et al., 2020; Kohtamäki et al., 2020).

Literature has provided initial insights into how manufacturers can transition connected products to PSSs, for instance, by providing growth paths for how manufacturers can transition connected products to PSSs (e.g., Gebauer, Arzt, et al., 2020; Gebauer, Fleisch, et al., 2020), by highlighting new technological means around the IoT to deliver PSSs (e.g., Zambetti et al., 2021), by outlining contracts to distribute rights and liabilities among involved parties (e.g., De Coster, 2011; Richter et al., 2010), or by outlining resources and capabilities for designing PSSs (e.g., Ulaga & Reinartz, 2011). However, research regarding PSS implementation is still an understudied research area (see Reim et al., 2015). There is limited knowledge, tools, or guidelines that can support manufacturers in their PSS transformations (Adrodegari & Saccani, 2020; Adrodegari et al., 2017; Barquet et al., 2013; Tukker & Tischner, 2006b).

Chapter 3

Research Approach

3.1 Research Gap and Questions

Previous studies have pointed out that manufacturers struggle to realize the expected economic benefits from their PSS investments (Gebauer et al., 2005; Gebauer, Fleisch, et al., 2020; Kohtamäki et al., 2020) and have emphasized the need for research that provides tools, knowledge, and guidelines to support manufacturers as they transition to PSSs (Adrodegari et al., 2017; Baines et al., 2017; Baines et al., 2009; Reim et al., 2015; Tukker & Tischner, 2006a). In order to address this research gap, this thesis aims to examine how manufacturers can transition connected products to sustainable PSSs. The term “sustainable” here refers to the triple bottom line of companies – i.e., economic, environmental, and social. The present thesis focuses on economic performance as it is a prerequisite for profit-oriented companies to adopt PSSs in the long run (Baines et al., 2009; Frishammar & Parida, 2021; Vasileiou & Morris, 2006). Consequently, the main research question (RQ) of this thesis is:

How can manufacturing firms transition connected products to sustainable product-service systems (PSSs)?

In order to fully address the RQ, we have divided it into three sub-research questions (SRQ) as outlined in Figure 6. Each SRQ is addressed individually through a dedicated study. The following subsections specify the three SRQ.

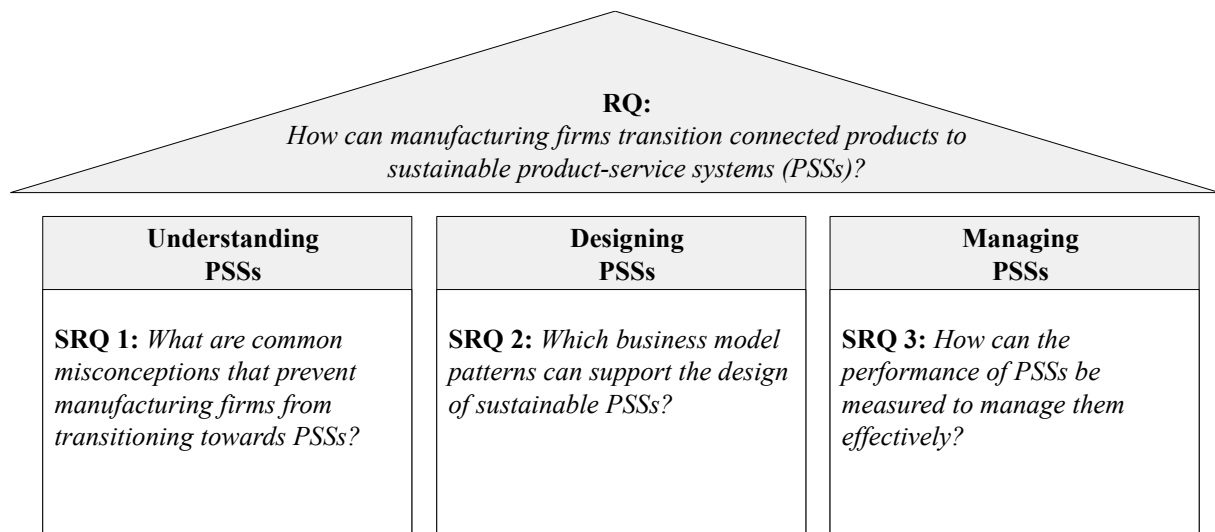


Figure 6: Research questions

3.1.1 Understanding PSSs

The first SRQ aims to provide an understanding of PSSs to transition connected products to PSSs. The first papers that focused on developing and implementing PSSs in manufacturers were published nearly 20 years ago in the early 2000s (e.g., Oliva & Kallenberg, 2003). Since then, the respective literature body has been rapidly emerging, driven by manufacturers' increasing interest in PSSs (Paschou et al., 2020; Pirola et al., 2020). However, there are indications of PSS misconceptions in practice. Scholars point out that theory sketches an oversimplified picture of PSSs and that practitioners often misunderstand PSS theory (Baines et al., 2017; Bigdeli et al., 2021; Kowalkowski, 2010; Perona et al., 2017; Tukker & Tischner, 2006a). To minimize this theory-practice gap and to provide practitioners with a clear understanding of the PSS concept, PSS misconceptions need to be identified (cf. Andriole, 2017; Fuller et al., 2019). Hence, the first study aims to answer the following SRQ:

SRQ 1: *What are common misconceptions that prevent manufacturing firms from transitioning towards PSSs?*

3.1.2 Designing PSSs

Although manufacturers' transition towards PSSs is inherently associated with the business model concept, the investigation of business models for PSSs is still in its infancy (Adrodegari & Saccani, 2017). Few studies characterize business models and their components for PSSs, and literature lacks tools that support managers in designing them (Adrodegari & Saccani, 2017; Paschou et al., 2020; Pirola et al., 2020). Business model patterns have gained considerable attention and represent an established tool to support the design of new business models (e.g., Gassmann et al., 2020). Hence, the second study aims to investigate PSS business models and identify patterns to support the design of PSS business models. Consequently, the second study addresses the following SRQ:

SRQ 2: *Which business model patterns can support the design of sustainable PSSs?*

3.1.3 Managing PSSs

The third and last SRQ refers to how manufacturers can manage PSSs. Performance measurement systems are essential for managing any business (Neely et al., 2005). But existing performance measurement systems in companies are rarely suitable for measuring the performance of PSSs in the realm of the IoT (Nudurupati et al., 2011; Nudurupati et al., 2016; Raskino, 2017; Wolcott, 2016). Hence, a substantial research gap exists in the ability to measure and manage the PSS transformation. To address this research gap, the third study aims to investigate how manufacturers can measure the performance of PSSs to manage them effectively. Hence, the third study seeks to answer the following SRQ:

SRQ 3: *How can the performance of PSSs be measured to manage them effectively?*

3.2 Research Design

This present thesis understands research as an iterative learning process, as illustrated in Figure 7. Accordingly, it is based on empirical knowledge and theoretical implications derived through a theory-guided and experienced-based systematic learning process (Kubicek, 1977; Tomczak, 1992). Based on this iterative learning process, the

underlying studies of this thesis utilize an inductive multiple case study approach in line with Yin (2018) and Eisenhardt (1989).

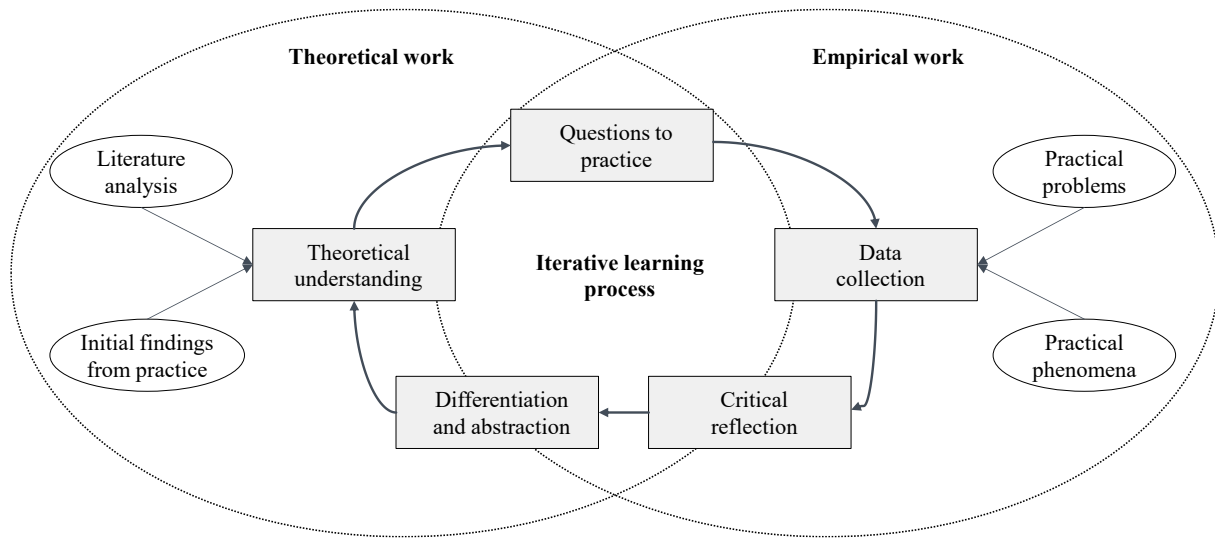


Figure 7: Iterative research process (based on Gassmann (1997, p. 15) and Tomczak (1992, p. 84))

Opting for such an inductive multiple case study method allowed us to gain a meaningful understanding of a complex, real-world phenomenon through studying actual practices – e.g., the PSS transition of manufacturing companies (Eisenhardt & Graebner, 2007). Furthermore, an inductive research approach allows for an investigation of emerging topics at an early stage where the underlying variables are rather unknown (Benbasat et al., 1987; Voss et al., 2002). Scholars point out that the multiple case study method is well-suited to investigate “how” and “why” research questions (Yin, 2018), which suits this thesis’ research question. Moreover, the multiple case study setting increases the generalizability and robustness of the results by allowing for comparisons of PSSs between manufacturing companies and between various industries (Eisenhardt & Graebner, 2007). As depicted in Figure 8, the research process used in this thesis comprises the three phases (1) study preparation, (2) data collection and case analysis, and (3) data validation and closure (cf. Eisenhardt, 1989; Yin, 2014). The subsequent subsections describe the individual steps of the three phases in greater detail.

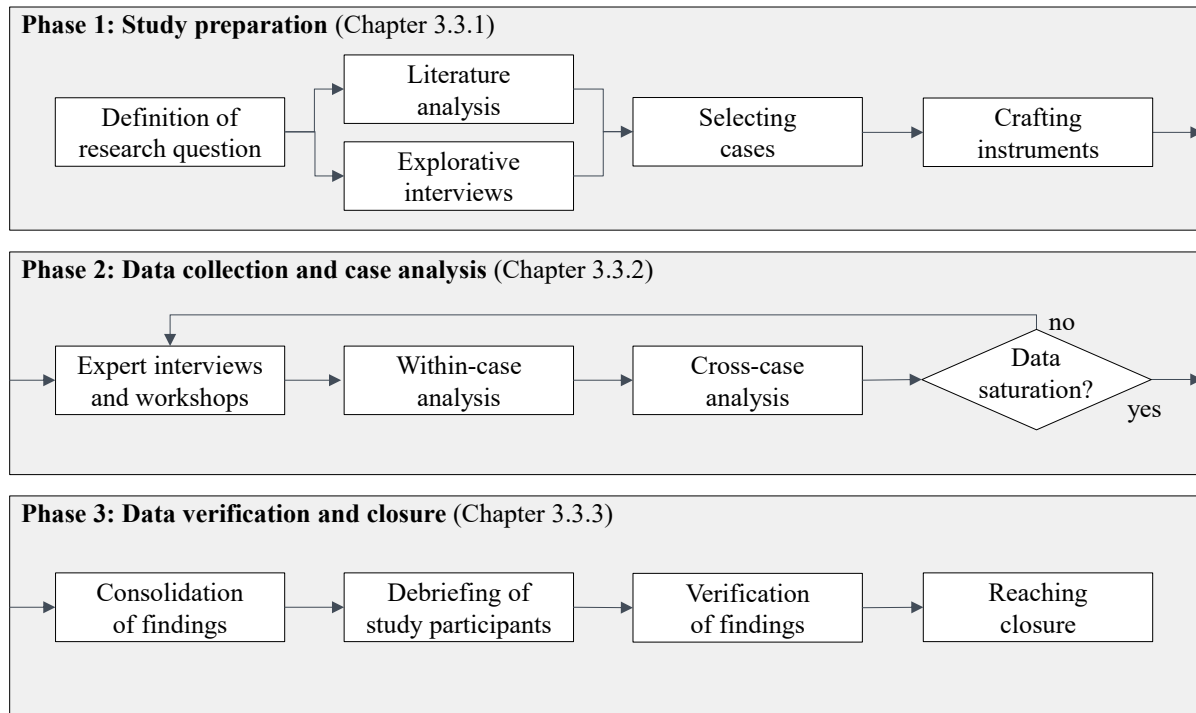


Figure 8: Research process (adapted from Yin (2018) and Eisenhardt (1989))

3.3 Multiple Case Study Method

3.3.1 Study Preparation

The first phase starts with defining a research question to specify the research focus and the scope of the study (Eisenhardt, 1989). After that, existing knowledge within the identified research field was gathered and structured through a literature review to sharpen the research problem and question (Yin, 2018). In addition to the literature review, explorative interviews with executives and leading experts were used to further familiarize the study's context and deepen insights into the relevant themes regarding the manufacturing firm's PSS transition (e.g., Ulaga & Reinartz, 2011). We conducted around 25 explorative interviews with relevant companies per study. Ultimately, the literature review and the explorative interviews built the basis for identifying interesting and relevant cases and crafting interview instruments.

We applied theoretical sampling to select and approach relevant companies for data collection (Eisenhardt & Graebner, 2007). The underlying sampling criteria dictated that (1) case companies must be manufacturing companies actively pursuing PSS business

both out of a strategic and offering perspective; (2) to increase variation among selected cases, the sample companies had to cover important sectors for the PSS transition (e.g., mobility, industrial manufacturing, appliances) to yield more generalizable results (see Jankowski, 2014; Tzuo & Weisert, 2018); and (3) we had had to be given access to necessary key informants (executives across functions and hierarchical levels) and secondary data.

The interview instruments were crafted based on the identified relevant themes and issues from the explorative interviews under consideration at the current state of research. The interview instruments that we created subsequently guided all further interviews within the data collection and case analysis phase.

3.3.2 Data Collection and Case Analysis

For the cases, semi-structured interviews and workshops were the primary data source³. Qualitative data sources were deemed appropriate for studying manufacturers' PSS transition because qualitative data can provide meaningful insights into complex social processes and bridge the gulf between practice and research (Wertz et al., 2011). Since the topics under investigation pertain to all functional areas and hierarchical levels, we selected interviewees from all relevant functions and hierarchical levels for each case. Furthermore, we collected data from PSS providers as well as from customers buying, using, and consuming the PSSs (cf. Tuli et al., 2007). As much as possible, all interviews and workshops were conducted in person, or via video conferencing due to accessibility reasons. These interviews were audio-recorded and transcribed verbatim, with the participants' consent. Otherwise, we relied on our notes taken during the interviews. To increase the depth and reliability of the data, a wide variety of secondary data led to data triangulation. For example, study participants provided supporting company materials, project documentation, reports, and public materials. Table 2 provides an overview of the empirical data set that represents the basis of this thesis. We compiled the interview transcripts from each company and the available secondary data into a case study description.

³ With an exception of study 2, where desk research was the primary data source.

Studies	Data samples	Data collection
<i>Study 1: Understand PSSs</i>		
• Explorative study	• 24 companies	• 28 interviews
• In-depth study	• 5 PSS cases	• 31 interviews; 18 workshops
<i>Study 2: Design PSSs</i>		
• Explorative study	• Study 1	• Study 1
• In-depth study	• 199 PSS cases	• Desk research; 9 interviews; 3 workshops
<i>Study 3: Manage PSSs</i>		
• Explorative study	• 26 companies	• 24 interviews; 5 workshops
• In-depth study	• 5 companies	• 32 interviews

Table 2: List of the empirical data set

As a next step, we then examined the case study descriptions through a content analysis procedure and pattern matching logic (Yin, 2018). The process started with a manual open coding of the verbatim transcribed interviews (Flick, 1998). Coding the common terms, phrases, and words mentioned by the interviewees allows for identification of first-order codes that express the interviewees' views in their own language. For example, the respondent's statement "Everyone comes with the Rolls-Royce example, but our business is totally different" was coded with the label "PSS works for Rolls-Royce but our business is different". The analysis continued with axial coding to group similar codes to reach more abstract second-order themes (Strauss & Corbin, 1990). Finally, we used first-order codes and second-order themes to classify our insights into third-order aggregate dimensions. After analyzing each case separately, we conducted a cross-case analysis to identify similarities, differences, and patterns (Yin, 2018). Phase two ended when we reached data saturation, which means that the data collection and case analysis steps were iterative and therefore repeated until redundancy occurred (Strauss & Corbin, 1990).

3.3.3 Data Verification and Closure

In the final phase of the research process, we consolidated and verified the findings before dissemination – i.e., misconceptions, patterns, and the KPI set. We debriefed all study participants to gather feedback and understand their perceptions of plausibility on the shared findings (Hancock & Algozzine, 2017). Parts of the findings were already implemented and applied in the case companies for transitioning connected products to PSSs. Here we observed how the patterns and KPI set work for day-to-day business.

Using the findings in workshops with practitioners and academics led to feedback and validation. Reporting the theoretical and practical implications of the studies marked the final step of the research process contributing to the ongoing process of refining and extending the respective knowledge base.

Chapter 4

Understanding PSSs – Six PSS Misconceptions⁴

4.1 Introduction

PSSs are nothing new. The famous “power-by-the-hour” offering from Rolls-Royce dates back to the early 1960s (Baines et al., 2007). Similarly, Xerox introduced its PSS for copiers, where customers no longer buy the copiers but pay for the actual printed pages in the late 1960s (Jacobson & Hillkirk, 1987). But only recently have PSSs gained considerable momentum through the advent of the IoT (Bertini & Koenigsberg, 2020a; Lerch & Gotsch, 2015). The IoT with its connected products enables entirely new (digital) services that make previously unrealizable PSS possible (see Chapter 2.2.2). However, despite a handful of widely known cases, PSSs are not yet mainstream (Kohtamäki et al., 2020; Wortmann et al., 2019).

Transitioning to PSSs is arguably an important, if not one of the most important, strategic decisions today. For many manufacturers, PSSs are likely the new imperative for future success (Connerty et al., 2016; Lerch & Gotsch, 2015). However, many firms struggle with their transition, and generated turnover from PSSs is still low (Gebauer, Fleisch, et al., 2020; Kohtamäki et al., 2020). PSSs require that manufacturers used to selling products adapt to a very different way of doing business (Sjödin et al., 2020). Research outlines potential barriers manufacturers face and calls for more research to provide practitioners with a deeper understanding of PSSs, as well as the underlying

⁴ Parts of this chapter were initially published or submitted for publication in the context of the following manuscript: Lamprecht et al. (2021).

business models, and how to implement them (Barquet et al., 2013; Reim et al., 2015). The respective literature body is rapidly emerging with many valuable contributions and laudable intentions to provide practitioners with a deeper PSS understanding (e.g., Adrodegari et al., 2017). However, literature also provides evidence that practice often misunderstands PSS theory and that there are discrepancies between the existing theory and real-world PSS cases leading to misconceptions about PSSs (Baines et al., 2017; Bigdeli et al., 2021; Kowalkowski, 2010; Perona et al., 2017; Tukker & Tischner, 2006a). For instance, Baines et al. (2017) point out that the style and language of many theoretically strong PSS publications present obstacles for practitioners to grasp and understand the concepts and recognize their value, or Perona et al. (2017) emphasize that PSS theory paints an oversimplified picture of PSSs. Actions based on misconceptions are not a good way to embrace PSSs and represent barriers for manufacturers transitioning to PSSs (Bigdeli et al., 2021).

If managers want to embrace the PSS transition in their organizations, the first step is to understand the realities of PSSs (cf. Andriole, 2017; Fuller et al., 2019). Hence, this chapter aims to investigate potential misconceptions in order to provide practitioners with an understanding of PSSs. Consequently, the following research question guides the investigations in this chapter:

SRQ 1: *What are common misconceptions that prevent manufacturing firms from transitioning towards PSSs?*

To answer this research question we applied a qualitative multiple case study method to capture first-hand insights from manufacturers. We conducted a total of 28 explorative interviews and conducted five in-depth case studies with manufacturers adopting PSSs. Through this study, we identified six common misconceptions that prevent manufacturers from effectively embracing and implementing PSSs. The identified misconceptions cover three areas: When PSSs are relevant, what PSSs are, and how firms should approach PSSs.

4.2 Methodology

To address the outlined research question, the study of this chapter relied on a qualitative multiple case study design to gain meaningful insights about PSSs in manufacturing companies (Eisenhardt, 1989; Yin, 2014). The research process consisted of an explorative study and an in-depth study. The explorative study aimed to gain insights into the main PSS misconceptions across a broad range of companies covering important PSS and IoT sectors. Five in-depth case studies followed the explorative study to deepen the interim findings. In the in-depth studies, we collected data from the PSS providing company and the PSS customers to capture both perspectives. We sampled case studies until we reached theoretical saturation – i.e., until a recurring pattern for PSS misconceptions emerged from the explorative and the in-depth studies (Strauss & Corbin, 1990).

Explorative study

In the explorative study, we collected data from a total of 24 companies between November 2019 and August 2020. The sample included 17 manufacturers offering PSSs, ranging from car-sharing to operator models for conveyors, 4 financial institutions financing PSSs across industries and sectors, 1 private equity firm investing in firms transitioning from selling products towards selling PSSs, and 2 consulting firms providing PSS consulting services (see Table 3). In total, we interviewed 28 managers and executives across functions and hierarchical levels. We conducted the interviews mainly via phone or video conferencing because of accessibility. The research focused on companies' key challenges and barriers when transitioning towards PSSs, what manufacturers understand as PSSs, the best practices, and the lessons learned from commercializing PSSs.

#	Case (anonymized)	PSSs	Roles (anonymized)
1	Solar Inc.	Solar panel as a service	Director Public Affairs
2	Financial Institution A	Pay-per-use financing	Head of Advanced Analytics; Operational Analyst
3	Compressor Inc.	Air as a service	Head of Engineering
4	Financial Institution B	Medical equipment financing	Country Manager
5	Consulting A Inc.	EaaS consulting	Chairman; Senior Product Manager
6	Financial Institution C	EaaS financing	Manager IoT Partnerships
7	Packaging A Inc.	Packaging solutions	Vice President Sales DACH
8	Food Equipment Inc.	Pay-per-use food processing	Digital Product Owner; Business Developer
9	Printing Equipment A Inc.	Pay-per-print	Managing Director
10	Hotel Bed Inc.	Smart lease for hotel beds	Chief Executive Officer
11	Financial Institution D Inc.	Financing partner	Financing Solution Partner
12	Consulting B Inc.	EaaS consulting	Senior Consultant
13	Forklift Trucks Inc.	Operator business	Manager Connected Products
14	Printing Equipment B Inc.	Pay-per-print	Product Owner; Head of Lifecycle Business
15	Robotic Inc.	Robotics as a service	Head of Sales
16	Conveyors Inc.	Operator models	Manager Corporate Sales
17	Artery Inc.	Pay-per-use artery	Chief Financial Officer
18	Lighting Inc.	Light as a service	Head of Sales
19	Automotive Inc.	Car sharing	Manager Uptime & IoT
20	Laundry Systems Inc.	Laundry room as a service	Chief Executive Officer
21	Packaging B Inc.	Packaging on demand	Chief Executive Officer
22	Automotive Supplier Inc.	Tire fleet management	Vice President
23	Private Equity A Inc.	PSS investments	Investment Partner
24	CNC Machine Inc.	Usage model	Head of Service Center

Table 3: Explorative interviews

In-depth study

In the in-depth study, we studied five PSS cases selected through theoretical sampling (Eisenhardt & Graebner, 2007) (see Chapter 3.3.1 for the sampling criteria). Table 4 provides an overview of the five in-depth cases. The selected PSS cases were from two companies, which actively pursue PSSs from a strategic and offering perspective. The PSS cases cover important PSS sectors – i.e., mobility, industrial manufacturing, and energy (Jankowski, 2014; Tzuo & Weisert, 2018). Furthermore, the selected companies were willing to discuss their PSSs and provided the research team with access to their PSS customers. In total, we conducted 49 workshops and interviews across the five

cases. Data triangulation was achieved by interviewing and conducting workshops with various representatives per case and including secondary information in the data collection and analysis process (e.g., meeting protocols, internal and external presentations, company reports). We collected data from the PSS-providing companies and also conducted 18 interviews with customers to capture the customer perspective. We considered the customer perspective relevant, as the objective of PSSs is to better solve customer needs by providing bundles of hardware, service, and software (Cook et al., 2006; Tukker, 2004). Due to home-office measures during the COVID-19 pandemic, we mainly held the interviews and workshops via video conferencing. All interviews and workshops were either recorded or the authors prepared field notes.

The collected data were analyzed using the approach detailed in Chapter 3.3.2. We began with manually coding the data to identify first-order codes (Flick, 1998). Here we used mentioned terms and phrases as codes to capture interviewees' views in their own language. Then we applied axial coding to group similar codes into more abstract second-order themes. Finally, we used the first-order codes and second-order themes to derive aggregate dimensions – i.e., the misconceptions (Strauss & Corbin, 1990). Figure 9 exemplarily outlines the data structure for one misconception. We ensured reliability and validity throughout the in-depth study in two ways. First, independent judges with different backgrounds reviewed the coding plan to ensure reliability. Second, validity was ensured by presenting the findings (i.e., misconceptions) to practitioners and academics in workshops, seminars, and presentations.

Company (anonymized)	Case (anonymized)	#	Type	Date	Roles (anonymized)
Engineering and technology company Revenue: 80 billion EUR Employees: 400'000	Retrofit as a service Machine retrofit for a guaranteed additional 10-year serviceability	1	WS	23.04.2020	3 Participants
		2	WS	25.05.2020	3 Participants
		3	IN-C	17.07.2020	Head of Special Machinery
		4	IN-C	17.08.2020	Project Manager
	Connectivity as a service IoT solution for off-highway applications	5	WS	04.05.2020	3 Participants
		6	IN	11.05.2020	Business Developer IoT
		7	IN	18.05.2020	Business Developer IoT
		8	IN	26.05.2020	IoT Product Manager
		9	WS	02.06.2020	6 Participants
		10	IN	04.06.2020	Sales Manager; Technology Manager; Software Engineer
		11	IN-C	16.06.2020	General Manager
		12	IN-C	17.06.2020	Head of Digital Solutions; Product Manager

Fuel savings as a service Dynamic cruise control for trucks with a guaranteed fuel savings	13	IN-C	30.06.2020	Managing Director; Team Leader IoT
	14	IN-C	01.07.2020	Marketing Director
	15	WS	29.06.2020	6 Participants
	16	IN-C	10.07.2020	Managing Director
	17	IN-C	13.07.2020	Head of Engineering
	18	WS	27.07.2020	6 Participants
	19	WS	13.07.2020	5 Participants
	20	IN	23.07.2020	Head of Data Driven Business
	21	WS	30.07.2020	3 Participants
	22	WS	11.08.2020	3 Participants
	23	IN-C	13.08.2020	Chief Executive Officer
	24	IN-C	17.08.2020	Project Manager
	25	IN-C	16.09.2020	Global Customer Manager; Vice President Auto-Mobility
	26	IN-C	29.09.2020	Head of Innovation
	27	WS	06.10.2020	3 Participants
	28	WS	14.10.2020	3 Participants
	29	WS	20.10.2020	3 Participants
	30	WS	10.11.2020	5 Participants
	31	WS	02.02.2021	10 Participants
	32	WS	03.02.2021	10 Participants
	33	IN	08.04.2021	Business Manager
Electrolyser company Revenue: 9 million EUR Employees: 130	34	IN	06.05.2020	Supervisory Board Member
	35	IN	13.05.2020	Supervisory Board Member
	36	IN	21.05.2020	Supervisory Board Member
	37	WS	29.05.2020	3 Participants
	38	IN	12.06.2020	Head of Strategy; Business Developer
	39	IN-C	10.06.2020	Sales Manager
	40	IN-C	11.06.2020	Senior Scientist
	41	IN-C	22.06.2020	Chief Executive Officer
	42	IN-C	25.06.2020	Technical Lead
	43	IN-C	30.06.2020	Co-Founder
	44	IN-C	01.07.2020	Professor
	45	WS	03.07.2020	3 Participants
	46	IN	10.07.2020	Chief Executive Officer; Head of Sales
	47	IN	13.07.2020	R&D Engineer
	48	IN	14.07.2020	Chief Executive Officer
	49	WS	24.07.2020	3 Participants

Legend: WS = Workshop, IN = Interview, IN-C = Interview with customer

Table 4: In-depth case interviews

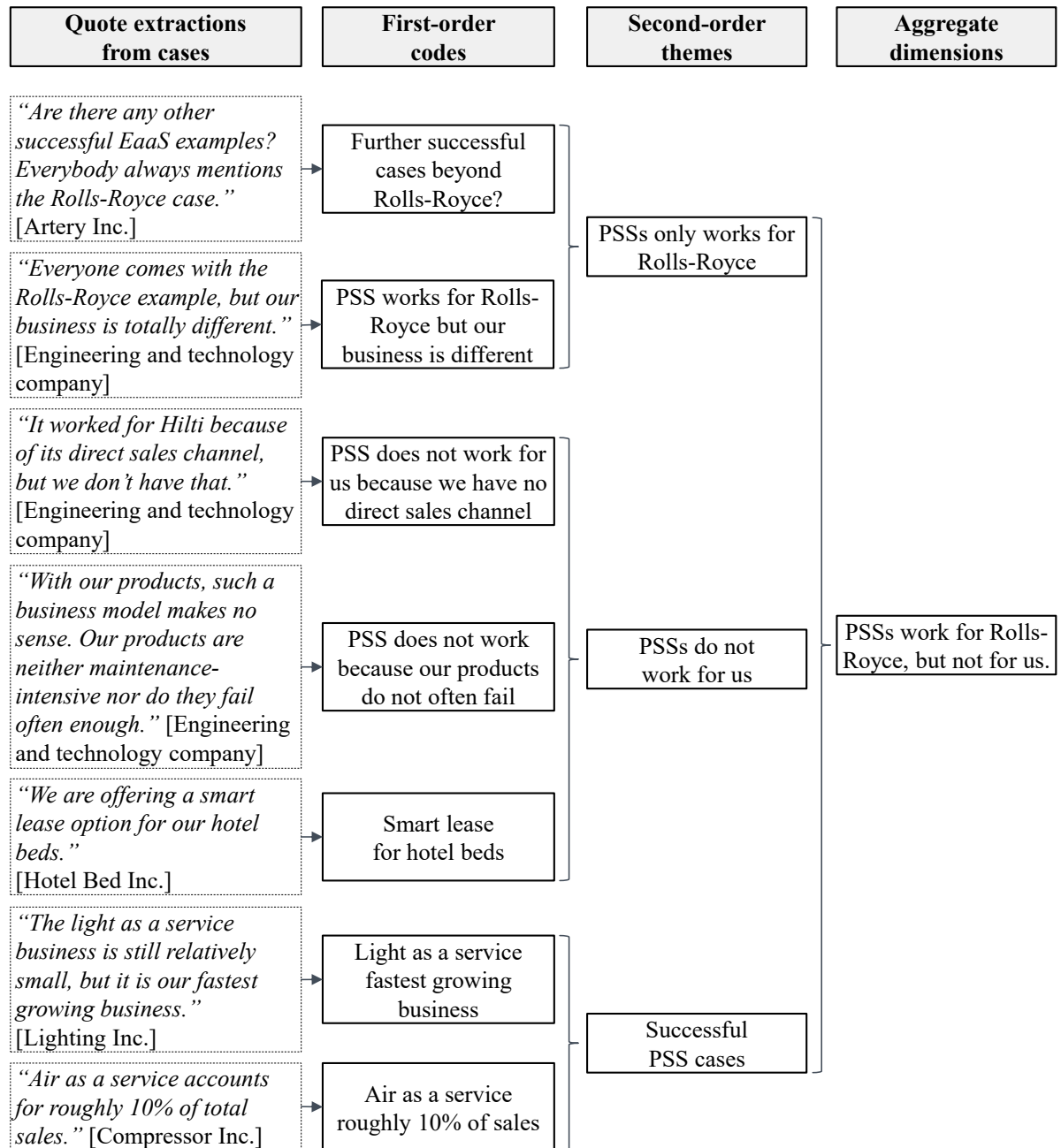


Figure 9: Exemplary data structure for one misconception

4.3 Results

We identified six common PSS misconceptions manufacturers face, which dissuade them from effectively embracing and implementing PSSs. The misconceptions cover three areas: When PSSs are relevant, what PSSs are, and how firms should approach

PSSs. The following sections outline the misconceptions in these three areas as well as the insights to address them.

4.3.1 When are PSSs relevant?

Misconception 1: PSSs work for Rolls-Royce, but not for us.

The interview data revealed that many managers assume that PSSs do not work for their products and industries. Surprisingly, this is not because of failed PSS attempts, such as Electrolux's "pay-per-wash" scheme for laundry machines in the early 2000s (Tukker & Tischner, 2006a), but because they assume that PSSs only works for specific products. For example, the interviewees mentioned: *"Everyone comes with the Rolls-Royce example, but our business is totally different"*, and *"With our products, such a business model makes no sense. Our products are neither maintenance-intensive nor do they fail often enough"*. The PSS success story of Rolls-Royce ("power-by-the-hour") is memorable and in every manager's head, which is unsurprising given that most PSS articles, presentations, or webinars mention Rolls-Royce as the prime PSS example (e.g., Davies et al., 2006; Monitor Deloitte, 2021; Ng et al., 2012; Parida et al., 2014). As a result, managers often infer that PSSs are only relevant for capital-intensive, complex products with high wear and tear (cf. Lacy & Rutqvist, 2015). Our study revealed that companies often dismiss PSS initiatives if their products do not have these attributes. However, there are no such limitations for which "products" PSSs can be relevant. We found successful PSS offerings across different industries and products:

- *Movable and immovable assets*: PSSs can be relevant for single machines and products regardless of whether these assets are movable or immovable, or capital intensive or not. Take, for example, Kaeser offering their capital expensive and immovable compressors as a PSS by bundling them with all spares and maintenance services as well as an uptime guarantee to sell compressed air instead of compressors (Kaeser Compressors, 2020). WeWash, on the contrary, does the same for relatively inexpensive laundry machines so that their customers (e.g., apartments, hotels, and property managers) can focus on their core business (WeWash, 2020).
- *Fleet of products*: In addition to single assets, PSSs can also be relevant for a fleet of products. Here the focus shifts from single assets to managing multiple products for customers. Hilti, for instance, provides its PSS called "fleet management" for

larger power tool fleets so that construction firms can outsource the challenge of managing hundreds of power tools to Hilti (Casadesus-Masanell et al., 2017).

- *Hardware and software components:* A PSS is also an option for hardware or software components that are just one part of a larger product, machine, or equipment. Audi, for example, does not sell the car itself through a PSS business model but equips its cars with advanced hardware features (such as an LED-Matrix-Light), which customers can activate through a monthly subscription (Vetter, 2019). Similarly, BMW offers drivers the opportunity to unlock their car with a phone (digital key) for 80 Euros per year (Vetter, 2019).
- *Consumables:* PSSs can also be relevant for consumables. On one hand, they can serve to completely outsource the hassle of managing consumables. Take, for example, Michelin's tire solution, where truck operators pay for the kilometer the tire is running, while Michelin is responsible for the complete tire management (Renault et al., 2010). On the other hand, producing consumables on-site can be much more efficient, more environmentally friendly, and less expensive than buying and shipping consumables. Yet many firms do not want to worry about production. Companies like Packsize address this challenge. Instead of ordering premade boxes in predefined sizes to pack their products, customers produce the necessary boxes on-site through a box-making machine fully managed by Packsize and pay per square meter of cardboard used (Packsize, 2021).

Misconception 2: PSSs are for customers that cannot afford to buy.

We found that managers and executives often believe that PSSs only attract financially weak customers that a firm would not want to have. It is easy to see why this misconception exists, as many interviewees associate PSSs with prominent marketing slogans such as “*no initial investment*,” “*no CAPEX*,” and “*no fixed costs*.” But studying successful PSSs and interviewing their customers revealed that these financial perks are most often secondary customer benefits.

Take, for example, Hilti's “fleet management”. Construction firms can use this offering to outsource the challenge of managing hundreds of power tools to Hilti. Hilti customers can focus on their core business without worrying about broken power tools or dealing with repairs and replacements (Casadesus-Masanell et al., 2017). Another example is SKF's “reliable rotation” solution. Customers use SKF's bearings in industrial machinery, and any bearing failure can bring entire machines or even factories to a

standstill. With SKF's "reliable rotation" solution, customers can outsource this operational risk – SKF takes responsibility for monitoring and predicting bearing failures to intervene in time and prevent unplanned downtime, ultimately reducing costs and boosting customer output. Thereby, SKF gets paid based on how well they improve customer performance (Brown, 2018). The famous "power-by-the-hour" offering of Rolls-Royce allows airlines to outsource highly skilled and costly technicians that are required to carry out maintenance, inspections, and repairs of jet engines, which are subject to high safety requirements (Davies et al., 2006; Kohtamäki et al., 2018).

The study revealed that PSSs are about outsourcing non-core business activities, being more flexible, aligning incentives between the PSS provider and customers, decreasing overall costs, overcoming skill shortages, increasing overall equipment effectiveness, and reducing operational and business risks. PSSs offer manufacturers more than just the widely known financial perks – it allows them to attract customers who pay premium prices for solutions that solve their wicked problems (cf. Grove et al., 2018). When companies limit their understanding of PSSs to the financial perks, they run the risk of missing the real value of PSS. Even worse, following misconception 2, companies are likely to attract the wrong (i.e., financially weak) customers.

4.3.2 What are PSSs?

Misconception 3: PSSs are pay-per-use.

We observed that managers often reduce PSSs to pay-per-use. If the tire, the jet engine, or the car is used, the customer is charged for the actual usage. Thereby product usage can be assessed through various indicators. For example, the kilometers run as in Michelin's pay-per-kilometer tire solution, the actual operating hours in the case of Rolls-Royce's power-by-the-hour offering, and the actual driving minutes for the car-sharing company Share Now. For the PSS customer, pay-per-use is ultimately about reducing operational and business risks. Products can break down or not run at their intended performance (operational risk). In addition, when demand falls short, product underutilization can have serious financial consequences (business risk).

However, pay-per-use is only one of many revenue models for PSSs. Selling outcomes (pay-per-outcome) or performance (pay-per-performance) are more effective de-risking schemes. For example, Atlas Copco does not charge for the hours its tunnel drilling machines are running (usage), but rather for the cubic meters of earth removed

(outcome) (Epiroc, 2016). This has benefits for both customer and the providing company: the customers prefer to pay for the earth removed, allowing them to pay for what they actually need and giving them full cost control, while Atlas Copco can better align its maintenance and service costs with its customers' payments as the cubic meters of earth removed better corresponds to the wear and tear on their drilling machines than the simple number of machine hours do. A further example is the “reliable rotation” offering of SKF mentioned above, where SKF gets paid by how well it can prevent machine downtime (performance) (Brown, 2018). So why are pay-per-outcome and pay-per-performance not the dominant PSS monetization schemes?

Pay-per-outcome and pay-per-performance models transfer substantial risk to the PSSs provider. Yet, our study revealed that most PSS providers are neither willing nor capable of assuming such a fundamental risk even if they have a strong financial partner. Even “pure” pay-per-use models are very rare in practice. We found that minimum contract terms most often limit risk transfer. For example, Heidelberger Druckmaschinen's pay-per-sheet is only a “pure” pay-per-use model at first glance. Customers have to agree to a monthly base print volume, and only thereafter does the model become a variable payment scheme. Thus, Heidelberger Druckmaschinen has only limited accountability for their customers' business risks (Heidelberger Druckmaschinen, 2021). In essence, PSSs are about de-risking, and the revenue model must be tailored to the specific PSS offering.

Misconception 4: PSSs are fully managed.

We observed that managers often interpret PSSs as a fully managed solution. More specifically, managers interpret that with PSSs, the providing company assumes responsibility for everything from financing, managing the product lifecycle, operating the product, and de-risking. Indeed, there are good theoretical reasons to maximize the scope of PSSs. Providing a comprehensive PSS allows a company to expand the amount of money a customer spends on the offering – e.g., increase the share of wallet by incorporation more and more services (financing, repair, and maintenance service, only to mention a few) into the PSS offerings (Keiningham et al., 2011; Rabetino et al., 2017). Typically these service revenues are associated with higher margins compared to product revenues (Korkeamäki et al., 2021; Oliva & Kallenberg, 2003). In addition, economies of scope might enable beneficial compound and spillover effects (Kastalli & Van Looy, 2013). Essentially, there are synergies between financing, managing the

product lifecycle, operating the product, and de-risking that companies can exploit with more comprehensive PSS offerings. However, the studied PSS cases do not follow this one-size-fits-all approach. The service elements are configured and tailored to define compelling value propositions that address specific customer needs. See Figure 10 for an overview of configurations of selected PSS cases.

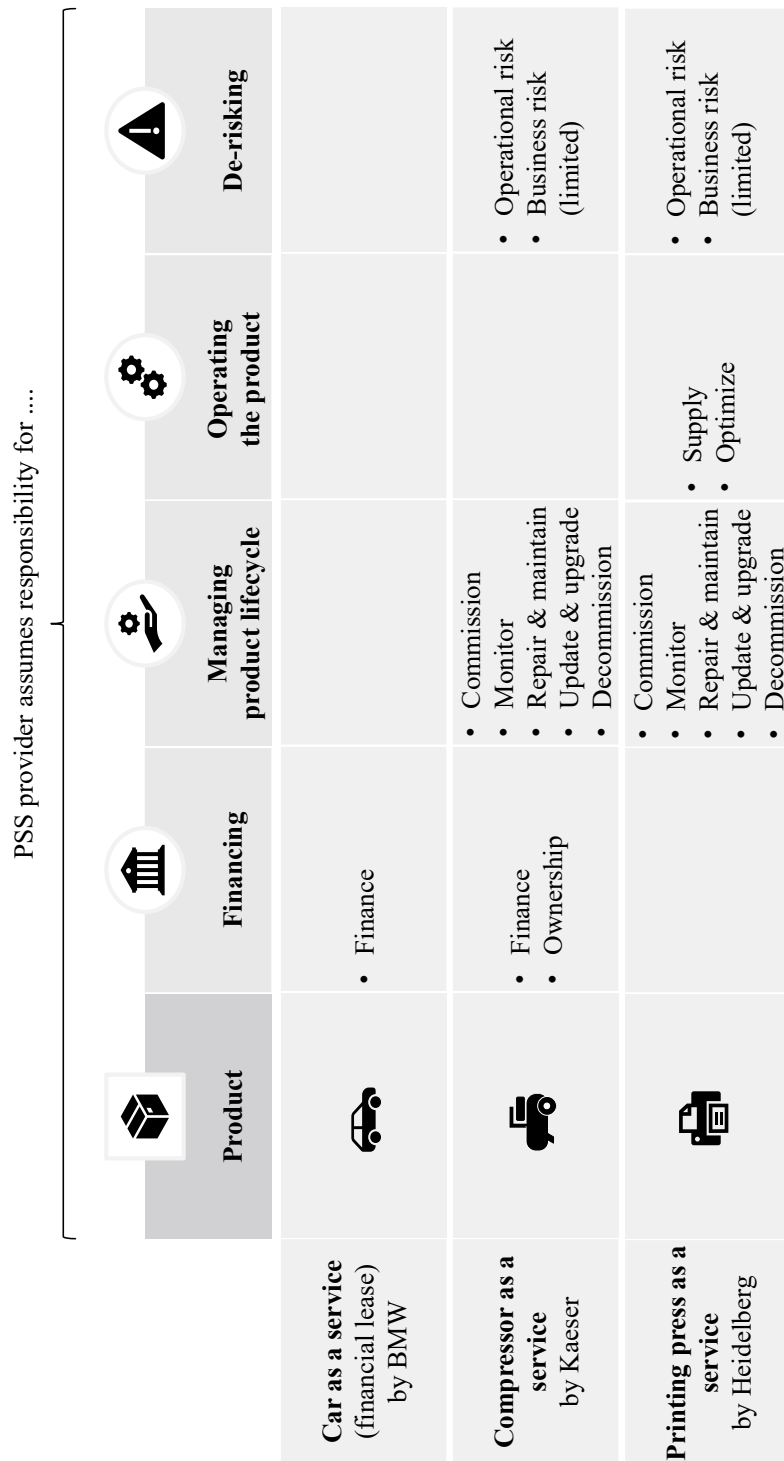


Figure 10: PSS configurations

BMW, for example, limits its “car as a service” offering to a basic financial leasing model, giving car users the contractual rights to use a car during the leasing period by paying a monthly leasing fee (BMW, 2021). Kaeser’s “compressor as a service” model lets customers pay for each cubic meter of compressed air. Kaeser finances and owns the compressors, provides all relevant services throughout a compressor’s lifecycle, and assumes operational risks in the case of unexpected compressor breakdowns. However, what Kaeser does not fully include are business risks. Kaeser requires its customers to purchase a minimum quantity of compressed air, and the customers must supply the energy for the compressors, which is subject to price fluctuations (Kaeser Compressors, 2020). Heidelberg Druckmaschinen’s “printing press as a service” model includes services for managing the product lifecycle and advancing customer operations (workflow management, consumable supply). Heidelberg Druckmaschinen assumes any operational risks stemming from unexpected breakdowns, as well as the business risks in terms of sudden reductions in the demand for printing jobs. However, the “printing press as a service” model does not include financing services for the printing press. It only covers managing the product lifecycle, advancing customer operations, and de-risking customer activities (Heidelberger Druckmaschinen, 2021).

4.3.3 How should a firm approach PSSs?

Misconception 5: Get your products connected first.

We found that managers often promoted product connectivity as a prerequisite for PSSs. For example, the engineering and technology company we studied started its transformation towards PSSs by technically enabling all products and defining a milestone to reach 100% connected products. However, we identified many successful PSS offerings that do not rely on product connectivity. Take Hilti’s fleet management as an example, where not a single one of its more than one million power tools under management is connected as of today. However, connectivity can play a crucial role in PSSs. Michelin struggled for many years to make its tire PSS commercially successful. It first became successful when Michelin was able to embed technology to remotely monitor tire wear, allowing Michelin to better manage tire usage and tire lifecycle costs. Similarly, General Electric reports that it now solves 95% of product failures remotely, rather than sending costly service technicians to customers. Thus, it lowers its service costs and ultimately enables PSSs (Gebauer, Fleisch, et al., 2020). The interviewees who

worked at companies that had successful PSS cases pointed out that it is not about “technology first”, but rather about finding compelling value propositions that address customer needs. Connected products can make PSSs more feasible, but it is the use case that really matters. Connected products alone only generate costs since equipping products with IoT components increases production costs, and maintaining connectivity and data processing incurs ongoing operation costs. Our case companies stated the following use cases that they use for their PSSs:

- *Remote monitoring*: Monitoring and inspections ensure seamless equipment operation. In the past, these activities required the presence of on-site technicians. However, today companies use remote monitoring and malfunction alerts to centrally manage hundreds of products 24 hours 7 days a week in a cost-effective way.
- *Remote access*: Remote access allows equipment to be remotely controlled, for example, to install new software packages, adjust parameters, or restart machines.
- *Remote support*: Remote support refers to the use of technology to help customers remotely fix problems by themselves without having to send expensive service technicians on-site.
- *Predictive maintenance*: The aim of predictive maintenance algorithms is to identify patterns in equipment data that indicate issues long before they materialize.

Misconception 6: We cannot swallow the fish.

In our study, managers often emphasized that transition toward PSSs blows up all budgets and alienates stakeholders. We collected quotes such as: “*How should we achieve this year’s financial targets with PSSs*”, “*we are not a bank*”, and “*our CFO makes PSSs impossible*”. Indeed, transitioning toward PSSs triggers a short-term drop in revenues as large lump sums of income (one-time, up-front product revenues) are replaced by smaller recurring PSS fees while, simultaneously, significant transition costs accrue. This financial gap is widely known as “the fish” and scares many companies away from PSSs (Lah & Wood, 2016). In sharp contrast to what is state of the art in digital innovation – e.g., rapid testing and iterative development (Ross et al., 2019) – the managers in our study often seemed to consider a “think big, start big” or “all-in” approach for PSSs. Such an approach leads to a large financial gap that is difficult to manage.

However, it is a misconception that companies cannot manage the financial gap – i.e., cannot swallow the fish. The successful PSS cases we studied kept the financial gap rather small. Hilti, for example, kept the financial gap relatively small by starting with a single pilot customer in Switzerland, expanding to a handful of selected customers, and, ultimately, scaling into new countries when profitability was achieved (Casadesus-Masanell et al., 2017). Audi limited its financial risk by exploring the PSSs for single car features (e.g., matrix LED headlights) rather than for the whole car (Vetter, 2019).

Another approach we found to manage the financial gap is to create a service journey and develop consecutive PSS offerings step-by-step. Research highlights that the transition from products to PSSs is not only a big leap for the providing company, but also for customers, as it often requires them to alter their consuming behavior (Mont, 2002a, 2002b). Hence, a stepwise transition across consecutive PSS offerings can minimize the necessary change in consuming behavior and guide customers step-by-step from buying products to PSSs. Take Caterpillar, which offers five levels of PSSs. It begins with level 1, giving customers access to basic connectivity services, such as remote monitoring and support. It is only at level 5 that Caterpillar provides a fully managed PSS in which Caterpillar fully manages the products (Caterpillar, 2021).

4.4 Discussion

4.4.1 Summary

The first papers providing insights into PSSs in manufacturing firms were published nearly 20 years ago (e.g., Davies et al., 2006; Oliva & Kallenberg, 2003). Driven by manufacturers' increasing interest in offering PSSs many theoretically strong contributions followed. However, indications exist that theory is often misunderstood and that PSS misconceptions exist, which prevents the uptake of PSSs in practice (Baines et al., 2017; Bigdeli et al., 2021; Kowalkowski, 2010; Perona et al., 2017; Tukker & Tischner, 2006a). Thus, this chapter's research strived to investigate potential PSS misconceptions that prevent manufacturing firms from transitioning towards PSSs. Based on case study research covering 26 companies, we identified six misconceptions that dissuade manufacturers from effectively embracing and implementing PSSs. The identified misconceptions cover three areas: When PSSs are relevant, what PSSs are,

and how firms should approach PSSs. Table 5 summarizes the six identified misconceptions.

	Misconceptions	Descriptions
When are PSSs relevant?	Misconception 1: PSSs work for Rolls-Royce, but not for us.	• Managers often infer that PSSs only work for Rolls-Royce – i.e., capital-intensive, complex products with high wear and tear. • However, there are no such limitations for which “products” PSSs can be relevant. • Successful PSSs exist for movable and immovable assets, capital-intensive and non-capital-intensive products, fleet of products, hardware and software components, and consumables.
	Misconception 2: PSSs are for customers that cannot afford to buy.	• Managers often believe that PSSs only attract financially weak customers. • However, PSSs is about solving wicked customer problems to attract customers who pay premium prices for these solutions. • The widely known financial perks of PSSs (i.e., no initial investment, no CAPEX, no fixed costs) are often only secondary customer benefits.
What are PSSs?	Misconception 3: PSSs are pay-per-use.	• Managers often reduce PSSs to pay-per-use. • However, pay-per-use is only one of many revenue models for PSSs. • Furthermore, companies often use minimum contract terms to limit the risk transfer of PSSs.
	Misconception 4: PSSs are fully managed.	• Managers often interpret PSSs as a fully managed solution. • While there are good theoretical reasons to maximize the scope of PSSs, PSSs do not follow this one-size-fits-all fully managed approach • The service elements of PSSs are configured and tailored to define compelling value propositions that address specific customer needs.
How should a firm approach PSSs?	Misconception 5: Get your products connected first.	• Managers often promote product connectivity as a prerequisite for PSSs. • However, many successful PSS offerings do not rely on product connectivity. • While connected products make PSSs more feasible, it is the use cases that matter.
	Misconception 6: We cannot swallow the fish.	• Managers often emphasize that transition toward PSSs results in a big financial gap (“the fish” – where costs exceed revenues) that is difficult to manage. • However, it is a misconception that companies cannot manage the financial gap. • Companies manage the financial gap, for example, by keeping the gap rather small by limiting PSSs to single customers or single features.

Table 5: Summary of the identified misconceptions

4.4.2 Practical and Theoretical Implications

This study has several implications for theory and practice. These are outlined in the following sub-sections.

Theory-practice disparities

First and foremost, the insights gained through this study advance the extant PSS literature on theory-practice disparities. Literature has provided indications that practice often misunderstands PSS theory and that misconceptions exist that prevent the uptake of the PSS concept in practice (Baines et al., 2017; Kowalkowski, 2010; Perona et al., 2017; Tukker & Tischner, 2006a). The findings of this chapter support and advance these indications by revealing six misconceptions regarding when PSSs are relevant, what PSSs are, and how firms should approach PSSs.

Practitioners should be aware of these misconceptions as they represent barriers to the increasing efforts to turn connected products into PSSs (Bigdeli et al., 2021). On the one hand, misconceptions prevent practitioners from recognizing the true value of PSSs and prevent them from making informed decisions (Baines et al., 2017; Kowalkowski, 2010). On the other hand, these misconceptions act as dysfunctional stereotypes (e.g., “PSSs work for Rolls-Royce, but not for us”, “PSSs are for customers that cannot afford to buy”) that reinforce a product-oriented culture. A product-oriented culture is a central barrier for PSSs in manufacturing firms (Bigdeli et al., 2021; Neely, 2008). Thus, eliminating these misconceptions is considered essential to embracing PSSs. The study provides practitioners with evidence and examples from practice that complement existing theory to dispel these misconceptions.

For theory, the six identified misconceptions represent useful directions for valuable future research to increase the uptake of the PSS concept among practitioners. For instance, identifying when specific types of PSSs are relevant could have immediate management implications, since PSSs have not always proven successful (Gebauer, Fleisch, et al., 2020; Kohtamäki et al., 2020; Valtakoski, 2017) and practitioners often lack an understanding of which PSSs are relevant and when (e.g., misconceptions 1 and 2).

Minimum contract terms are the norm

Second, the study provides insights that minimum contract terms are the norm in PSSs, as this limits the risk transfer of pay-per-use, pay-per-outcome, and similar revenue models. At first glance it appears that many PSSs are based on “pure” pay-per-use or pay-per-outcome revenue models. An illustrative example is Homie offering pay-per-use laundry machines with free delivery and installation. At a second glance, however, it becomes evident that the contract includes a minimum usage term (approximately 15 wash cycles per month) and a minimum contract duration (12 months) before the contract can be canceled free of charge (Homie, 2021). Hence, the pay-per-use laundry machine offering is more like a 12-month subscription including 15 wash cycles per month and only after that does it become a “pure” pay-per-use model. Such minimum contract terms limit the risk transfer from the customer towards the manufacturer (cf. Simon & Fassnacht, 2019). In the Homie case, they bear the risk of laundry machines breaking down but limit their exposure to the risk of customers ordering a laundry machine and not needing it or not using it. Hence, minimum contract terms allow manufacturers to limit their risk exposure to those risks that they can influence or handle. Practitioners and scholars alike should be aware of them, as many PSSs are inconceivable in practice without these minimum contract terms.

In the extant literature, these minimum contract terms have only been mentioned in passing (e.g., Bertini & Koenigsberg, 2020a; Gebauer, Haldimann, et al., 2017; Van Ostaeyen et al., 2013). Pay-per-use and similar revenue models, in which customers only pay for the availability, or only pay a usage fee, or only pay for the actual outcomes, have been propagated as advantageous and future-oriented (cf. Bertini & Koenigsberg, 2020a; Porter & Heppelmann, 2015). However, there has not been sufficient critical reflection on the risk transfer involved – i.e., what manufacturers can deliver and what they cannot. Future research should explicitly reflect on minimum contract terms as a means of limiting risk transfer between PSS customers and providers.

Scaling gradually

Finally, the study provides insights into the importance of scaling gradually. With PSSs, manufacturers assume responsibility for outcomes (e.g., jet engine functioning in the case of Rolls-Royce) and face penalties for any shortcomings (e.g., jet engine breakdown) (Grubic & Jennions, 2018). Hence, practitioners and scholars often describe

the shift to PSSs as a high-gain and high-risk strategy associated with significant investments (Gebauer, Fleisch, et al., 2020; Kohtamäki et al., 2019; Korkeamäki et al., 2021; Lah & Wood, 2016; Sjödin et al., 2020). The study provides practitioners with practical insights into how manufacturers can minimize investments and mitigate risks by scaling gradually. For instance, exploring PSSs with a handful of pilot customers or with a single product feature allows manufacturers to learn and fail quickly with manageable risks. The insights into the importance of scaling gradually are consistent with the research on designing PSSs to move from linear to iterative approaches (Clayton et al., 2012; Pezzotta et al., 2012; Tukker, 2015). Future research that responds to the call to provide practitioners with knowledge and guidance for implementing and scaling PSSs should consider the importance of iterative approaches.

4.4.3 Limitations

The findings of this chapter are not free of limitations. First, the explorative interviews and the in-depth case studies are based on a convenience sample. The theoretically selected samples from manufacturing companies, interview partners, and workshop participants were small and opportunistic. While this limits the findings' generalizability and representativeness, the close relationships we built with the case companies provided us with access to key informants (executives across functions and hierarchical levels), which allowed us to gather in-depth knowledge and rich stories on a strategic and timely topic (Saunders et al., 2019). Second, the findings are qualitative and, to some extent, anecdotal due to the study's methodological approach. Thus, further empirical validation through systematic studies may be necessary to transfer the findings of this study to other companies and industries.

Chapter 5

Designing PSSs – 58 PSS Patterns⁵

5.1 Introduction

Instead of simply selling products, manufacturers increasingly combine products with software and services to offer PSSs that solve complex customer problems and create a sustainable competitive advantage (Kowalkowski et al., 2017; Mont, 2002a; Neely, 2008). However, PSSs require entirely new business models for manufacturers that so far have mainly relied on product-centric business models (Barquet et al., 2013; Sjödin et al., 2020; Zancul et al., 2016). The shift affects the value proposition, the value capture, and the value creation of a business model:

- Value proposition (what?): Offering PSSs implies delivering value-in-use instead of value-in-exchange (Sjödin et al., 2020). That is what a product or service does for the customer – for instance, the flying hours in the case of Rolls-Royce’s “power-by-the-hour” offering (Baines et al., 2007) or compressed air in the case of Kaeser’s compressors (Kaeser Compressors, 2020). Thereby, manufacturing companies assume responsibility for activities previously handled by customers or third parties (e.g., financing, maintenance, repairs) (Tukker, 2004; Ulaga & Reinartz, 2011).
- Value capture (why?): Providing PSSs also implies new revenue models. Traditionally, manufacturers’ revenue models were based on transferring ownership through selling products. With PSSs, the revenue model is anchored in use, outcome, or performance (Bertini & Koenigsberg, 2020a; Gebauer, Haldimann, et al., 2017; Wortmann et al., 2017).

⁵ Parts of this chapter were initially published or submitted for publication in the context of the following manuscript: Wortmann, Lamprecht, et al. (2021).

- Value creation (how?): Value is created closer and customized to the customers' needs by leveraging technologies around the IoT (Rymaszewska et al., 2017). Rolls-Royce, for instance, is using IoT technology to remotely monitor sensor data from its jet engines to perform maintenance based on actual demand rather than statistical assumptions (Paschou et al., 2020).

Many manufacturers struggle to design or redesign their business models for PSSs (Christensen et al., 2016; Gebauer et al., 2005; Gebauer, Fleisch, et al., 2020; Kohtamäki et al., 2020). Redesigning a business model can involve vast transformations for a company and is referred to as “business model innovation” (BMI) (Foss & Saebi, 2016; Gassmann et al., 2020). Although PSSs in manufacturing firms are associated with BMI (Barquet et al., 2013; Sjödin et al., 2020; Zancul et al., 2016), research adopting a business model perspective is still at an early stage (Adrodegari & Saccani, 2017; Paschou et al., 2020; Pirola et al., 2020; Reim et al., 2015). The studies that adopt a business model perspective are often relatively superficial and lack structure and do not provide enough detail describing the business model elements and sub-elements of PSSs (Adrodegari & Saccani, 2017). Furthermore, tools that support manufacturers with designing PSS business models are still scarce (Pirola et al., 2020).

In practice, the design of new business models is often based on trial-and-error experimentation that also fails (Chesbrough, 2010; Sosna et al., 2010). For this reason, an approach that uses learning from recurring patterns that have been successful in the past has gained considerable attention as a way of supporting the design of new business models (Amshoff et al., 2015). The basic idea behind the pattern concept is to capture and share proven business models or business model building blocks in an accessible format to reduce complexity and increase efficiency in the design process (Amshoff et al., 2015).

Patterns were first applied in architecture. In the late 1970s, architectural theorist Christopher Alexander formulated 253 patterns that provide proven solutions for recurring problems in designing buildings, towns, and constructions (Alexander, 1977). Since then, patterns have been applied in various domains reaching from software design (Gamma et al., 1995) to engineering (Salustri & Eng, 2001) and business models (Gassmann et al., 2020). See Table 6 for an overview of different domains where patterns are being applied.

Domains	Authors	Descriptions
Architecture	Alexander (1977)	Patterns for designing buildings, towns, and constructions
Software design	Gamma et al. (1995)	Patterns for object-oriented software design
	Kerth and Cunningham (1997)	Patterns to improve the use of objects and architectures in software design
	Cloutier and Verma (2006)	Patterns for architecting complex system (enterprise) architectures
	Pahl and Barrett (2010)	Patterns for service-oriented software systems
Engineering	Salustri and Eng (2001)	Patterns for multidisciplinary design engineering
Human-computer interaction	Borchers (2008)	Patterns to create user interfaces
	Tidwell et al. (2020)	Patterns for the effective design of human-computer interactions
E-learning	Goodyear (2005)	Patterns for designing e-learning in higher education
Business models	Osterwalder and Pigneur (2010)	Business model framework
	Fleisch et al. (2014)	Patterns for IoT business models
	Amshoff et al. (2015)	Patterns for using disruptive technologies
	Weking et al. (2020)	Patterns for industry 4.0 business models
	Gassmann et al. (2020)	Patterns for generic business models
	Takacs et al. (2020)	Patterns for circular economy business models
	Ebel et al. (2021)	Patterns for smart services

Table 6: Patterns in different domains

These business model patterns differ based on their granularity. On the one hand, complete frameworks, such as the Business Model Canvas (Osterwalder & Pigneur, 2010), represent very abstract business model patterns. On the other hand, solution patterns represent “proven building blocks for designing business models” (Amshoff et al., 2015, p. 6). This thesis understands business model patterns as solution patterns: aggregated and abstract building blocks based on empirical observations to support the design of business models (Amshoff et al., 2015; Chung et al., 2004). Such patterns mirror the notion that new business models usually recombine existing building blocks (Beverungen et al., 2018; Gassmann et al., 2020). For instance, Gassmann et al. (2020) find that over 90% of BMIs represent a combination of existing business model patterns.

Business model patterns exist for generic business models (Gassmann et al., 2020), industry 4.0 business models (Weking et al., 2020), IoT business models (Fleisch et al., 2014), circular economy business models (Takacs et al., 2020), smart services (Ebel et al., 2021), and for using disruptive technologies (Amshoff et al., 2015), to only mention a few. To the best of our knowledge, patterns have not been investigated for PSSs. This

is in line with fellow researchers calling for tools and approaches with the necessary structure and detail to describe business model elements that can help manufacturers design PSS business models (Adrodegari & Saccani, 2017; Pirola et al., 2020).

To minimize this research gap, this chapter's objective is to provide patterns that can support manufacturers as they design business models for PSSs by identifying patterns in existing PSS business models. Hence, the following research question guides the research in this chapter:

SRQ 2: Which business model patterns can support the design of sustainable PSSs?

To address this research question, we analyzed 199 PSSs cases through a qualitative multi-case study approach. The systematic analysis of 199 PSSs business models revealed 58 patterns. Manufacturing companies can use these patterns to support the design of business models for PSSs.

5.2 Methodology

The investigation of the research question relied on a qualitative multi-case study research design similar to that used in previous business model pattern studies (e.g., Ebel et al., 2021; Goldenberg et al., 1999; Weking et al., 2020). Thereby, a sample of PSS business models is examined for recurring characteristics to derive patterns. We divided the research process into an explorative study and an in-depth study. In the explorative study, we aimed to familiarize ourselves with the study's context and identify PSS cases relevant to the study. In the in-depth study, we analyzed the business model elements of 199 PSS cases to derive patterns that represent recurring business model elements of PSSs.

Explorative study

The study in Chapter 4 represents the explorative study used for this chapter's research. We used the 77 interviews and workshops with 26 companies to familiarize ourselves with the context of PSSs, gain insight into the main design challenges regarding PSS business models, and gather PSS cases relevant for the in-depth study. Furthermore, we

used the data collected in the exploratory study to supplement the data for the respective PSS cases analyzed in the in-depth study.

In-depth study

To obtain a comprehensive picture of business model patterns for PSSs, we considered it relevant to include a heterogeneous sample of PSSs. Therefore, we did not limit the PSS sample to a specific industry or geographic region. However, we included only those PSSs in the sample for which we had access to necessary data and insights. In total we investigated a sample consisting of 199 PSS cases.

We identified the PSS cases by applying theoretical sampling (Eisenhardt & Graebner, 2007). On the one hand, the PSSs of the explorative study and the PSSs recommended by the interviewees and workshops participants served as a starting point. On the other hand, we searched journal articles, practitioner books and magazines, practitioner presentations, and internet forums to identify relevant PSSs. We systematically examined these sources and successively transferred the identified PSS cases into a PSS database. After the initial search to identify relevant PSS cases, we conducted further desk research to create a detailed description of the business model elements for each PSS case. We collected data through extensive desk research, including articles, magazines, reports, company presentations, brochures, and annual reports to craft business model descriptions⁶. Additionally, we supplemented the desk research with primary data from the explorative study. Table 19 in the appendix provides an overview of the 199 studied PSS cases.

We analyzed the 199 PSS business model descriptions through a content analysis procedure and pattern matching logic, as outlined in Chapter 3.3.2. We first manually coded the case descriptions to identify first-order codes (Flick, 1998) and applied axial coding to cluster similar codes into more abstract themes (Strauss & Corbin, 1990). For example, “*only operating expenses*” and “*off balance sheet*” were clustered to “*OPEX*”. In a last step, we looked for similar themes to derive pattern codes. Thereby the pattern codes “pull together material into smaller and more meaningful units” (Punch & Oancea, 2014, p. 226). For example, second-order themes such as “*OPEX*” and “*No CAPEX*” were subsumed under the pattern “*get OPEX and not CAPEX*”. After evaluating the

⁶ The extensive desk research was conducted with the help of bachelor and master students.

patterns for mutual consistency, we identified a total of 58 patterns across the business model elements. For each pattern, we prepared textual descriptions as well as two examples and produced pattern cards (see Figure 11 for two pattern examples).

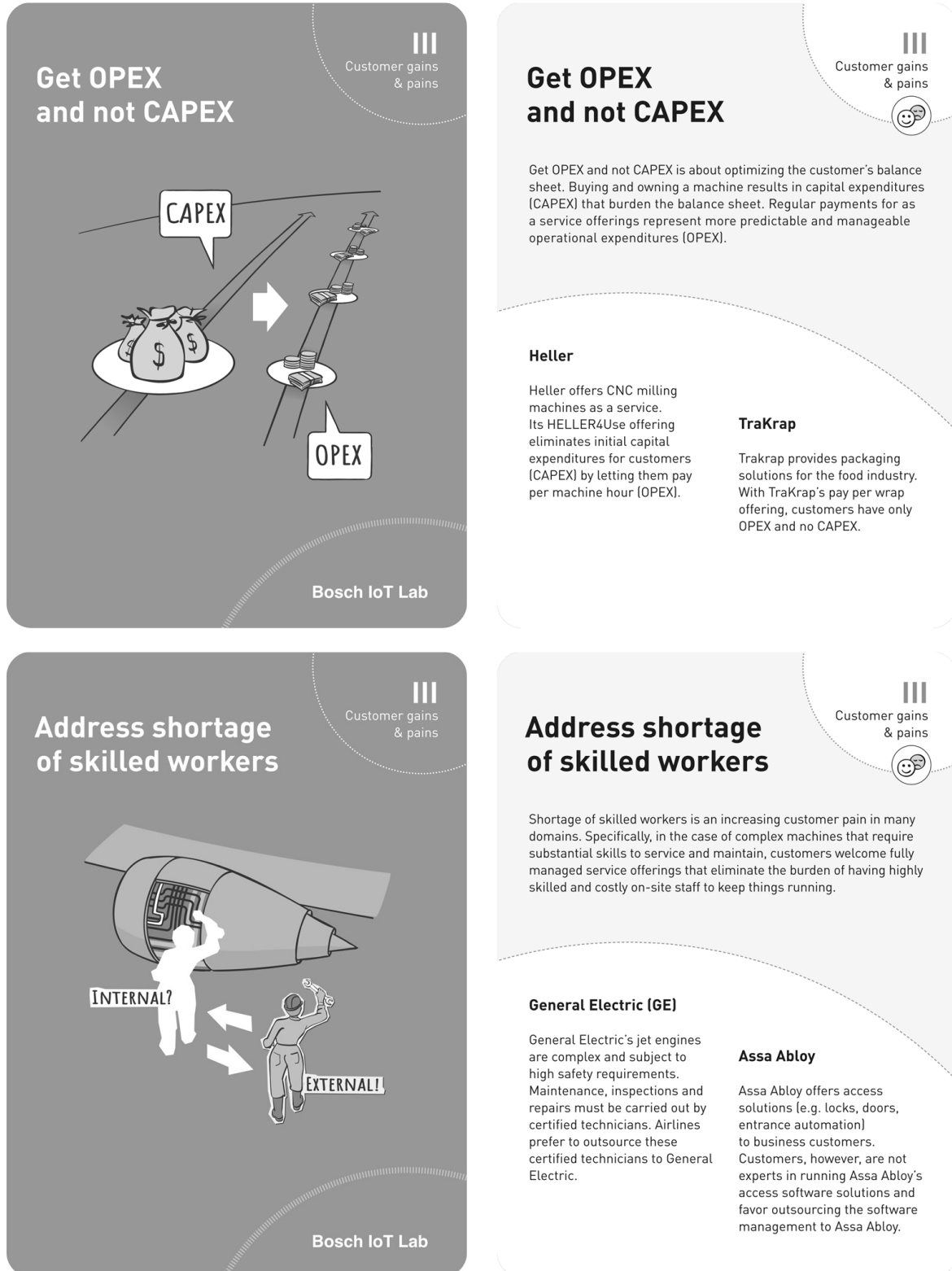


Figure 11: PSS pattern cards

We used these pattern cards to conduct workshops with companies to design their PSS business models. We also provided pattern cards for companies to use independently. In both cases, we conducted follow-up interviews to gather feedback and iteratively refine the patterns. See Table 7 for an overview of the conducted workshops and follow-up interviews.

#	Case (anonymized)	Sector	Type	Roles (anonymized)
1	Gripping System Inc.	Manufacturing	WS	4 Participants
			FI	CTO, VP Services
2	Heating FL Inc.	Heating	FI	Product Owner
3	Car Parts and Service Inc.	Mobility	WS	11 Participants
			FI	BUD
4	Heating DE Inc.	Heating	FI	System Architect
5	Scales Manufacturing Inc.	Scientific Instruments	WS	17 Participants
			FI	Head of Service, Head of Manufacturing
6	Conglomerate Inc.	Conglomerate	FI	Head of UX, Expert UX
7	Power Tools Inc.	Power Tools	FI	VP Digital Business, BUD
8	Consultancy Inc.	Professional Services	FI	Partner, Head of Manufacturing
9	Financing Inc.	Financial Services	FI	Founder

Legend: WS = Workshop, FI = Feedback Interview, CTO = Chief Technology Officer, VP = Vice President, UX = User Experience, BUD = Business Development Manager

Table 7: Workshops and follow up interviews

5.3 Results

This chapter presents the business model patterns that we identified through our research. The examination of a total of 199 PSSs resulted in 58 patterns for a business model's value proposition, value capture, and value creation elements. First, we present the patterns regarding the value proposition. We outline customer gains and pains that PSSs can address, and the service elements required to do so. Second, we present the identified value capture patterns that describe why PSSs generate value for a company. We identified revenue models used in PSSs to generate financial income, as well as strategic rationales beyond the financial income of the revenue model. Third, we focus on how companies create and deliver PSSs – i.e., value creation. Here we present management tactics for common challenges as well as technology use cases that support value creation.

5.3.1 PSS Value Proposition Patterns

The value proposition of a PSS business model refers to the value a PSS generates for customers (Teece, 2010). From a customer perspective, that value is represented by the pains and gains that PSSs address. Whereas from the provider perspective, the value proposition is what services are bundled with products to accomplish this (Gassmann et al., 2020). Through our research, we identified 9 customer pain and gain patterns as well as 11 PSS service patterns. We structure them into four fundamental categories: (a) financing, (b) managing the product lifecycle, (c) operating the product, and (d) de-risking (see Figure 12). Subsequently, we outline the identified value proposition patterns along this structure – first the customer pain and gain patterns and then the PSS service patterns.

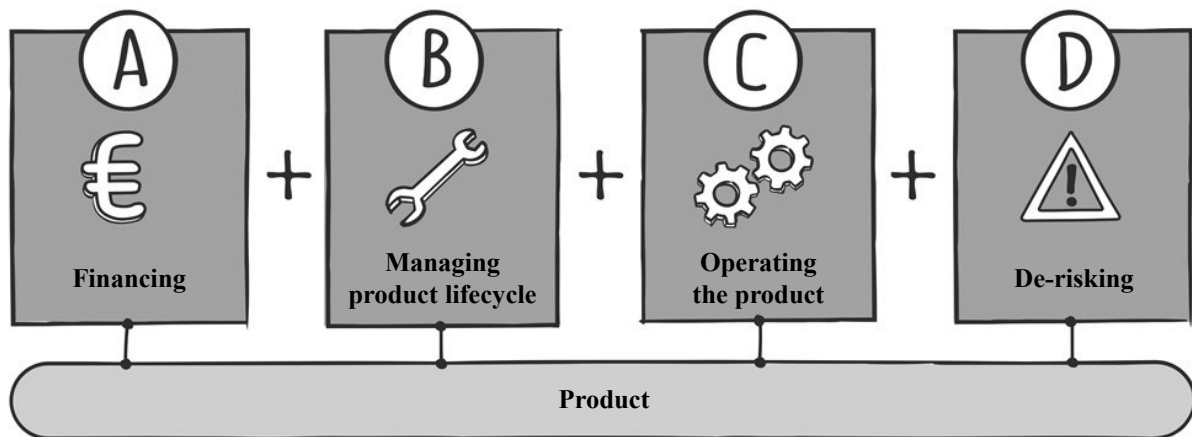


Figure 12: Categories for PSS value proposition

Customer pain and gain patterns

We identified 9 customer pain and gain patterns that outline pain points where customers can benefit from PSSs. See Table 8 for an overview of these customer pain and gain patterns.

Categories	#	Patterns	Examples*
Financing	1	Get OPEX and not CAPEX	Heller, Kaeser, TraKrap,
	2	Align revenue and cost	Elite, Packsize, Volvo
Managing product lifecycle	3	Address shortage of skilled workers	Assa Abloy, General Electric, Rolls-Royce
	4	Decrease TCO	Hilti, MAN Truck & Bus, Signify
	5	Align incentives	Atlas Copco, BASF Coating, Siemens Healthineers
Operating the product	6	Be more flexible	Heller, Hilti, Jungheinrich
	7	Improve OEE	Bosch Rexroth, General Electric, Rolls-Royce
De-risking	8	Reduce operational risk	Beumer Group, Boge Kompressoren, Hitachi Rail,
	9	Reduce business risk	Coborn, Homie, Winterhalter

*For every pattern three exemplary examples are provided. Note that multiple patterns may apply to a single PSS case and are not listed here in a comprehensive manner.

Table 8: Customer pain and gain patterns

First, we identified patterns that represent gains and pains concerning the financing of products:

- *Get OPEX and not CAPEX*: When a company buys and owns products, it has to show its investments as capital expenditures (CAPEX) on its balance sheet and depreciate them over the product lifecycle. However, companies (especially CFOs) often want to minimize their CAPEX and instead have more predictable and manageable operational expenditures (OPEX) that are off-balance sheet.⁷ The pattern “*get OPEX and not CAPEX*” captures this pain. PSSs provide the opportunity to turn CAPEX into OPEX. One example is Heller, a leading manufacturer of CNC machines. With its PSS called “HELLER4Use”, Heller eliminates initial capital expenditures for customers (CAPEX) by letting them pay-per-machine hour (OPEX) (Gebr. Heller Maschinenfabrik, 2021).
- *Align revenue and cost*: In addition to CAPEX that burden customer balance sheets, traditional product investments are detached from the customers’ revenue generated by the products. For example, if a hotel buys beds from Elite, a bed manufacturer, their investment slowly recovers over time as hotel guests book rooms and sleep in these beds. The “align revenue and cost” pattern captures this pain of misaligned

⁷ See Helo et al. (2017) for a detailed comparison of CAPEX and OPEX and an explanation of why companies often prefer OPEX.

revenues and costs. With Elite's PSS called "smart lease", the bed costs are aligned with the hotel's revenue streams, as hotels only pay an overnight fee to Elite when guests book and pay for the hotel rooms (Elitebeds, 2018). Hence, PSSs can replace customers' initial investment through regular payments throughout the asset's lifecycle to better align cost and revenue streams.

Second, in addition to financing gains and pains, we identified three patterns regarding managing the product lifecycle:

- *Address shortage of skilled workers*: The shortage of skilled workers that can service and maintain products is an increasing customer pain, specifically in the case of complex machines that require highly qualified staff to be maintained and serviced (cf. Tukker & Tischner, 2006a). Here customers frequently seek PSSs that eliminate the burden of having highly skilled and costly on-site staff to keep things running. A typical example is jet engines, where safety regulations require accredited technicians to carry out maintenance, inspections, and repairs. Airlines often outsource these accredited technicians to jet engine manufacturers such as General Electric (GE) or Rolls-Royce.
- *Decrease TCO*: Minimizing the total cost of ownership (TCO) is a key concern of product customers⁸. With PSSs, providers manufacture the product and provide related services (e.g., financing, maintenance, repair). Such a one-stop offering enables unique opportunities for optimization that can significantly reduce customers' TCO (e.g., Rabetino et al., 2015). In the case of Hilti's fleet management PSS, construction firms can outsource the challenge of managing hundreds of power tools to Hilti by paying a fixed monthly fee to cover the power tools, service, and repair costs. This simplifies things for the construction firm and cuts out hidden costs, ultimately reducing the TCO of the power tools (Casadesus-Masanell et al., 2017)
- *Align incentives*: This pattern outlines the pain of having to handle different interests. Customers traditionally have to collaborate with the manufacturer, a service provider, and sometimes even with component manufacturers and banks throughout the product lifecycle. All these parties have their own interests, which might even contradict each other. Handling different interests can be a pain for customers.

⁸ TCO represents the overall costs associated with a product or service throughout its lifecycle. This includes direct costs (e.g., purchase price) as well as indirect costs (e.g., maintenance, service, downtime caused by failure, disposal costs). For a detail description of the TCO, see Ellram (1995).

Integrated PSSs have the potential to align incentives and significantly reduce friction for the customer. In the case of BASF Coating, customers (e.g., car manufacturers) are increasingly concerned about reducing their environmental impact. Car manufacturers and BASF aligned their incentives by modifying BASF's coating as a service offering, from being paid for every coated car to every liter of coating *not* used. This way, BASF is incentivized to use as little paint as possible to reduce the environmental impact of car manufacturers (Worm et al., 2017).

Third, we identified two pains that customers can experience when operating the products:

- *Be more flexible*: Customers experience pain when special-purpose equipment is not at hand when needed. Or when they need more machine capacity to meet short-term peaks. PSSs can provide customers with the necessary flexibility to address these pains. For example, Hilti's fleet management covers customers' peak demand and temporary need for highly specialized power tools. Customers enjoy flexibility regarding the number as well as the type of power tools they need (Casadesus-Masanell et al., 2017).
- *Improve OEE*: This pattern captures the customer pain and gain of maximizing the overall equipment effectiveness (OEE) – i.e., the time a piece of equipment is genuinely productive. OEE is driven by equipment availability, performance, and quality (Dal et al., 2000). With PSSs, manufacturers assume responsibility for activities that affect these drives (e.g., maintenance) and can leverage their know-how to enhance them. For instance, hydraulic oil contaminations cause 25% of the industrial hydraulic plant shutdown costs. Bosch Rexroth, a manufacturer of industrial hydraulics, leverages its know-how about avoiding oil contamination to take responsibility for handling the oil and, ultimately, to increase the OEE of the hydraulic plants for its customers (Bosch Rexroth, 2018).

Fourth, we identified two patterns that represent gains and pains for de-risking:

- *Reduce operational risk*: When purchasing and operating products, customers face the risk of products breaking down or not running at the desired performance, which is known as operational risk. For example, baggage handling is crucial for airports. Any downtime of the baggage handling system means potential delays for connecting flights with corresponding costs. By guaranteeing the availability of their baggage handling systems, the Beumer Group reduces such operational risks for airports (Beumer Group, 2021).

- *Reduce business risk*: In addition to operational risk, customers also face the risk of product underutilization because of a decline in demand, which is known as business risk. Reducing business risk can be vital for customers. For instance, with Winterhalter's pay-per-wash offering for commercial dishwashers, restaurants outsource their business risk as they only pay a defined fee per wash cycle when using them. So if a restaurant suddenly has no customers, the dishwashers are not used, and there are no costs for the restaurant (Pay Per Wash, n.d.).

PSS service patterns

While the customer pain and gain patterns capture the customer perspective, we also identified 11 PSS service patterns that represent services that manufacturers can include in PSSs to address these customer pains and gains. Table 9 outlines the PSS services we identified.

Categories	#	Patterns	Examples*
Financing	1	Finance	Michelin, Siemens Healthineers, Trumpf
	2	Own	Packsize, TraKrap, ZK System
Managing product lifecycle	3	Commission & decommission	Bartec Syscom, Bosch Thermotechnik, Viessmann
	4	Monitor	Claas, Liebherr, SKF
	5	Repair & maintain	Hilti, Share Now, Trilux
	6	Update & upgrade	365FarmNet, KleverKey, Tesla
Operating the product	7	Operate	Fendt, MAN Truck & Bus, Volvo Trucks
	8	Supply	Packsize, Viessmann, Würth Group
	9	Optimize	Heidelberger Druckmaschinen, Komatsu Forest, Signify
De-risking	10	Take operational risk	Continental, Kaeser, Kone
	11	Take business risk	Homie, Weisser, Winterhalter

* For every pattern three exemplary examples are provided. Note that multiple patterns may apply to a single PSS case and are not listed here in a comprehensive manner.

Table 9: PSS service patterns

First, we identified two services regarding the financing of products:

- *Finance*: The finance pattern describes the service of financing products. That means that the PSS provider takes care of the product financing and eliminates the initial investment for its customers.
- *Own*: While the finance service eliminates the initial investment, customers still have to show the products on their balance sheet. The pain of having products on their

balance sheet (i.e., CAPEX) is eliminated if PSS providers also own the product or retain product ownership. For instance, Packsize – a manufacturer of packaging machines – finances and owns the packaging machines with their PSS called “on demand packaging”. Ultimately, customers can use the packaging machines without making an initial investment to purchase them and without having them on their balance sheet (Packsize, 2021).

Second, in addition to financing services, we identified three service patterns included in PSSs for managing the product lifecycle:

- *Commission & decommission*: The commissioning and decommissioning of products often require specialized personnel and dedicated procedures. The installation of a heating system, for example, involves safety approval from a certified technician. To ensure a hassle-free experience, PSS providers can take care of product commissioning and decommissioning. Depending on the product, this includes, for example, customer-specific product adaption, installation, calibration, or safety approval. The heating system manufacturer Bosch Thermotechnik, for instance, includes in their PSS “Heizung+ Wärme” the complete installation and approval by a certified Bosch technician (Bosch Thermotechnik, 2021).
- *Monitor*: The monitor service refers to monitoring product conditions and functions to identify problems before they escalate into costly issues. PSS providers leverage their in-depth product know-how to monitor their customers’ products. This implies that while the customer uses the products, the provider monitors their functions, tracks maintenance intervals, and intervenes if problems occur. Take, for example, bearings, where the worst case is when these bearings fail and cause a machine shutdown. In order to prevent this, SKF monitors the bearings in their “reliable rotation” PSS to intervene in time and avert unplanned machine shutdowns (Brown, 2018).
- *Repair & maintain*: Well-maintained products are essential for trouble-free operation. With repair and maintenance services included in PSSs, customers can concentrate on their core business and enjoy full cost control, as costs for unexpected repairs are eliminated. Take, for example, Hilti’s “fleet management”. It includes repair and maintenance services for the power tools so that customers (e.g., construction firms) can focus on their core business of using the power tools (Casadesus-Masanell et al., 2017).

- *Update & upgrade*: Especially in the era of software-enabled products, “product sold, case closed” no longer applies. Software always has bugs that need fixing or security patches that need updating. Furthermore, software-enabled products provide the possibility for continuous upgrades that allow for extending product functionality (Fleisch et al., 2014). Hence, the update & upgrade service pattern describes the service of providing customers with the latest product. Tesla uses software updates and upgrades to improve its cars continuously. With the 2020.40.7 release, for example, Tesla improved the energy consumption of the climate control system, giving the car an additional range of about 10 miles (Teslascope, 2021).

Third, in addition to services for financing and managing the product lifecycle, we identified three services that manufacturers offer to support customers operating the products:

- *Operate*: The operate service pattern refers to taking over product operation. However, unlike outsourcing and contracting, with PSSs, core product operation usually remains in the customer’s hands unless companies can automate the product operation. The customer still drills the holes in the Hilti PSS outlined above. Similarly, airlines still fly the airplanes themselves despite opting for Rolls-Royce’s “power-by-the-hour” offerings.
- *Supply*: The supply service pattern refers to handling the consumable supply. Consumables are a necessary evil to keep operations running. Without consumables, machines stand still. However, managing the consumable supply can be quite cumbersome and costly. Thus, various PSS providers manage consumable supply for their customers to ensure hassle-free operation of the machines. For instance, with Viessmann’s PSS, called “Wärme Flex”, customers do not have to worry about ordering fuel for their heating systems since Viessmann fully manages the supply (Viessmann Climate Solutions, n.d.).
- *Optimize*: The optimize service pattern captures services to optimize customers’ product operations. These range from training to consulting and customer-specific product optimization. For example, Heidelberger Druckmaschinen not only supplies customers with the printing systems, the consumables, and the possibility to pay-per-sheet, but also with training and consulting. Heidelberger Druckmaschinen analyzes customers’ KPIs (key performance indicators) and processes, compares them with benchmarking data, and uses this information to derive customer-specific recommendations (Heidelberger Druckmaschinen, 2021).

Lastly, we identified two service patterns for de-risking. These patterns represent service elements that allow customers to transfer risks to the PSS provider (see also Azarenko et al., 2009):

- *Take operational risk*: This pattern outlines the service element of transferring operational risk to the PSS provider. This is achieved by selling value-in-use (i.e., what a product or service does for the customer) instead of value-in-exchange (i.e., the product or service). For instance, Kaeser takes on the operational risk of compressor breakdowns or compressors not reaching their intended energy efficiency by selling their customers compressed air instead of the compressors themselves (Kaeser Compressors, 2020).
- *Take business risk*: Business risks can be transferred from customers to the PSS provider through revenue models such as pay-per-use. Here customers only have to pay when they actually use the product. Hence, if market demand decreases and customers use products less, then they also incur fewer costs.

5.3.2 PSS Value Capture Patterns

After discussing the patterns for the value proposition in the previous chapter, this chapter presents the patterns we identified for the value capture element. The value capture element defines the monetary viability of the business model, describing why the business model generates value for companies' shareholders and stakeholders (Gassmann et al., 2020; Teece, 2010). Our analysis resulted in 8 revenue model patterns that outline revenue models to monetize PSSs. In addition to the revenue models, we identified 10 strategic rationale patterns for why PSSs can generate value for a company's shareholders and stakeholders.

Revenue model patterns

We identified 8 revenue model patterns that represent revenue models that manufacturers use to monetize PSSs; see Table 10 for an overview. The identified patterns fall into two categories. The first category includes patterns representing revenue models to generate financial income. In contrast, the second category comprises the patterns that capture restrictions for these revenue models used to limit the risk transfer between the PSS provider and the customer.

Categories	#	Patterns	Examples*
Revenue models	1	Subscription	BMW, Fitbit, Geely
	2	Pay-per-use	Electrolux, Share Now, Winterhalter
	3	Pay-per-outcome	Atlas Copco, Magazino, Marble
	4	Pay-per-performance	Kone, Signify, SKF
	5	Pay-per-consumable	KaffeeCenter, Packsize
Revenue model restrictions	6	Minimum usage	Bundles, Heidelberger Druckmaschinen, Packsize
	7	Minimum contract term	Gebr. Heller Maschinenfabrik, Kaeser, Schaeffler
	8	Enable exit	Bühler, Homie, Kaeser

* For every pattern three exemplary examples are provided. Note that multiple patterns may apply to a single PSS case and are not listed here in a comprehensive manner.

Table 10: Revenue model patterns

The first category represents revenue models used to monetize PSSs. We identified 5 different revenue models that differ in what the payments are tied to:

- *Subscription*: With a subscription revenue model, companies tie payments to time periods. Hence, customers pay a weekly, monthly, or yearly fee to have access to products or to specific functions, regardless of actual usage. BMW, for example, offers its digital key solution as a subscription. BMW equips its vehicles with the option of unlocking via smartphones in addition to the regular keys. Customers can use the digital key for a yearly subscription of 80 Euros (Vetter, 2019).
- *Pay-per-use*: The pay-per-use pattern refers to a revenue model where customers pay based on their effective usage rather than paying a fixed fee (Gebauer, Haldimann, et al., 2017). Companies meter the usage of products or specific functions and charge customers a predefined usage fee when they use them. Depending on the PSS, usage is billed differently – typical ways are the duration (minutes/hours) of use or used units. For instance, Winterhalter charges restaurants a usage fee every time they run a wash cycle with their PSS for commercial dishwashers (Winterhalter, n.d.).
- *Pay-per-outcome*: With a pay-per-outcome revenue model, companies link customer payments with customer outcomes. For example, Atlas Copco uses a pay-per-outcome revenue model for their tunnel drilling machines. The desired customer outcome is the dirt “moved” with the drilling machines. Instead of paying for the hours the tunnel drilling machine is used, customers pay a predefined fee for every cubic meter of dirt “moved”. This gives customers full cost control over their drilling operations (Epiroc, 2016).

- *Pay-per-performance*: The pay-per-performance pattern represents a revenue model where companies get paid based on how well they do something. For instance, the previously outlined “reliable rotation” offering from SKF, where SKF monitors the bearings and intervenes in time to prevent machine shutdowns, is based on a pay-per-performance revenue model. The customers pay according to how well SKF can prevent downtime caused by machine shutdowns. This means that the customer pays SKF a share of the additional profits generated by cost savings and increased factory output (Brown, 2018).
- *Pay-per-consumable*: The pay-per-consumable pattern refers to the amortization of PSSs through charging for consumables. When using the corresponding PSSs, customers are obliged to purchase the consumables from the PSS provider. For example, Packsize relies on a pay-per-consumable revenue model. Packsize provides its customers with fully managed packaging machines to produce right-sized cartons on-site for product packing and shipping (Packsize, 2021). Customers pay only for the cardboard (consumable) used by the packaging machines, which they must purchase from Packsize.

These revenue models transfer substantial risk from the customer to the PSS provider. However, PSS providers are often not willing to assume – or are not capable of assuming – such fundamental risks. Therefore, in practice, “pure” subscription, pay-per-use, pay-per-outcome, pay-per-performance, or pay-per-consumable revenue models are rare (see Chapter 4.3.2). We identified revenue model restrictions that are used to limit this risk transfer:

- *Minimum usage*: The minimum usage restriction refers to a contractually defined minimum usage level. Regardless of actual use, customers must always pay at least the amount specified by the minimum usage level. For example, Heidelberger Druckmaschinen’s pay-per-sheet offering for their printing machines includes a minimum printing volume. Regardless of the actual printing volume, customers must always pay at least the amount defined by the minimum print volume level (Heidelberger Druckmaschinen, 2021). Thus, Heidelberger only assumes limited accountability for their customers’ business risks.
- *Minimum contract term*: This pattern represents a contractually defined minimum contract term. For example, with the previously outlined PSS from Kaeser, where Kaeser provides customers with compressors and charges them a fee for every cubic meter of compressed air used, customers must agree to a minimum usage level and

a minimum contract term. Typically the contracts run 5 to 10 years to justify the high initial investments Kaeser has in installing and commissioning the compressors at the customer's site.

- *Enable exit*: For long-term contracts, we identified that PSS providers provide customers with the option to terminate contracts early. For example, Kaeser's PSS comes with a contract term between 5 and 10 years. Customers can terminate the contract early by paying a predefined amount to cover Kaeser's sunk costs.

Strategic rationale patterns

In addition to the revenue models that generate financial income, we identified 10 strategic rationales that outline why PSSs generate value for manufacturers and their share- and stakeholders. See Table 11 for an overview of the patterns. To present the patterns, we divided them into three overarching categories: (1) sustainable business models, (2) strong market position, and (3) superior solutions.

Categories	#	Patterns	Examples*
Sustainable business models	1	Stabilize revenues	BSH Hausgeräte, Cisco, Philips
	2	Reduce environmental impact	Lenovo, Mitsubishi Electric, Rent the Runway
Strong market position	3	Unlock customer demand	Bristol Siddeley, Signify, Xerox
	4	Close the gap	Boge Kompressoren, Gebr. Heller Maschinenfabrik, Geely
	5	Increase margins and share of wallet	Apple, Bosch Thermotechnik, Otis
	6	Win market shares	Caterpillar, General Electric, Xerox
	7	Establish strategic partnerships	BASF Coating, Siemens Healthineers, Trumpf
Superior solutions	8	Leverage premium product quality	Hilti, Michelin, Mobisol
	9	Avoid the commodity trap	Continental AG, Signify, Würth
	10	Enable full data access	Bosch Auto Parts, Heidelberger Druckmaschinen, Konecranes

* For every pattern three exemplary examples are provided. Note that multiple patterns may apply to a single PSS case and are not listed here in a comprehensive manner.

Table 11: Strategic rationale patterns

First, we identified two patterns that represent strategic rationales related to sustainable business models:

- *Stabilize revenues:* While product sales are often one-off revenues and depend on economic cycles, PSSs generate recurring revenues. Recurring revenues are less dependent on economic cycles and therefore more predictable (Helo et al., 2017). Tzuo and Weisert (2018) illustratively outline this by comparing companies with and without recurring revenues. A company that only has one-off revenues starts every year with no money in the bank, whereas a company with €20 billion revenues, of which 80% are from active PSS contracts, starts every year with €16 billion in the bank. To increase their share of recurring revenues, manufacturers are increasingly opting for PSSs. For example, BSH Hausgeräte heavily invests in PSSs (e.g., leasing home appliances (BlueMovement), renting home appliances (Papillon)) to increase their share of recurring revenues from 1% currently to 10% in 2026 (BSH Hausgeräte, 2021).
- *Reduce environmental impact:* Manufacturers pursue PSSs to mitigate the environmental impact of their products and services. PSSs have the potential to move business models from a linear model of take-make-dispose to a circular model of make-use-reuse-recycle (Frishammar & Parida, 2021). With PSSs, the manufacturer takes responsibility for the product lifecycle allowing products to be repaired, upgraded, refurbished, optimized, reused, or recycled. For example, Lenovo – a technology company and manufacturer of notebooks – addresses electronic waste with its PSS called “device as a service”. Lenovo takes responsibility for the entire device lifecycle, including collecting older notebooks, deleting customer data, reusing notebooks, and recycling parts (Lenovo, 2021).

Second, we identified strategic rationales that relate to a strong market position:

- *Unlock customer demand:* PSSs eliminate risk, friction, and high upfront customer investments. Thereby, they can unlock latent demand and attract completely new customer segments (cf. Gebauer, Haldimann, et al., 2017). For instance, when Bristol Siddeley launched its Viper aircraft engine, the company initially intended to *sell* the jet engine. But customer demand was low, despite the Viper being a superior jet engine at a fair price. Why? Because airlines faced high uncertainty regarding maintenance costs and spare parts availability. Bristol Siddeley unlocked customer demand by offering the aircraft engine, including maintenance costs, for a defined price per flying hour (Nomadic Learning, 2020).
- *Close the gap:* Manufacturers can offer PSSs to provide customers with new purchase options. For instance, in the automotive sector, customers traditionally

could choose to buy a car, go for a short-term rental (usually a couple of days or a few weeks), or take a multi-year leasing deal. Geely, a Chinese car manufacturer, launched Lynk to extend these customer choices and to close the gap between short-term rental and multi-year leasing. Lynk is a month-to-month subscription model where subscribers get exclusive access to an SUV (Lynk&Co, 2021).

- *Increase margins and share of wallet:* Research has shown that services usually offer significantly higher margins than products (see Korkeamäki et al., 2021; Oliva & Kallenberg, 2003). For example, the service margins are typically around 25% in the elevator industry, while elevator sales yield margins of only 5% to 10% (Shah, 2019). PSSs can serve as a means of capturing these high margin services by not only selling the product (e.g., the elevator) but by increasing the share of wallet through bundling the product with services (e.g., taking over elevator maintenance, operation, and optimization). Key players in the elevator industry launched PSS offerings – such as Otis with “Otis One”.
- *Win market shares:* Companies can offer PSSs to win or protect market shares from competitors (cf. Gebauer, Haldimann, et al., 2017). For example, Hilti offers its fleet management service to customers who have diverse tool fleets – e.g., customers using Hilti power tools and tools from Bosch, Makita, or any other power tool manufacturer. The aim is to replace power tools from competitors with Hilti tools over time in order to win market shares with existing customers. Similarly, PSSs can help companies maintain advantages over competitors in the aftermarket for services and spare parts since customers source service and spare parts directly from the PSS provider. Caterpillar, for instance, sells excavators, including services and spare parts, to secure and capture the value of the aftermarket business.
- *Establish strategic partnerships:* A PSS can help companies to establish strategic partnerships. PSSs often rely on a strong integration between customers and providers that depends upon complementary, well-intertwined competencies that are difficult for competitors to imitate. For example, BASF, a coatings supplier, offers automotive manufacturers a PSS (coating as a service) in which BASF assumes responsibility and operates the complete paint shop in the manufacturing plant. Rather than being a simple coating supplier, BASF collaborates closely with its automotive customers and is tightly integrated into their manufacturing processes as a strategic partner (Worm et al., 2017).

Third, we identified strategic rationales that relate to superior solutions:

- *Leverage premium product quality*: Manufacturers use PSSs as a means to monetize premium quality. Exceptionally durable products with low maintenance costs, for example, can become a decisive cost advantage for providing PSSs. For instance, Michelin's tires lead the industry in terms of total tire mileage, but they come with a price premium compared to Michelin's competitors. Customers might be unsure of whether paying this premium pays off. With Michelin's pay-per-kilometer offering, such justifications are obsolete since customers pay a fixed price regardless of how long the tires last. The premium quality (e.g., superior total tire mileage) is turned into a sustainable cost advantage for Michelin (Renault et al., 2010).
- *Avoid the commodity trap*: Companies leverage PSSs to avoid the commodity trap. With a PSS, companies can create a competitive advantage even in commodity markets where they have few opportunities to differentiate their offerings from established product and service offerings. For instance, Signify – an LED light manufacturer – faces commoditization as their LED lights are essentially deemed identical to those offered by competing companies. Signify avoids the commoditization trap by offering “light as a service”, a fully managed light offering with guaranteed energy savings (Signify, 2021). Thereby the competitive advantage is shifted away from low prices to improving customers' energy costs.
- *Enable full data access*: As PSS providers retain product ownership, they have direct access to all product-generated data. This is seldomly the case when products belong to customers as the customers then also possess the data. Full data access allows manufacturers to gather insights on the product state, how customers use products, and especially how the product performs. These insights can be leveraged for new (digital) services and for improving internal processes such as equipment development, product, sales, or service (see Chapter 2.1.2). For example, the previously outlined PSS from Heidelberger Druckmaschinen generates data streams from the printing machines. Heidelberger leverages these data streams for new applications such as data-driven sales – i.e., new offerings are targeted based on the actual usage profile of running customer machines (Bilgeri et al., 2019).

5.3.3 PSS Value Creation Patterns

The previous chapters discussed the value of PSSs for customers (value proposition) and the providing company (value capture). This chapter is devoted to how companies

can create and deliver PSSs – i.e., the value creation element of a business model (Clauss, 2017). Our analysis revealed 11 management tactic patterns that represent “best practices” for addressing common value creation challenges. Furthermore, we identified 9 patterns that outline technology use cases around the IoT to create and deliver PSSs effectively.

Management tactic patterns

The 11 management tactic patterns that we identified represent “best practices” for tackling common challenges when creating and delivering PSSs. See Table 12 for an overview of the identified patterns regarding: (1) where to start with PSSs, (2) how to market PSSs, and (3) how to run and scale PSSs.

Categories	#	Patterns	Examples
Where to start with PSSs?	1	Go for the recurring payers	Liebherr, Packsize, Waterlogic
	2	Build upon provable ROI cases	Komatsu Forest, Signify, Urban Volt
	3	Leverage past customer requests	Hilti, Michelin
	4	Take the As	Bühler, Hitachi Rail, Philips Medical Capital
How to market PSSs?	5	Enter with a trojan horse	Audi, BMW, DMG Mori
	6	Go freemium	365FarmNet, Bühler, Fitbit
	7	Take customers on a service journey	Caterpillar, Pay Per Wash, WeWash
How to run and scale PSSs?	8	Swallow the fish	Adobe, Commerzbank, Trumpf
	9	Enforce “be gentle it’s a rental”	Konecranes, PubliBike, Share Now
	10	Let the customer do the work	DMG Mori, DriveNow, Xerox
	11	Increase stickiness	Microsoft, NavVis, Würth

* For every pattern three exemplary examples are provided. Note that multiple patterns may apply to a single PSS case and are not listed here in a comprehensive manner.

Table 12: Management tactic patterns

First, we identified management tactics for where to start with PSSs. The research revealed that companies:

- *Go for the recurring payers*: We identified that companies actively target recurring payers with their PSS offerings. Why? Because recurring payers are a promising market segment as they are already used to making regular payments. These customers do not have to adopt a new payment paradigm (from one-time to

recurring) and can easily compare the recurring costs (with and without PSSs). Take Waterlogic, a manufacturer of water dispensers, as an example. They recognized that offices already have a monthly expense for their monthly water bottle delivery. Instead of selling them their water dispensers, Waterlogic targets these offices with its water dispenser as a service offering where the customer pays a monthly fee for the water dispensers. The offices still have a monthly expense for water and can easily compare the monthly costs for water dispensers versus the bottle delivery.

- *Build upon provable ROI cases*: We identified that companies target those customers to whom they can prove the return on investment (ROI) of PSSs. For instance, the LED lights of Signify impact customers' energy consumption. Hence, Signify ties the value proposition of their PSS (called light as a service) to this key performance indicator by guaranteeing certain levels of energy savings (Signify, 2021). They ultimately achieve a “no brainer” for their customers to opt for the light as a service offering. Unfortunately, it is not always easy to realize an objective and transparent with-without comparison.
- *Leverage past customer requests*: Successful PSS offerings, such as Michelin's pay-per-kilometer tire solution or Hilti's fleet management, emerged because customers demanded it. In 1999 Batigroup, back then Switzerland's largest construction company and a strategically important customer of Hilti, requested a fleet management solution. Hilti agreed in order to keep an important customer and soon realized that they could scale the fleet management business model beyond one specific customer (Casadesus-Masanell et al., 2017). Hence, customer requests for PSSs or PSS-like offerings can represent a great starting point for PSSs. They potentially indicate a customer need that several customers might have, and meeting these customer requests can generate learnings for developing corresponding PSSs.
- *Take the As*: We identified that companies often start with a handful of pilot customers, preferably with so-called A-customers. These, customers handle products carefully (i.e., induce minimal recurring costs for the PSS provider), on the one hand, and, on the other hand, tolerate potential issues that might arise when companies are still figuring out the art and science of PSSs. Analyzed companies leveraged long-lasting relationships with customers to identify and win A-customers for their PSSs.

Second, we found patterns for how to market PSSs:

- *Enter with a trojan horse*: This pattern describes the tactic of letting PSSs, specifically hardware add-ons and software add-ons, sell themselves. Companies

equip products with add-ons that the customers have not ordered (i.e., a trojan horse). The add-ons are then unlocked free of charge for a trial period. The premise is to get customers used to the add-ons and the value they add in order to charge a usage fee after the trial period for the add-ons has ended. For example, Audi – an automotive manufacturer - is applying this tactic for its LED-Matrix-Light. Audi equips its cars with both the standard light as well as with the advanced LED-Matrix-Light. Car customers can try out this advanced lighting feature during a free trial period, after which they must subscribe to continue using the feature (Vetter, 2019).

- *Go freemium*: The go freemium pattern refers to providing basic features free of charge, while customers need to pay for the premium features that extend the functionalities of the free version (cf. Kumar, 2014). Companies use the free basic features to attract a large customer base and ultimately upgrade them to premium features and services. The challenge is to generate enough value with the free version while keeping the value gap between free and premium large enough. For example, Fitbit – a manufacturer of wearable fitness trackers – applies this tactic. While Fitbit’s fitness trackers come with a free app that provides basic health and fitness stats, customers can only access the premium applications (e.g., personalized workouts, comprehensive health analysis stats) by paying a monthly subscription fee (Fitbit, 2021).
- *Take customers on a service journey*: Research points out that the transition from products to PSSs is a big leap for customers as it often requires them to alter their consuming behavior (see Mont, 2002a, 2002b). This pattern captures the tactic manufacturers use to minimize the necessary changes in consuming behavior by offering consecutive PSSs that guide customers step-by-step from buying products to PSSs. For instance, Caterpillar – a heavy equipment manufacturer – provides five levels of PSSs. Caterpillar provides basic connectivity services with level 1 “access”, such as remote monitoring and asset management software. In contrast, level 5 “manage” is a comprehensive PSS where Caterpillar supplies the equipment so that customers can focus completely on their core business by using Caterpillar equipment (Caterpillar, 2021).

Third, we identified four patterns on how to run and scale PSSs:

- *Swallow the fish*: Transitioning towards PSSs can cause a financial gap where costs exceed revenues, known as “the fish” (Lah & Wood, 2016). A financial gap arises as large lump sums (one-time, up-front product revenues) are replaced by smaller

recurring PSS fees, as transition costs are simultaneously incurred. However, companies actively manage the financial gap to minimize the financial exposure, colloquially known as “swallowing the fish”. For example, Audi minimized the financial gap by launching a PSS for single car features (e.g., matrix LED headlights) rather than for the whole car (Vetter, 2019). Similarly, Hilti managed the period where costs exceeded revenues by limiting its PSS to a handful of customers and only offering it to new customers when profitability has been achieved (Casadesus-Masanell et al., 2017). Trumpf – an industrial manufacturing company – joined forces with Munich Re to offer their PSS called “pay-per-part”. As a reinsurance company, Munich Re provides the necessary financial means and risk management competencies to cope with the financial consequences of PSSs (Trumpf, 2020).

- *Enforce “be gentle it’s a rental”*: With PSSs, manufacturers often assume responsibility for the products and thus also costs such as maintenance and repairs. Moral hazards, however, can cause higher costs than expected (Ulaga & Reinartz, 2011). Take the case of BMW and Daimler’s car-sharing service Share Now, which had higher costs than anticipated. True to the saying “don’t be gentle it’s a rental”, reckless driving by customers led to considerable maintenance and repair costs. To counteract, Share Now implemented a driver monitoring system and extended its terms and conditions to penalize reckless driving (Share Now GmbH, 2021b). Generally speaking, monitoring customer usage and defining misuse in the general terms and conditions allow PSS providers to cope with moral hazards.
- *Let the customer do the work*: Considerable costs can accrue for the PSS provider if service staff frequently needs to travel to distant customer sites. To minimize such costly work, PSS providers incentivize and empower their customers to do work that would otherwise have to be done by the PSS provider (cf. Fleisch et al., 2014). Referring back to BMW and Daimler’s car sharing service Share Now, customers are given a 5 Euro credit if they fully refuel or recharge a car (Share Now GmbH, 2021a). This financial incentive is a simple and effective way to encourage customers to refuel or recharge cars. If customers are not refueling or recharging cars, Share Now has to send staff to refuel and recharge the car fleet.
- *Increase stickiness*: PSSs usually only pay off over time, as small recurring fees are collected over time in contrast to one-time up-front revenues when selling products. Hence, customer retention becomes a success factor and PSS providers strive to increase the lock-in or “stickiness” of their PSSs. For example, we observed that companies sought to integrate PSSs into customers’ enterprise resource planning

systems to increase switching costs – i.e., generate a lock-in and raise the likelihood of customers sticking to the PSSs.

Enabling technology patterns

In addition to the management tactic patterns, we identified 9 enabling technology patterns. These represent technology use cases around the IoT that manufacturers use to deliver PSSs effectively. We identified use cases for (1) managing the product lifecycle, (2) improving product operations, and (3) running and developing PSSs (see Table 13).

Categories	#	Patterns	Examples*
Managing the product lifecycle	1	Remote monitoring	Nordex, Rolls-Royce, WeWash
	2	Remote access	Carl Zeiss, Trumpf, Valmet
	3	Remote support	Beumer Group, DMG Mori, Kone
	4	Predictive maintenance	Continental, Liebherr, Michelin
	5	Over the air updates & upgrades	Audi, Bosch Rexroth, Porsche
Improving product operations	6	Automatic operation	BOGE, Kaeser, Signify
	7	Automatic replenishment	Philips, Viessmann, Würth
Running and developing PSSs	8	Order-to-cash management	Briggs & Stratton, Konecranes, Schneider Electric
	9	Continuous improvement	KleverKey, Konecranes, Tesla

* For every pattern three exemplary examples are provided. Note that multiple patterns may apply to a single PSS case and are not listed here in a comprehensive manner.

Table 13: Enabling technology patterns

First, we identified patterns that represent enabling technologies to manage the product lifecycle:

- *Remote monitoring*: Monitoring products throughout their lifecycle is essential to ensure seamless product operations. In the past, monitoring required the presence of technicians on site. With the rise of the IoT, more and more products are connected to the internet and equipped with sensors to monitor products automatically, diagnose problems remotely, and request attention from technicians. For example, remote monitoring enables the previously outlined “power-by-the-hour” offering of Rolls-Royce by allowing them to monitor thousands of jet engines simultaneously. By monitoring jet engine data, Rolls-Royce ensures that parts and personnel are available for impending maintenance and repairs when they are needed (Smith, 2013).

- *Remote access*: While remote monitoring allows companies to monitor and read error codes from products centrally, companies use remote access to solve certain issues immediately. Remote access allows remote control of the products, such as installing new software packages, adjusting parameters, or restarting a machine. Remote access eliminates or reduces the need to send a technician on-site to resolve certain issues. For example, Trumpf uses remote access to minimize downtime. As soon as the operator of the laser cutting machine grants clearance, Trumpf service technicians can remotely access the machine control system to identify errors and immediately take corrective measures to get the machines up and running again (Trumpf, n.d.).
- *Remote support*: The remote support pattern refers to using technology (e.g., virtual reality glasses) to help customers remotely fix problems by themselves without sending service technicians on-site. For example, DMG Mori – a manufacturer of cutting machine tools and CNC machines – equips customers of their PSS “Pay with Zero Risk” with cameras. With these cameras, customers can provide DMG service technicians with visual images of the problems, increasing the likelihood of solving them remotely (DMG Mori, 2021).
- *Predictive maintenance*: Manufacturers leverage the data from connected products and advances in data analytics to identify patterns in product data that indicate product issues before they materialize. This allows them to carry out maintenance work when needed rather than according to a pre-determined schedule. The objective is to reduce costs by performing maintenance and repairs only when they are required. For example, Michelin utilizes tire data (e.g., tire pressure and temperature) for predictive maintenance algorithms that predict flat tires to ensure a profitable “pay-per-mile” offering. Predictive maintenance allows Michelin to optimize when they replace tires – i.e., as late as possible to maximize their mileage, yet early enough to prevent customer downtimes due to flat tires (Gebauer, Fleisch, et al., 2020).
- *Over the air updates & upgrades*: This pattern refers to the technology use case of leveraging product connectivity to provide software updates and upgrades over the air. Providing updates and upgrades over the air saves costs and is convenient for customers (cf. Fleisch et al., 2014). For example, when customers subscribe to Audi’s LED matrix light, the feature is simultaneously unlocked through Audi over the air. Without this technology, the car would have to be taken to a workshop to unlock the LED matrix light manually.

Second, we identified patterns that represent technologies for improving product operation through automation:

- *Automatic operation:* Manufacturers leverage the possibility of automizing the operation of products to minimize human errors. Why? Humans make mistakes – including the customer when using products provided through PSSs. For instance, Signify guarantees energy savings with their PSS (light as a service) – but if customers forget to switch off the lights, the promised energy savings are harder to achieve. Thus, Signify leverages sensor technology to automate switching lights on and off to ensure that lights are only on when needed.
- *Automatic replenishment:* Keeping consumable stock low is vital to minimizing inventory costs. Running out of consumables, however, can have dramatic consequences for production. In the past, manual stocktaking was necessary to determine inventory levels. Today's sensor technology allows automating these processes. A growing number of PSS providers that offer comprehensive automatic replenishment solutions exploit these opportunities. For example, Viessmann – a heating systems manufacturer – offers customers heat as a service. With this PSS, Viessmann provides heating systems, takes care of maintenance and repairs, as well as the ordering of heating fuel. To do so, Viessmann relies on sensors that trigger an automatic replenishment if the heating fuel runs low (cf. Fleisch et al., 2014).

Third, we identified enabling technology patterns for running and developing PSSs:

- *Order-to-cash management:* The existing order-to-cash process and the underlying enterprise resource planning (ERP) system used by manufacturers is usually designed for selling products – delivering value-in-exchange resulting in single upfront payments. However, with PSSs, manufacturers deliver value-in-use where customers pay recurring fees. For instance, Schneider Electric – an electrical equipment manufacturer – is transitioning towards PSSs to deliver value-in-use. Their existing ERP system could not handle the vast amount of journal entries necessary to bill customers on a recurring basis. Hence, the order-to-cash process and the underlying ERP systems often have to be adapted or dedicated solutions must be designed for PSSs. Schneider Electric opted for a dedicated PSS solution providing them with the necessary order-to-cash capabilities (Zuora, 2021).
- *Continuous improvement:* With PSSs, manufacturers often have access to data generated by the products. This includes, for instance, data on product state, product performance, wear and tear, and failure information. These data points serve

manufacturers as invaluable inputs to continuously improve existing products and services as well as internal processes (cf. Bilgeri et al., 2019). For example, Konecranes – an industrial crane manufacturer – uses field data from cranes to build comprehensive digital twins (e.g., computer models of the cranes). These digital twins allow engineers to test and evaluate new crane features more quickly and cheaply without the need for physical prototypes.

5.4 Discussion

5.4.1 Summary

Manufacturers often struggle to design business models for PSSs (Christensen et al., 2016; Gebauer et al., 2005; Gebauer, Fleisch, et al., 2020). Various authors have pointed out that research lacks practitioner-oriented tools that can support the design of PSS business models (Adrodegari & Saccani, 2017; Pirola et al., 2020). To contribute to addressing this research gap, this chapter's research has sought to shed light on business model patterns that can support the design of PSS business models. Thereby, patterns represent reusable design knowledge – i.e., aggregated and abstract building blocks of existing PSS business models (Amshoff et al., 2015).

By systematically analyzing the business model of 199 existing PSS cases through a qualitative multi-case study approach, we have identified 58 patterns. Figure 13 summarizes the 58 identified patterns. The figure also highlights which patterns apply to Hilti's fleet management business model. We identified patterns for the value proposition, value capture, and value creation elements of a business model.

Value proposition		Value capture		Value creation
Customer pain and gain patterns	PSS service patterns	Revenue model patterns	Strategic rationale patterns	Management tactic patterns
		Enabling technology patterns		
1. Get OPEX and not CAPEX	1. Finance	1. Subscription	1. Stabilize revenues	1. Remote monitoring
2. Align revenue and cost	2. Own	2. Pay-per-use	2. Reduce environmental impact	2. Remote access
3. Address shortage of skilled workers	3. Commission & decommission	3. Pay-per-outcome	3. Unlock customer demand	3. Remote support
4. Decrease TCO	4. Monitor	4. Pay-per-performance	4. Close the gap	4. Predictive maintenance
5. Align incentives	5. Repair & maintain	5. Pay-per-consumable	5. Increase margins and share of wallet	5. Over the air updates & upgrades
6. Be more flexible	6. Update & upgrade	6. Minimum usage	6. Win market shares	6. Automatic operation
7. Improve OEE	7. Operate	7. Minimum contract term	7. Establish strategic partnerships	7. Automatic replenishment
8. Reduce operational risk	8. Supply	8. Enable exit	8. Leverage premium product quality	8. Order-to-cash management
9. Reduce business risk	9. Optimize		9. Avoid the commodity trap	9. Continuous improvement
	10. Take operational risk		10. Enable full data access	
	11. Take business risk			

Figure 13: 58 PSS patterns (patterns marked in gray apply to Hilti’s fleet management)

For the value proposition, the findings revealed stimulating insights regarding the customer value of PSSs. We identified customer needs (*customer gain and pain patterns*) that PSSs can address along the customer journey of using products – i.e., financing, managing the product lifecycle, operating the product, and de-risking. In addition, we also identified the services bundled with products to do so (*PSS service patterns*).

We identified *revenue model patterns* and *strategic rationale patterns* regarding the value capture element. The revenue model patterns reveal revenue models used to monetize PSSs and highlight commonly used “restrictions” or “add-ons” in the form of minimum contract terms to limit the risk transfer of these revenue models (see also Chapter 4.4.2). In addition to the revenue model patterns, our findings regarding strategic rationales provide insights into why PSSs can generate value for a manufacturer.

Lastly, we identified patterns for the value creation element. On the one hand, the *management tactic patterns* reveal best practices for how to deliver PSSs regarding (1) where to start with PSSs, (2) how to market PSSs, and (3) how to run and scale PSSs. On the other hand, the *enabling technology patterns* represent identified technology use cases around the IoT that manufacturers use to deliver PSSs.

5.4.2 Practical and Theoretical Implications

Contributions to practice

This study makes three major contributions to practice. First, the 58 patterns we identified can support the ideation phase of designing PSS business models by providing building blocks companies can reuse (cf. Amshoff et al., 2015; Ebel et al., 2021). In the words of Gassmann et al. (2020, p. 20): “[...] patterns are the LEGO bricks needed to innovate existing or develop new business models [...]”. By suggesting these patterns for PSS business models, we concur with research arguing that new business models do not need to be built from scratch. The design of business models can be more efficient and effective when existing knowledge is recombined (Amshoff et al., 2015; Gassmann et al., 2020). Practitioners can reuse, reassemble, and recombine the identified patterns (i.e., building blocks) of existing PSS business models to design their PSS business models more efficiently and effectively (cf. Abdelkafi et al., 2013).

Second, the insights can inspire practitioners to think in terms of customer outcomes. More precisely, to consider customer needs along the entire customer journey, from financing to managing the product lifecycle, and from operating the product to de-risking. Too often, practitioners limit their understanding of PSSs to providing a “get OPEX and not CAPEX” solution for customers (cf. Monitor Deloitte, 2021). This narrow view can lead to PSSs that do not address truly pressing customer needs (cf. Gebauer, Fleisch, et al., 2020; Grove et al., 2018; Reim et al., 2015). Practitioners should be aware that “get OPEX and not CAPEX” is just one of many customer pains and gains that PSSs can address and that “get OPEX and not CAPEX” is often only a secondary need of customers (cf. Chapter 4.3.1). PSSs are about aligning customer revenue and costs, overcoming customer skill shortages, decreasing customers’ TCO, aligning incentives between the PSS provider and customers, customers being more flexible, increasing overall equipment effectiveness, and reducing operational and business risks for customers. In addition, it should be pointed out that providing “get OPEX and not CAPEX” is becoming increasingly difficult because of new accounting regulations (PwC, 2021). The presented customer gain and pain patterns outline the customer needs addressed by the analyzed PSSs and serve practitioners as a starting point to design compelling value propositions that address customer needs.

Third, the study revealed insights into the technology use cases around the IoT to deliver PSSs. The findings confirm that IoT is a key enabler for delivering PSSs. However, it is interesting that rather simple IoT use cases (e.g., remote monitoring, remote support, or automatic replenishment) can effectively enable PSSs. Only a handful of the PSSs analyzed rely on the prominently discussed “blockbuster” IoT use case of predictive maintenance. Practitioners should be aware of this as, all too often, IoT is perceived as nearly synonymous with predictive maintenance in the context of PSSs (Bilgeri et al., 2019).

Contributions to theory

In addition to the contributions to practice, the study makes three contributions to theory. First and foremost, the customer pains and gains we presented provide a more nuanced understanding of the customer value of PSSs. Existing theory remains rather abstract and superficial, characterizing the value for customers. The understanding is limited to reduced initial investments, minimized operating costs, and reduced risks (Adrodegari & Saccani, 2017; Adrodegari et al., 2017; Barquet et al., 2013; Lee et al., 2015). This

unclear understanding is also reflected in the fact that many companies struggle to design customer-centric PSSs and to articulate their benefits to customers (Grove et al., 2018; Grubic & Peppard, 2016). An improved understanding of the customer value of PSSs will enable future research on overcoming these barriers.

Second, literature provides tactics such as “swallow the fish” (Lah & Wood, 2016) or “go freemium” (Kumar, 2014) that support companies in delivering and implementing PSSs. However, scholars have highlighted that research providing knowledge on how to deliver PSSs is still scarce (Reim et al., 2015). Through our study of 199 existing PSSs, we are able to provide new tactics for how to deliver PSSs. For example, we present tactics for how companies can deal with moral hazards (see the pattern enforce “be gentle it’s a rental”). This study thus contributes to the body of literature on how to deliver PSSs.

Third, our findings offer a more refined view of PSS business models. Although the business model concept is noted in the literature as being useful for implementing PSSs, research characterizing PSS business models is still nascent (Reim et al., 2015). The extant research (e.g., Barquet et al., 2013; Ferreira et al., 2013) is only moderately comprehensive concerning the business model elements investigated, and their characterization often lacks detail (Adrodegari & Saccani, 2017). This study’s insights contribute to this emergent research topic by identifying 58 business model patterns of PSSs. The identified patterns enable a more fine-grained understanding of the characteristics and configurations of the value proposition, value creation, and value capture elements. Of course, the 58 patterns are not exhaustive (e.g., regarding resources and capabilities needed). However, our findings should stimulate further research on identifying and extending the characteristics of PSS business models.

5.4.3 Limitations

The findings presented in this chapter should be viewed in light of their limitations. First, since we relied on a qualitative research approach, the usual limitations about generalizability apply (Saunders et al., 2019). Second, limitations arise due to the underlying sample of this study: with a total of 199 PSS cases from various industries, the sample represents a rather small empirical data sample compared to the total population of PSSs offered by manufacturers. Furthermore, while we sought to capture patterns associated with sustainable PSSs to identify proven building blocks of PSS

business models, the study did not measure how sustainable the analyzed PSSs are – i.e., to what degree the PSS contributes to the triple bottom line of the company – since this information is mostly inaccessible. A third limitation refers to changing PSSs. We collected the data for crafting the PSS business model descriptions in 2020 and 2021 and derived the patterns based on this data. However, the analyzed PSSs are likely to change (e.g., Hilti's PSS changed over time – see Casadesus-Masanell et al. (2017)). Thus, the PSS cases and the identified patterns should be considered snapshots of a particular point in time.

Chapter 6

Managing PSSs – A KPI Set for PSSs⁹

6.1 Introduction

PSSs have gained considerable momentum among manufacturers. On the one hand, the emerging IoT with its connected products is paving the way for PSSs (Bertini & Koenigsberg, 2020a; Lerch & Gotsch, 2015). On the other hand, simply selling products is often no longer sufficient to maintain a competitive advantage (Bertini & Koenigsberg, 2020a; Connerty et al., 2016). The fact that companies see great potential in PSSs can be seen in the targets that companies communicate:

- Bosch plans to generate 10% of its revenue with PSSs in 2026, up from 1% today (BSH Hausgeräte, 2021).
- Volkswagen aims to generate 20% of total revenue from PSSs (e.g., car subscriptions) in 2030 (Volkswagen, 2021).

Despite high expectations and high targets, PSSs are not a given, and it's a long way there (Gebauer, Fleisch, et al., 2020; Wortmann et al., 2019).

As with any business initiative, performance measurement systems (PMS) are an important key success factor (Neely, 2005; Neely et al., 1995, 2005). A PMS captures and compiles a set of key performance indicators (KPIs) that companies monitor to improve future performance (Bititci et al., 2012; Neely et al., 1995). These systems help companies mediate a strategy, guide middle management and successive management levels, and facilitate a control and correction function by reporting current performance

⁹ Parts of this chapter were initially published or submitted for publication in the context of the following manuscripts: Lamprecht et al. (2022a) and Lamprecht et al. (2022b).

and comparing it to desired performance levels (Davis & Albright, 2004; Franco-Santos et al., 2007). Most popular has been the balanced scorecard (BSC). The BSC balances financial and operational metrics, resulting in a framework consisting of four perspectives (financial, customer, internal, and learning) and corresponding KPIs to provide a multi-dimensional company assessment (Kaplan & Norton, 1992, 1993). However, both researchers and practitioners highlight that existing PMS in manufacturing companies are not suitable for managing the emerging IoT-enabled PSS business (Nudurupati et al., 2011; Nudurupati et al., 2016; Raskino, 2017; Wolcott, 2016). On the one hand, existing PMS rarely capture important KPIs for PSSs (e.g., recurring revenue or usage metrics) (Momsen, 2019; Thaler & Pierer von Esch, 2020). On the other hand, existing PMS do not capture the business logic of PSSs in the IoT era (Baines & Lightfoot, 2013a). This logic is essentially about getting products connected, receiving data about product usage, and then leveraging these data for new (digital) services in PSSs to solve customer problems and, ultimately, getting customers to pay for these offerings on a recurring basis (Lerch & Gotsch, 2015; Rymaszewska et al., 2017).

Without an adequate PMS that can gauge the progress in the PSS transformation, companies investing in PSSs can only hope that these investments will capitalize (Harvard Business Review Analytic Services, 2019; Melnyk et al., 2013). Worse, PMS that are not aligned with the business logic of PSSs are dysfunctional, mislead companies, and cause managers to drive the wrong actions (Allmendinger & Lombreglia, 2005; Wolcott, 2016).

Research has already put forward individual KPIs to assess the performance of individual aspects of manufactures' transition towards PSSs. Scholars have suggested KPIs such as recurring revenue (Hui, 2014; Tzuo & Weisert, 2018), usage metrics (Heinis et al., 2018), customer lifetime value (Momsen, 2019), and conversion rate (Thaler & Pierer von Esch, 2020). Although these KPIs are important, individual KPIs only provide partial insight for managing the multifaceted and complex transition towards PSSs (cf. Bititci et al., 2012; Neely et al., 1995). Hence, a research gap exists regarding the ability to manage a manufacturer's transitions toward PSSs. To minimize this research gap, this chapter aims to develop a KPI set for PSSs that companies can use and adapt to manage their PSS transformation. The research addresses the following research question:

SRQ 3: *How can the performance of PSSs be measured to manage them effectively?*

We applied a qualitative case study approach to answer the research question. In total, we studied the PSS efforts of 31 companies via 61 interviews and workshops, which resulted in three key insights into measuring PSSs: i) measurement traps when steering the PSS business, ii) a KPI set for the PSS business, and iii) recommendations for implementing the KPI set. The KPI set can be interpreted as a set of recommended KPIs that practitioners can adapt to measure and manage their PSS business.

6.2 Methodology

We relied on qualitative research to gain meaningful insights about PMS as a complex social process (Eisenhardt & Graebner, 2007). We divided the research process into an explorative study and an in-depth study. The explorative study aimed to gain insight into challenges and traps regarding current PMS, and to identify relevant KPIs for PSSs. The in-depth study was set up to deepen the interim insights into the KPI set and its implementation. We sampled until we reached theoretical saturation for the KPI set – i.e., until a recurring pattern for a KPI set emerged from the explorative study and the in-depth case study (Strauss & Corbin, 1990).

Explorative study

Twenty-six companies participated in our explorative study. We collected data from these companies by conducting 24 interviews and 5 workshops with 110 participants (see Table 14 for an overview). We analyzed the interview transcripts and workshop protocols with a content analysis procedure that yielded three common measurement traps and an initial set of 35 possible KPIs to steer the PSS business (see Table 15).

#	Case (anonymized)	Revenue	Type	Roles (anonymized)
1	Surveying and Mapping Inc.	31 million USD	IN	Chief Executive Officer
2	Yarn Processing Equipment Inc.	1.1 billion EUR	IN	VP Technology Center
3	Technology Consultancy	7.5 billion USD	IN IN	Senior Manager Senior Manager IoT
4	Technology and Software Inc.	110 billion USD	IN	Group Finance Lead
5	Conglomerate A Inc.	83 billion EUR	IN	Head of Platform
6	Filtration System Inc.	3.9 billion EUR	IN	Chief Technology Officer
7	Digital Platform Inc.	5 million USD	IN	Director
8	Beverage Inc.	32 billion USD	IN	Board Member
9	Surveying and Engineering Inc.	3.8 billion EUR	IN	Head of IoT
10	Cloud Computing Inc.	230 billion USD	IN	Head of Industrial Software
11	Industrial Machine Inc.	3.6 billion EUR	IN	Assistant to the Board
12	Industrial Automation Inc.	4.1 billion CHF	IN	Industry 4.0 Architect
13	Heavy Farming Equipment Inc.	38 billion USD	WS	30 Participants
14	Steel Production Inc.	41 billion EUR	WS	29 Participants
15	Optical System Inc.	5.8 billion EUR	WS WS	7 Participants 7 Participants
16	Industrial Equipment Inc.	9.8 billion EUR	IN	Head of eBusiness
17	Private Equity Inc.	0.9 billion EUR	IN	Senior Investment Director
18	Hydraulic Lifting Inc.	1.1 billion EUR	IN	Head of IoT and Data Science
19	Conglomerate B Inc.	77 billion EUR	IN	CTO IoT Platform
20	Food Processing Inc.	3.3 billion CHF	WS IN	37 Participants Digital Service Manager
21	Home Appliance CH Inc.	1.1 billion CHF	IN	Chief Technology Officer
22	Energy Systems Inc	25 billion Euro	IN	Head of BD
23	Farming Equipment Inc.	3.8 billion EUR	IN	Head of Platform Business
24	Automation Equipment Inc.	86 billion EUR	IN	Sales Manager
25	Communication Equipment Inc.	50 billion USD	IN	Digital Officer
26	Building Technology Inc.	35 billion USD	IN	IoT Expert

Legend: WS = Workshop, IN = Interview, BD = Business Development, CTO = Chief Technology Officer, VP = Vice President

Table 14: Explorative interviews

#	PSS KPIs
1	Number/ratio of products sold that are connectable
2	Number/ratio of products sold that are connected
3	Number/ratio of products connected before and after warranty
4	Number/ratio of products that are connected with registered users (billable users)
5	Number/ratio of registered users
6	Number of new registered users
7	Number of app downloads
8	Daily active users (DAU)
9	Monthly active users (MAU)
10	DAU/MAU
11	New service subscribers
12	Total service subscribers
13	Customer lifetime value
14	Churn rate
15	Net promoter score (NPS)
16	App ratings
17	Conversion rate (from free to premium)
18	Conversion rate (from products to service)
19	Service usage rate
20	Number of employees working on PSS projects
21	Number of open IoT jobs
22	Uptime
23	First time fix rate
24	Switching costs
25	Number of ecosystem partners
26	Revenue generated with ecosystem partners
27	Number of ecosystem interactions
28	New ecosystem users/products
29	PSS revenue
30	PSS revenue profitability
31	Share of PSS revenue (PSS revenue/total revenue)
32	Monthly recurring revenue (MRR)
33	Annual recurring revenue (ARR)
34	Average monthly PSS revenue per user
35	Degree of fulfillment PSS business case

Table 15: Initial set of PSS KPIs

In-depth study

Five purposively selected companies participated in our in-depth study. We selected relevant companies based on three criteria: (1) Is the company actively pursuing PSSs? (2) Does the company operate in an important IoT sector (e.g., mobility, industry, or building)? (3) Does the company provide access to necessary key informants?

For the in-depth case study, we opted for an inductive case study design (Eisenhardt, 1989) with a set of semi-structured interviews lasting 1–2 hours as a primary source of data for each of the five case companies. Altogether, we conducted 32 interviews with informants from various relevant functions and hierarchical levels across the 5 cases. We strived to include interviewees from various functions and hierarchical levels as the design and use of PMS pertain to all functional areas and across hierarchical levels of a company (see Neely, 2005). Hence, we interviewed business managers (e.g., chief digital officers, presidents, and vice presidents) to understand the necessary alignments between PSS strategy and performance measures. We interviewed finance and controlling experts to grasp the financial perspective. The data collection ended with an interview of a management board member to gain a perspective of the company as a whole (see Table 16). The interview guidelines were structured in three parts: i) general experience with the 35 possible KPIs revealed in the explorative study, ii) relevant KPIs for turning connected products into PSSs, and iii) obstacles during implementation of the KPI set.

We then compiled the multiple interviews per studied company into a case study description about KPIs for managing PSSs business. Thereby, we manually coded the verbatim transcribed interviews by applying open coding (Flick, 1998) to identify the recommended KPIs and traps and how to avoid these traps. In a further step, we grouped similar codes using axial coding to determine more abstract categories (Strauss & Corbin, 1990). Accordingly, these case studies were analyzed through a content analysis procedure starting with a within-case analysis and then a cross-case analysis. This procedure first identified the relationships between KPIs and then categorized these measures into more abstract categories. For example, the KPIs *Net promoter score*, *Service usage rate*, *Conversion rate* and *Churn rate* were categorized into the more abstract perspective *Services adopted?* This content analysis led to a KPI set combining four perspectives with multiple indicators.

Company (anonymized)	Company size	#	Date	Roles (anonymized)
Car Parts and Service Inc. A world-leading automotive supplier, with activities reaching from powertrain peripherals, injection technology, and electrified mobility to connectivity enabled mobility and vehicle services. With a strategic priority on providing smart mobility solutions through seamlessly connecting users and vehicles.	Revenue: 48 billion EUR Employees: 235'000	1	Mar 2019	Executive Vice President
		2	Mar 2019	President
		3	Mar 2019	Chief Financial Officer
		4	Apr 2019	Chief Digital Officer
		5	Apr 2019	Head Portfolio Management
		6	Aug 2019	Executive Vice President
		7	Sep 2019	Management Board Member
		8	Nov 2019	Management Board Member
Hydraulic System Inc. A global specialist for industry automation. Amongst other things, their portfolio includes hydraulic and electric solutions. In particular, they prioritize software solutions and their interfaces to the internet of things for industry 4.0 use cases.	Revenue: 7.5 billion EUR Employees: 40'000	9	Mar 2019	President
		10	Apr 2019	Vice President Engineering
		11	July 2019	Industry 4.0 Expert
		12	Aug 2019	Industry 4.0 Technical Sales
		13	Nov 2019	Management Board Member
Home Appliance Inc. A world-leading company for consumer goods. The portfolio covers household appliances, ranging from refrigerators to coffee machines. The company leverages IoT technology for smart home applications and services.	Revenue: 18 billion EUR Employees: 79'000	14	Mar 2019	Head Digital Transformation
		15	Mar 2019	Owner Digital Offerings; Owner Digital Business
		16	May 2019	Chief Digital Officer
		17	Aug 2019	CEO IoT Services
		18	Nov 2019	Management Board Member
Heating and Security System Inc. A leading provider of security, communications, and energy management solutions for commercial and industrial buildings. Including smart home solutions (web-enabled and app-controlled) for heating and air conditioning, as well as room monitoring through surveillance cameras, motion, and fire detectors.	Revenue: 5.6 billion EUR Employees: 33'000	19	Mar 2019	VP Integrator Business Europe
		20	Apr 2019	Director Business Strategy
		21	Apr 2019	Director BD
		22	May 2019	Director Controlling
		23	May 2019	Senior Vice President
		24	May 2019	Key Account Manager
		25	July 2019	Executive Assistant; System Architect
		26	Nov 2019	Management Board Member
Machine Manufacturer Inc. A leading global industrial machining solutions provider. With specialization in the safe transpiration of liquids and gases, high-precision manufacturing processes, and lightweight casting elements.	Revenue: 4.1 billion CHF Employees: 15'000	27	Apr 2019	President
		28	Apr 2019	Sales Manager
		29	Apr 2019	Strategic Marketing
		30	Apr 2019	Chief Digital Officer
		31	Apr 2019	Digital Service Designer
		32	May 2019	Management Board Member

Legend: VP = Vice President, BD = Business Development, CEO = Chief Executive Officer

Table 16: In-depth case interviews

To observe how the KPI set functions in day-to-day work, we also accompanied the implementation efforts of three case companies. These observations helped us learn how companies implement and use the KPI set. As a final step, we validated the KPI set by presenting and discussing it with academics and other practitioners in small-scale seminars.

6.3 Results

Our research resulted in three key insights. First, we identified three common PSS measurement traps that lead to dysfunctional PMS. Second, we developed a KPI set that manufacturers can use to derive a comprehensive PMS to manage their PSS business. Third, we offer three recommendations for the implementation of the KPI set.

6.3.1 PSS Measurement Traps

As Peter Drucker put it, “you can’t manage what you can’t measure”. But PMS that are not appropriately aligned with the philosophies and dimensions of a PSS business are ineffective and often dysfunctional. The studied companies reported three traps when measuring PSS business that lead to dysfunctional PMS:

1. Measuring PSS business with a product-centric PMS;
2. Only measuring “lagging” KPIs;
3. Excluding important but “hard to measure” KPIs (see Table 17).

Traps	Representative quotations
Trap 1: Measuring PSS business with a product-centric PMS	<i>We realized that we need an entirely new set of KPIs to manage our PSS business. Simply adding one or two IoT KPIs to the existing KPIs doesn't work.</i> [Chief Technology Officer, Filtration System Inc.] <i>The business logic of our PSS business is entirely different from that of our traditional business. [...] To measure and manage it, we introduced dedicated new KPIs. The existing product-centric KPIs would not only have been meaningless but would also have prevented the PSS business from flourishing.</i> [Assistant to the Board, Industrial Machine Inc.] <i>Our traditional business lies in selling diagnostic tools and spare parts to car repair shops. We heavily invested in IoT technologies and realized that we can leverage diagnostic tool connectivity to let customers order the needed spare parts directly with the diagnostic tool. With this direct link to the customer, we can significantly increase our spare parts sales by offering our spare parts or those from our partners. Thus, we planned to provide car repair shops with free "connected" diagnostic tools and earn our money only with the spare parts sales. Despite being beneficial in the long run, our controllers rejected this business model several times because of the financial targets we had to reach this year. Costing us valuable time, during which a competitor had already occupied 3'000 workshops with its diagnostic tools.</i> [Executive Vice President, Car Parts and Service Inc.]
Trap 2: Only measuring "lagging" KPIs	<i>We need to measure the whole continuum. We can't just look at financials. We need leading KPIs that capture the key drivers of our PSS business.</i> [CEO IoT Services, Home Appliance Inc.] <i>We invest in connecting our laundry machines and developing services like the automated ordering of detergent. We will only earn money with these services if customers continue to use them for years to come. With today's PMS designed to track costs and sales of laundry machines, we miss, for example, analyzing whether customers are starting to use services less, which may indicate they are about to terminate the subscription.</i> [Management Board Member, Home Appliance Inc.] <i>Our current PMS does not include leading indicators like user activity, conversion rate, or churn rate. Without these metrics, we are practically flying blind with our PSS business.</i> [Chief Digital Officer, Machine Manufacturer Inc.]
Trap 3: Excluding important but "hard to measure" KPIs	<i>At first, we did not consider the Net Promoter Score [NPS] because measuring it is not easy and [is] costly. But we realized that it is a crucial metric for our PSS business. That's why we are now developing ways to measure the NPS efficiently.</i> [CTO IoT Platform, Conglomerate B Inc.] <i>The NPS was considered too time-consuming since we could not simply query it. But we quickly realized that we were missing direct feedback from customers for our new services.</i> [Digital Service Designer, Machine Manufacturer Inc.] <i>From a technical perspective, we have access, but we lack the customer's consent that allows us to use customer usage data. We should have simply obtained the consent in the general terms and conditions, just like all the software companies do.</i> [System Architect, Heating and Security System Inc.]

Table 17: Three common PSS measurement traps

Trap 1: Measuring PSSs with a product-centric PMS

Measuring PSS business with product-centric PMS raises barriers that can inhibit PSS business models. As the following statement outlines, pure product-centric financial metrics can prevent the launch of a PSS:

“Our traditional business lies in selling diagnostic tools and spare parts to car repair shops. We heavily invested in IoT technologies and realized that we can leverage diagnostic tool connectivity to let customers order the needed spare parts directly with the diagnostic tool. With this direct link to the customer, we can significantly increase our spare parts sales by offering our spare parts or those from our partners. Thus, we planned to provide car repair shops with free ‘connected’ diagnostic tools and earn our money only with the spare parts sales. Despite being beneficial in the long run, our controllers rejected this business model several times because of the financial targets we had to reach this year. Costing us valuable time, during which a competitor had already occupied 3’000 workshops with its diagnosis tools”.
[Executive Vice President, Car Parts and Service Inc.]

Why is that? The core business model in product companies is still selling products. However, PSSs require more service-centric business models. In the extreme case, that can mean that instead of selling a product, a company provides the product for free and the customer only pays for product usage (e.g., no upfront payment, but recurring payments over the product lifecycle). Financial metrics that push strongly for direct revenue or positive cash flow favor customers paying one time, but these metrics become dysfunctional when they encounter recurring revenue models (Allmendinger & Lombreglia, 2005).

Trap 2: Only measuring “lagging” KPIs

When product companies realize that certain metrics in their PMS prevent them from pursuing PSSs, they adjust these metrics. The Home Appliance Inc., for example, adjusted its revenue, profitability, and cash flow metrics to capture recurring payments over a period of time, so that subscription- and pay-per-use-based PSSs were not systematically excluded. However, many interviewees reported that this leads to PMS that no longer prevent PSSs, but mainly measure lagging KPIs for PSSs. This is because PSSs require leading KPIs beyond the leading KPIs previously used in product companies (e.g., production costs, manufacturing error rates, production volume, or

inventory turnover). The following statement shows that companies are looking for new leading indicators for their PSS businesses:

“We invest in connecting our laundry machines and developing services like the automated ordering of detergent. We will only earn money with these services if customers continue to use them for years to come. With today’s PMS designed to track costs and sales of laundry machines, we miss, for example, analyzing whether customers are starting to use services less, which may indicate they are about to terminate the subscription”. [Management Board Member, Home Appliance Inc.]

By not measuring leading metrics that capture the value drivers of PSSs, companies miss opportunities to respond to immediate challenges (e.g., Kaplan & Norton, 1996). Companies can avoid the trap by balancing both leading and lagging indicators.

Trap 3: Excluding important but “hard to measure” KPIs

When product companies start to focus on leading indicators, we find that companies exclude important KPIs because they are “hard to measure”. What is often not measured are customer-related measures such as customer satisfaction (e.g., net promoter score (NPS) (Reichheld, 2003)) or customer usage metrics that serve as a proxy for customer satisfaction. These are often not captured despite being the gold standard in the software industry for measuring subscription, pay-per-use, or other service-centric business models (Könsgen & Schaarschmidt, 2016). The following statement highlights this trap:

“At first, we did not consider the net promoter score [NPS] because measuring it is not easy and [is] costly. But we realized that it is a crucial metric for our PSS business. That’s why we are now developing ways to measure the NPS efficiently”. [CTO IoT Platform, Conglomerate B Inc.]

The study revealed two reasons why companies do not measure customer-related metrics. On the one hand, these metrics are more complex to measure due to product companies’ existing IT systems (e.g., enterprise resource planning systems) that often lack the data points needed for analysis. On the other hand, companies often lack customers’ consent to track certain customer-related measures. The following statement highlights this:

“From a technical perspective, we have access, but we lack the customer’s consent that allows us to use customer usage data. We should have simply obtained the

consent in the general terms and conditions, just like all the software companies do”.
[System Architect, Heating and Security System Inc.]

When companies exclude “hard to measure” KPIs, they often miss customer-related KPIs. These are, however, important leading indicators to help companies understand and capture the dynamics of PSSs (cf. Schrage & Kiron, 2018).

6.3.2 A KPI Set for the PSS Business

With the in-depth study, we strived to develop a KPI set that manufacturers can use and adapt to manage their PSS business. Our in-depth study revealed a KPI set consisting of 12 KPIs distributed across four perspectives (see Figure 14). The perspectives categorize KPIs that provide answers to the same underlying question:

- *Products connected?* – Are our products getting connected?
- *Services adopted?* – Do our customers adopt the services?
- *Viable ecosystem?* – Do we have a viable ecosystem for developing the PSS business?
- *Sustainable profits?* – Do we make sustainable profits in the PSS business?

The following subsections describe the identified perspectives as well as the included KPIs in greater detail.

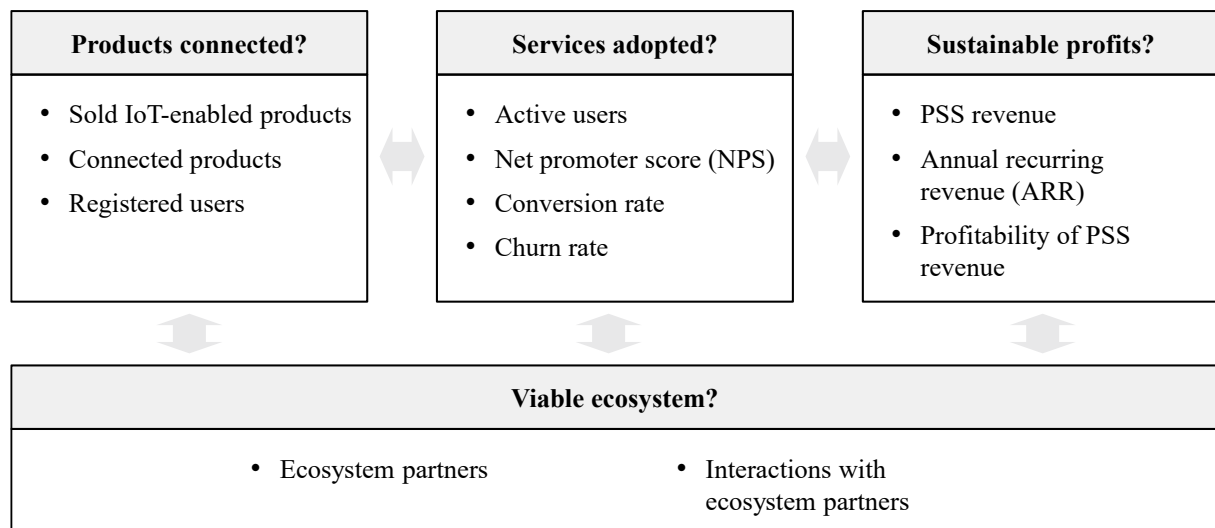


Figure 14: PSS KPI set

Products connected?

This dimension incorporates the KPIs to manage if products are getting connected. The logic is that connected products are often a prerequisite to providing PSSs. However, to achieve this, products must first be IoT enabled – i.e., equipped with software, sensors, actuators, and connectivity components to connect to the internet and exchange data. In a further step, IoT-enabled products must actually be connected and customers (or users) must be registered. The following three KPIs emerged from the study.

KPI #1: Sold IoT-enabled products – The interviewees emphasized measuring how many of today's products are IoT-enabled through software, sensors, actuators, and connectivity components. IoT enablement can include new products sold to the customer or already installed products that can be reconfigured and/or retrofitted to become IoT-enabled. Why measure IoT-enabled products? On the one hand, to understand the market opportunity for PSSs, as connected products are often a prerequisite for many PSSs. On the other hand, the KPI allows managers to incentivise their organization to drive the IoT enablement of their products.

KPI #2: Connected products – The study participants emphasized the importance of measuring connected products because they represent a product company's physical access points to the digital world. For example, for the home appliance provider, only when the dishwashers and washing machines are connected do they provide the necessary data points for IoT services, such as the automatic replenishment of detergent or dishwasher tabs included in their dishwasher PSS.

KPI #3: Registered users – The interviewees further stressed the importance of measuring registered users, since companies can only sell services if they "know" the customer behind the connected products. Knowing a customer means that customers have provided their contact details and payment details.

Services adopted?

The first dimension incorporates the KPIs that measure the enablement for PSSs. However, the interviewees pointed out that connected products alone only generate costs. Customers are not willing to pay more merely for the IoT enablement of products, and there are ongoing operating costs for maintaining connectivity and data processing. The business value lies in leveraging the data from connected products for (digital) services bundled with the products to solve customer needs (see Section 2.2.2). Hence,

interviewees recommended metrics that follow the objective to measure whether customers adopt services.

KPI #4: Active users – The interviewees mentioned measuring how many users (or customers) are actively using a service as a way to capture the success of a service. The chosen metric was either daily active users (DAU) or monthly active users (MAU), depending on the type of service and the respective typical usage frequency.

KPI #5: Net promoter score (NPS) – Study participants considered the NPS, or related metrics, such as the customer satisfaction score (CSAT), necessary to understand how satisfied customers are. Only satisfied customers are likely to continue using and paying for services and thus generate profits for the company. Companies can collect the NPS using a survey in which customers are asked to answer the question, “How likely are you to recommend our service to a friend?” on a scale of 1 to 10 (Reichheld, 2003). Similarly, with the CSAT, customers are asked to rate their satisfaction with a service typically on a scale of 1 to 5 (Marr, 2012). The average rating of all customer responses is then the NPS or the CSAT score. The following statement highlights the importance of measuring customer satisfaction:

“At first, the NPS was considered too time-consuming since we could not simply query it. But we quickly realized that we were missing direct feedback from customers for our new services. Today we call and ask our customers, but we are working on an automated solution. Our goal is that the operator can simply press a smiling or sad smile on the hydraulic units”. [Vice President Engineering, Hydraulic System Inc.]

KPI #6: Conversion rate – This metric captures the success rate of turning potential customers into paying customers. The study participants pointed out that “freemium” or “free trial” become important business models in the PSS business. Freemium entails offering a basic service free of charge but charging money for a premium service. Free trial means customers can use the service free of charge for a limited period. The basic premise behind both strategies is to convince customers to sign up for a free version and to subsequently convert them into paying customers. The conversion rate captures the effectiveness of this strategy and thus becomes an important metric to measure PSS business. The conversion rate is also suitable for tracking upgrades and downgrades for PSS, making it possible to track increases and losses of revenues.

KPI #7: Churn rate – The study participants emphasized that many PSSs usually pay off over time, as they often involve revenue models where smaller fees are collected over time through a subscription or a pay-per-X revenue model. Thus, customer retention becomes a key success factor. For instance, the head of digital transformation of the home appliance provider pointed out that their home appliance subscription has a minimum contract term of three months, but profitability will only be achieved if customers remain subscribers for years. The study participants recommended measuring customer retention through the churn rate, which is the percentage of customers lost over a particular period.

Viable ecosystem?

With PSSs, the focus shifts to solving comprehensive customer problems. It is increasingly unlikely that a single company can provide all of the required elements of such a solution - let alone that a single company has the necessary resources and capabilities to do so (Bigdeli et al., 2021; Jacobides, 2019). As a result, manufacturers are increasingly dependent on ecosystem partners to provide PSSs. The study revealed KPIs for measuring the ecosystem.

KPI #8: Ecosystem partners – Interviewees pointed out to track the number of partners in the ecosystem. For instance, the Car Parts and Service Inc. sells e-bike components and digital services such as advanced shifting solutions or an advanced range planer. While the components are sold to e-bike manufacturers, the advanced features can be unlocked by the e-bike users via the dedicated smartphone app. To maximize the reach of these advanced features, the company partners with, for example, well-known bike route providers to have the features promoted. Thus, the company tracks the number of ecosystem partners to track progress in their ecosystem-building strategy.

KPI #9: Interactions with ecosystem partners – Increasing the number of partners is just one part of building a viable business ecosystem. The interviewees also emphasized tracking the interactions with ecosystem partners. In the e-bike example, the company has begun monitoring partner interactions by measuring how many features are unlocked by its partners' users. The higher the number, the stronger the partnership between the companies as profits are shared.

Sustainable profits?

Lastly, the interviewees also reported metrics that aim to capture the financial perspective of the PSS business.

KPI #10: PSS revenue – Investments in the IoT and the development of services for PSSs only pay off if companies can achieve corresponding revenues or cost savings. Companies record PSS revenue separately to track progress in the PSS business. The chief digital officer with a home appliance manufacturer explained that the company's goal is to drive revenue growth from PSS, such as selling washing machines and getting customers to pay for an automatic detergent replenishment service. He said,

“To track the progress, we specified PSSs as a separate revenues category compared to the classic services such as field services and product sales. [...] Through this separate category for PSSs, we could formulate concrete strategic objectives to generate 5 percent of our total revenue with PSSs by 2025”.

Measuring the PSS revenue creates three advantages. First, putting up PSSs as a separate revenue category avoids the tendency to give new developed (digital) services away for free to promote product sales (cf. Ulaga & Michel, 2019). Second, tracking the PSS revenues makes it easier to incentivize the sales force to market PSSs more actively. Third, companies can track the PSS revenue per customer, making it easier to assess whether customers start using and paying for more and more services.

KPI #11: Annual recurring revenue (ARR) – In addition to measuring PSS revenue, companies reported introducing ARR as a revenue category. ARR refers to the revenue that a company expects to receive from active customer contracts (e.g., subscriptions) plus revenues from new customers and upgrading services in the next year, minus revenue lost from customers expected to terminate their contracts and downgrading their service level during the year (Tzuo & Weisert, 2018). ARR is, therefore, a metric to predict revenues, and serves to forecast future PSS revenues. Introducing ARR as a metric appeals to stakeholders and shareholders since it signals a constant revenue stream (Hui, 2014).

KPI #12: Profitability – Companies also reported to measure the profitability of the PSS business. Profitability measures help to ensure that the PSSs achieves the same or even a higher margin as the traditional business.

6.3.3 Implementing the PSS KPI Set

We accompanied three case companies in using the KPI set to develop their PMS for managing the transition to PSSs. The resulting PMS the companies implemented are outlined in Figure 15. From this work, three recommendations emerged about using and implementing the KPI set for the PSS business:

1. *Complement, do not replace*: The KPI set for the PSS business should not replace existing PMS. Introduce a dedicated PSS KPI set that complements existing PMS to avoid potential resistance to changing the established PMS.
2. *Make it simple, not complex*: Complementing existing PMS does not mean having a complex new KPI system. Start with a minimal viable KPI system for the PSS business. Test how these few KPIs help the company better manage the PSS business before integrating further metrics for the development and expansion of the PSS business.
3. *Change KPIs over time*: The KPI set simplifies the selection of relevant KPIs. Selected KPIs are not fixed and static but rather change over time. Depending on the stage in the expansion of the PSS business, KPIs such as “connected products” or “registered users” might become less relevant, and KPIs such as “ecosystem partners” or “profitability” might become more critical.

KPI set for PSSs		Car Parts and Service Inc.	Home Appliance Inc.	Machine Manufacturer Inc.
Products connected?	•Sold IoT-enabled products	•App downloads	•Share of IoT enabled products sold	
	•Connected products		•Share of connected products	•Number of connected machines during & post warranty
	•Registered users	•New registered users •Total registered users	•Number of products with account registration	•Share of products with service contracts
Services adopted?	•Active users	•Active users this month	•Monthly active users	•Frequency of usage •Machine failures solved remotely
	•Net promoter score (NPS)	•App ratings average		•Machine availability of connected vs non-connected machines
	•Conversion rate	•Conversion rate from registered to active users		
	•Churn rate			•Renewal rate for service contracts and digital services
Viable ecosystem?	•Ecosystem partners	•Number of ecosystem partners		•Number of services offered through partners
	•Interactions with ecosystem partners	•New users from ecosystem	•Monthly active ecosystem partner users	
Sustainable profits?	•PSS revenue	•PSS revenue	•PSS revenue	•IoT service revenue
	•Annual Recurring Revenue (ARR)	•ARR	•ARR	
	•Profitability of PSS revenue		•Profitability of PSS revenue	•Gross margins

Figure 15: Derived PMS to manage PSS business

6.4 Discussion

6.4.1 Summary

PSSs open up new business opportunities beyond today's core business of manufacturing companies. However, selling PSSs is an entirely different way of doing business and, as such, requires a new set of KPIs (Nudurupati et al., 2011; Nudurupati

et al., 2016; Raskino, 2017; Wolcott, 2016). These KPIs differ from the existing PMS steered toward increasing efficiency and effectiveness in today's core business of manufacturing firms. Getting the right KPIs to manage the PSS business is difficult. Case study research conducted together with 31 companies resulted in three important takeaways. First, the study revealed three possible measurement traps when measuring PSS business that companies should be aware of: (1) measuring the PSS business with a product-centric PMS; (2) only measuring "lagging" KPIs; and (3) excluding important but "hard to measure" KPIs. Second, the study resulted in a KPI set suggesting 12 KPIs to measure the PSS business in the realm of IoT and to avoid the outlined measurement traps. The presented KPI set helps companies answer four key questions when developing the PSS business related to connectivity, adoption of services, availability of a viable ecosystem for developing the PSS business, and sustainable profits. Third and finally, the work on implementing the KPI set resulted in the following three recommendations: (1) ensuring that PSS KPI systems complement existing PMS, (2) ensuring that they are simple and not too complex, and (3) that they change over time. Altogether, the measurement traps, the KPI set, and implementation recommendations make it easier to manage the PSS business.

6.4.2 Practical and Theoretical Implications

Contributions to theory

Our findings allow us to contribute to theory in three ways. First, the study shows that product-centric PMS represent all kinds of barriers to IoT-enabled PSSs investments. We found that financial metrics favoring one-time upfront payments are dysfunctional for recurring revenue models used with PSSs. Moreover, the study showed that simply adjusting these metrics results in PMS that do not systematically exclude PSSs but fail to capture essential value drivers of PSS business models. Hence, to manage manufacturers' efforts of turning connected products into PSSs, new ways of measuring performance are necessary. These findings are consistent with previous literature emphasizing the need for innovative new performance measurement methods (Nudurupati et al., 2011; Nudurupati et al., 2016; Raskino, 2017; Wolcott, 2016).

Second, the study enhances the extant literature on measuring manufacturers' efforts of turning connected products into PSSs. Previous studies pointed out individual measures to manage the transition to PSSs (e.g., Heinis et al., 2018; Hui, 2014; Momsen, 2019;

Thaler & Pierer von Esch, 2020; Tzuo & Weisert, 2018). However, individual measures in isolation only provide partial insights to manage a multifaceted and complex transition (Bititci et al., 2012; Neely et al., 1995). The study proposes a KPI set that integrates four distinct perspectives (related to connectivity, adoption of services, availability of a viable ecosystem for developing the PSS business, and sustainable profits) and corresponding KPIs that together provide a more comprehensive assessment of progress and outcome of the transition.

Third, the research of this chapter integrates a performance measurement and management focus into the PSS literature. The study offers critical theorization on PSS performance by providing a KPI set to quantify the progress and outcome of manufacturers' transition toward PSSs. PSS literature is currently emerging from mainly exploratory research (research predominantly based on individual cases to understand the PSS transition) to more explanatory research (quantitative or comparative research) in order to understand different PSS approaches and the resulting implications (Kowalkowski et al., 2017). The ability to quantify outcomes and progress enables researchers to determine the effect specific PSS initiatives create. Understanding the impact of various PSS initiatives will help advance the PSS literature from a primarily exploratory to a more explanatory focus.

Contributions to practice

Besides the theoretical implications, this study has important managerial contributions. The most important contribution rests in the provision of a KPI set and the implementation recommendations. Manufacturers starting to explore PSS business can use the KPI set to identify relevant KPIs and derive a PMS suitable for their PSS transformations. A PMS aligned with the business logic of PSSs enables manufacturers to evaluate and manage the progress and outcome of their PSS investments. In addition, a dedicated PMS allows manufacturers to communicate the PSS strategy to everybody in the organization by making it tangible (Davis & Albright, 2004; Franco-Santos et al., 2007). A tangible PSS strategy is of utmost importance to align efforts across an organization and drive the cultural change needed to solve customer problems (Grove et al., 2018; Wolcott, 2016).

The research not only provides practitioners with a KPI set and recommendations for implementation, but also outlines why new PMS are necessary. For many

manufacturers, PSSs are increasingly a new strategic imperative for future success (Connerty et al., 2016; Lerch & Gotsch, 2015). However, to date, numerous manufacturing firms still rely solely on product-centric PMS to assess the progress and performance of their PSS initiatives (Bigdeli et al., 2018; Nudurupati et al., 2016; Raskino, 2017; Wolcott, 2016). This study provides empirical evidence of mismanagement with product-oriented PMSs and, therefore, encourages practitioners to rethink existing PMS for their PSS initiatives.

6.4.3 Limitations

The presented findings are not free of limitations. First, the study applied a qualitative multiple case study approach. Consequently, the generalizability of the derived traps, the KPI set, and the implementation recommendations is limited (Saunders et al., 2019). Second, both the explorative and the in-depth study were based on a convenience sample, resulting in a small and opportunistic sample. While representativeness suffers from this, it allowed us to include those companies where we had access to key informants across hierarchical levels and functions that were willing to provide us with insights into a highly strategic and timely topic. Third, although three case companies have implemented the KPI set, the developed KPI set has not yet been used and assessed by companies outside the sample companies of this study.

Chapter 7

Conclusion

7.1 Summary and Key Findings

The shift from selling products to offering PSSs has gained considerable momentum with the rise of the IoT (Iansiti & Lakhani, 2014; Lerch & Gotsch, 2015). For many manufacturers, embracing this transformation will likely mean the difference between upcoming success and stagnant survival (Bertini & Koenigsberg, 2020a; Kowalkowski et al., 2017). However, PSSs are not yet a mature phenomenon and many manufacturers struggle with their PSSs transformations (Gebauer, Fleisch, et al., 2020; Kohtamäki et al., 2020). Despite the rapidly emerging body of literature, manufacturers still lack knowledge, tools, and guidelines on implementing PSSs (Adrodegari & Saccani, 2020; Adrodegari et al., 2017; Barquet et al., 2013; Reim et al., 2015). In order to address this research gap, this thesis examined how manufacturing firms can transition connected products to sustainable PSSs.

To comprehensively address this research question, we formulated three SRQ and individually addressed them in dedicated studies. The first study aimed to provide a clear understanding of PSSs by identifying misconceptions that prevent manufacturers from embracing PSSs. The second study uncovered business model patterns that support PSS business model design. The third study identified how companies can measure PSS performance to enable effective PSS management. The following subsections summarize the key findings of these three studies.

7.1.1 Understanding PSSs – Six PSS Misconceptions

The objective of the first study was to provide an understanding of PSSs by identifying misconceptions that prevent manufacturers from transitioning towards PSSs. We identified six such misconceptions through case study research covering 26 companies.

The findings confirm and advance the extant literature that provides indications of PSS misconceptions in practice (e.g., Baines et al., 2017; Kowalkowski, 2010; Perona et al., 2017; Tukker & Tischner, 2006a). We identified six misconceptions regarding when PSSs are relevant (i.e., *PSSs work for Rolls-Royce, but not for us; PSSs are for customers that cannot afford to buy*), what PSSs are (i.e., *PSSs are pay-per-use; PSSs are fully managed*), and how firms should approach PSSs (i.e., *get your products connected first; we cannot swallow the fish*). Both scholars and practitioners should be aware of these misconceptions. On the one hand, they represent research directions that scholars can pursue to improve practitioners' understanding of the PSS concept and, thus, increase the concept's uptake (Baines et al., 2017). On the other hand, practitioners should be aware of them, as they represent dysfunctional stereotypes and prevent informed decision-making. As such, they create barriers to manufacturers' ambitions to transition to PSSs (cf. Bigdeli et al., 2021).

Furthermore, the findings reveal that minimum contract terms are the norm for limiting the risk transfer associated with PSSs. At first glance, many PSSs are based on “pure” pay-per-use, pay-per-outcome, or similar revenue models. An example is Homie, which requires a minimum of 15 wash cycles per month and a minimum contract period of 12 months for its pay-per-use laundry machines (see Chapter 4.4.2). Surprisingly, minimum contract terms have received little attention in the extant literature (e.g., Bertini & Koenigsberg, 2020a; Gebauer, Haldimann, et al., 2017), even though they appear to be a critical means of limiting risk transfer in PSSs. Without minimum contract terms, many PSSs are not feasible in practice.

Another finding relates to the identification of gradual scaling approaches designed to minimize the investments and risks involved in the PSS transition. The extant literature has highlighted the financial challenges and risks associated with transitioning towards PSSs (e.g., the widely known “fish” model; Lah & Wood, 2016). However, insights and guidance that can help manufacturers overcome these challenges and risks are limited, which may explain why numerous companies fail in their transitions (Reim et al., 2015) and why misconceptions such as “we cannot swallow the fish” (see Chapter 4.3.3) exist.

This study extends the knowledge base by providing practical insights into gradual scaling approaches used by companies to minimize investments and mitigate risks (i.e., how companies “swallow the fish”). For instance, companies explore PSSs with single product features rather than with the whole product.

7.1.2 Designing PSSs – 58 PSS Patterns

The second study explored business model patterns in order to support the design of PSS business models. Using a qualitative case-study method, we systematically analyzed the business models of 199 existing PSSs and uncovered 58 patterns.

Theory and practice acknowledge that PSSs require business models that differ from those traditionally used to sell products or services (Sjödín et al., 2020). The identified patterns extend the extant literature, which offers only moderate detail on the characteristics of PSS business models (Adrodegari & Saccani, 2017). The patterns, which represent abstract building blocks for the value proposition, value capture, and value creation elements, provide a more detailed understanding of the characteristics and configurations of PSS business models. Practitioners can use the patterns to more effectively design PSS business models. Instead of designing these business models from scratch, practitioners can reuse, recombine, and reassemble proven building blocks (cf. Amshoff et al., 2015; Gassmann et al., 2020).

Another key insight is found in the identified patterns of customer gains and pains. These patterns show that PSSs are about solving customer problems along the entire customer journey from financing to managing the product lifecycle to operating the product to de-risking. These findings extend the extant research and practitioner-led discussions that often limit customer value to shifting from CAPEX to OPEX (i.e., no initial investments and no fixed costs; cf. Gebauer, Haldimann, et al., 2017; Helo et al., 2017; Monitor Deloitte, 2021; Wopata, 2020). The findings show that the shift from CAPEX to OPEX is just one of numerous customer problems and that this shift is often not the main reason customers opt for PSSs.

Another key insight relates to the identified technology use cases around the IoT employed to deliver PSSs. While the findings confirm that IoT is a key enabler of PSSs, they also show that the widely discussed “blockbuster” use case – i.e., predictive maintenance (Bilgeri et al., 2019) – is only found in a handful of PSS cases. Most PSS

cases rely on rather simplistic IoT use cases, such as remote support, remote monitoring, or automatic replenishment.

7.1.3 Managing PSSs – A KPI Set for PSSs

The objective of the third study was to shed light on how manufacturers can measure the performance of PSSs to enable effective PSS management. Case study research covering 31 companies led to three key findings: (1) the existence of PSS measurement traps, (2) a KPI set for PSS business, and (3) implementation recommendations.

First, we identified three possible measurement traps: (1) measuring the PSS business with a product-centric PMS, (2) only measuring “lagging” KPIs, and (3) excluding important but “hard to measure” KPIs. When companies fall into these traps, their PSS measures can become dysfunctional, leading managers to pursue misguided actions or make ill-informed choices. These traps confirm previous literature suggesting that PSS business models require innovative ways of measuring performance (Nudurupati et al., 2011; Nudurupati et al., 2016; Raskino, 2017; Wolcott, 2016).

Second, we derived a set of 12 KPIs across four dimensions for measuring manufacturers’ transitions toward PSSs. These findings extend the extant literature, which points to individual KPIs that provide only partial insights into the multifaceted and complex transition (cf. Bititci et al., 2012; Neely et al., 1995). Companies exploring PSSs can use the KPI set to identify relevant KPIs and derive a KPI system to measure and manage their PSS transformations. From a theory perspective, the ability to quantify the progress and outcome of manufacturers’ transitions to PSS allows researchers to determine the impact of different PSS approaches. This will help advance PSS literature beyond exploratory research and toward a more explanatory focus (Kowalkowski et al., 2017).

Third, three implementation recommendations for the KPI set emerged from the case studies, suggesting that companies ensure: (1) that the PSS KPI system complements existing PMS, (2) that the PSS KPI system is simple and not complex, and (3) that the relevant KPIs change over time depending on the PSS transformation stage. Altogether, the measurement traps, the KPI set, and the implementation recommendations support effective PSS measurement and management.

7.2 General Implications

We summarized the three studies' contributions to theory and practice above. In addition to these specific contributions, this thesis offers aggregated, high-level insights across the three studies into how manufacturing firms can transition connected products to PSSs.

Solving customer problems

The shift from selling products to offering PSSs is all about solving customer problems (Baines et al., 2009; Berkovich et al., 2011). It seems logical that this shift must start with the customer in order to understand their problems and then develop suitable PSSs to solve them. In practice, however, manufacturers often develop PSSs from an internal perspective without understanding customers' actual needs (Grove et al., 2018; Grubic & Peppard, 2016). This results in PSS failures, as the PSSs simply do not address pressing customer needs (Gebauer, Fleisch, et al., 2020; Grove et al., 2018; Reim et al., 2015). In our examination of many manufacturers transitioning from products to PSSs, we observed numerous barriers that can prevent manufacturers from effectively focusing on customer problems. First, the mindset and culture of many manufacturers may lead to technology-driven PSS developments. Just because a PSS is technologically possible does not mean that it solves a customer problem. In our case studies, these PSSs were referred to as "pure science projects" or "solutions in need of problem projects". Second, teams developing PSSs often have limited direct access to customers, which they need to develop and refine PSS value propositions. In many cases, sales organizations "own" the customer relationships, and make it difficult or even impossible for PSS development teams to involve customers in the development process. Third, tight project deadlines combined with high expectations and the absence of a failure culture can lead PSS teams to neglect lengthy iterations with customers, as the focus is on meeting deadlines and expectations. Manufacturers should be aware of these barriers. Moreover, they are advised to actively involve customers in developing PSSs and to create a customer business case for PSSs.

In addition to these internal barriers, the narrative shaped by the extant literature and thought leaders that PSSs embody a shift from CAPEX to OPEX (i.e., the elimination of initial investments and fixed costs for customers by letting them pay for use or output without buying the product itself) keeps manufacturers from focusing on actual

customer needs (cf. Gebauer, Haldimann, et al., 2017; Helo et al., 2017; Monitor Deloitte, 2021; Wopata, 2020). As a result, PSSs are often viewed as pure financing solutions (see misconception 2 in Chapter 4.3.1). However, our research shows that financing problems are just one of many customer problems addressed through PSSs. PSSs are about solving customer problems along the entire customer journey from financing to managing the product lifecycle to operating the product and de-risking. In fact, many customers reported that financing problems were not the reason they chose the PSS. Hence, the extant PSS discussions provide only a limited and rather unreflective understanding of customer value, and they lead to misconceptions that prevent manufacturers from addressing real customer problems.

Understanding the value of IoT

Another insight lies in the value of IoT for PSSs. Several papers describe the IoT with its connected products as a game-changer and a key enabler for PSSs (Porter & Heppelmann, 2014, 2015; Rymaszewska et al., 2017). However, recent research indicates that despite high IoT investments and a growing number of connected products, manufacturers are struggling to realize the expected returns from PSSs (Gebauer, Fleisch, et al., 2020; Kohtamäki et al., 2020; Kranz, 2017). Discussions among practitioners and scholars about the IoT's impact on PSSs are often one-sided and focus mainly on a handful of blockbuster use cases (e.g., predictive maintenance or digital twins; Bilgeri et al., 2019; Paschou et al., 2020; Pirola et al., 2020). In this regard, our findings allow us to derive a more nuanced understanding of how the IoT is used to offer PSSs.

First, the IoT is being used to *reduce expensive manual labor* in order to make PSSs economically viable and scalable by, for instance, automating critical services. Typical examples include the use of remote monitoring and malfunction alerts to centrally manage hundreds of products without the need for on-site technicians, and the use of sensor technologies to automatically trigger the replenishment of consumables when they are running low. Manual labor costs are also reduced by enabling customer self-service. An example is found in car sharing, where connected cars allow customers to unlock the cars themselves via their smartphones.

Second, the IoT is used to *realize revenue models, such as pay-per-use or pay-per-outcome*. Through connected products, manufacturers can receive information about the

use, output, or performance of their products, and they can bill customers based on that information. For example, the only reason Homie requires customers to connect laundry machines to their household Wi-Fi is to obtain information about the wash cycles. It then sends each customer a bill on a pay-per-use basis (Homie, 2021).

Third, the IoT is used to *minimize the moral hazards of customers*. Many manufacturers find that customers are not careful with products they do not own. They may, for instance, engage in reckless use, extensive use, or other behaviors that negatively affect a product's condition, leading to soaring repair and maintenance costs for the PSS provider (Tukker, 2004; Ulaga & Reinartz, 2011). Consequently, manufacturers are using the IoT to monitor customer usage and penalize misuse as defined in the general terms and conditions.

Approaching PSSs

The shift to PSSs is often described as a complex transformation associated with high risks (Reim et al., 2016; Sakao et al., 2013), substantial capital needs (Lah & Wood, 2016; Tukker, 2004), and high investments in new competencies and capabilities (Tukker, 2015). This picture discourages many manufacturers from approaching PSSs (Baveja et al., 2004), causes skepticism among employees, and leads to situations in which companies talk to financial institutions about how to offer PSSs before asking customers what they actually need (cf. Section 4.3.3). Our findings from studying manufacturers who transitioned to PSSs offer three insights into how to approach and master the transition.

First, manufacturers need to *create momentum for PSSs*. The manufacturers' product-centric mindset and the performance metrics that perpetuate this philosophy are assigned so much importance that it takes a great deal of momentum and leadership to shift to PSSs. Manufacturers need to ensure top management's commitment, eliminate dysfunctional PSSs stereotypes (e.g., PSSs work for Rolls-Royce, but not for us), introduce new KPIs (e.g., ARR), and identify concrete PSS opportunities that target pressing customer needs. Ultimately, financial business success is the best means to generate momentum in enterprises. Bosch, for example, recognizes and awards the most promising PSS projects in order to establish lighthouse projects that demonstrate the financial success of PSSs and, thereby, generate momentum among employees (BSH Hausgeräte, 2021).

Second, manufacturers should engage with customers on an iterative basis to *develop and refine PSS value propositions*. A common challenge is that manufacturers do not think in terms of the customer profit and loss statement (P&L), which results in failing PSSs because those systems do not address customer needs (Gebauer, Fleisch, et al., 2020; Grove et al., 2018). Our findings show that successful companies collaborate with customers early on to co-develop PSSs that generate a win-win situation. These PSSs offer compelling business cases for both the customer and the provider (cf. Gassmann & Ferrandina, 2021).

Third, manufacturers should *gradually scale their PSSs* to manage the financial consequences of the PSS transition and mitigate possible risks. Most of the companies we studied started with a handful of pilot customers or single product features in order to iteratively determine the unit economics of PSSs. With known unit economics, the companies then scaled (also with the help of financial institutions) to an increasing number of local customers. The emphasis here is on *local*, as unit economics can change in different parts of the world. The companies only scaled to new countries when they achieved profitability in the countries in which the PSSs had already been introduced.

7.3 Future Research

In the course of our studies, possible new research questions emerged that might be of relevance for future research on PSSs. The first study identified PSS misconceptions that prevent companies from transitioning towards PSSs. The study was limited to identifying these misconceptions, but companies must resolve them if they are to effectively adopt PSSs. This raises the first question for future research: How can PSS misconceptions be resolved in manufacturing companies?

In the second study, we identified 58 business model patterns for PSSs. As such, we provided a fine-grained characterization of PSS business models elements, but this represents a rather static approach. Future research can build on this fine-grained characterization to define archetypal business model configurations that can describe the transition from products to PSSs along different service-growth trajectories (Kowalkowski et al., 2015).

The third study uncovered a KPI set that practitioners can use to measure and manage their PSS transformations. The study reveals that the relevant KPIs are not static but change depending on the transformation stage. In this regard, future research should explore which KPIs are applicable in different stages of the PSS transformation.

In addition, this thesis focused on the economic performance of PSSs. However, PSSs can provide economic, environmental, and social value. In other words, they can contribute to companies' triple bottom lines (Norman & MacDonald, 2004; Van Halen et al., 2005). PSSs are considered an effective instrument for breaking the linear take-make-dispose model and moving towards a more resource-efficient circular economy (Tukker, 2015). Given the urgency of the climate crisis, a valuable future research question might be: How can companies realize environmental benefits with PSSs while still meeting their economic targets?

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Appendix

Concepts	Definitions/Descriptions
Business model	A business model is a conceptual model that describes how a company “creates and delivers value to customers, and then converts payments received to profits” (Teece, 2010, p. 173).
Business model patterns	Business model patterns are defined as solution patterns – i.e., aggregated and abstract proven building blocks based on empirical observations to support the design of business models (Amshoff et al., 2015; Chung et al., 2004).
Connected products	Connected products are defined through three components: the physical components that comprise a product’s electrical and mechanical parts, the smart components that amplify the value of the physical parts, and the connectivity components that enable information exchange with and between products (Porter & Heppelmann, 2014).
Key performance indicators (KPIs)	KPIs are “quantifiable measures an organization uses to determine how well it meets its declared operational and strategic goals” (Schrage & Kiron, 2018, p. 3).
Product-service systems (PSSs)	Product-service systems represent an “integrated bundle of hardware, software, and service elements” to solve customer problems (Berkovich et al., 2011, p. 369).
Internet of Things (IoT)	The IoT “is a new technology paradigm envisioned as a global network of machines and devices capable of interacting with each other” (Lee & Lee, 2015, p. 431).

Table 18: Overview of used concepts

#	Case companies	PSSs	Industries	Sources
1	365FarmNet	Farm management software	Agriculture	Link
2	ABB	Pay-per-use condition monitoring for motors, pumps, and general machinery	Electrical equipment	Link
3	Adobe	Software as a service	Software	Link
4	ATC Aluvation	Heat treatment as a service	Heat treatment	Link
5	Alvero	Office furniture rental	Office furniture	Link
6	Amazon	Dash replenishment	E-commerce	Link
7	Amazon Web Services	Infrastructure as a service	Cloud computing	Link
8	Ameresco	Energy as a service	Energy	Link
9	Assa Abloy	Access management software as a service	Manufacturing	Link
10	Atlas Copco	Tunnel drilling machines as a service	Industrial equipment	Link
11	Atlas Copco	Compressor as a service	Industrial equipment	Link
12	Audi	LED-Matrix-Light on demand	Automotive	Link
13	Bartec Syscom	Vibration monitoring systems as a service	Manufacturing	Link
14	BASF Coating	Coating as a service	Chemicals	Link
15	BASF Digital Farming	Healthy fields – guaranteed leaf health	Agriculture	Link
16	Baxi	Heat plans	Heating	Link
17	Beumer Group	Operator models for airport baggage handling systems	Manufacturing	Link
18	Bilz Werkzeugfabrik	Pay-per-use	Manufacturing	Link
19	Blacksocks	Clothing as a service	Clothing	Link
20	BMW	Digital car key add-on	Automotive	Link
21	Boge Kompressoren	Boge flat rate	Compressed air	Link
22	Bombardier Transportation	Train as a service	Engineering	Link
23	Bond	E-bike on demand	Mobility	Link
24	Bonsai Systems	Pay-per-use or flat rate	Electrical equipment	Link
25	Bosch Auto Parts	Bike share	Mobility	Link
26	Bosch Rexroth	CytroBox pay-per-use services	Factory automation	Link
27	Bosch Security and Safety Systems	Fully open camera platform	Security technology	Link
28	Bosch Thermotechnik	Heat as a service (Heizung+ Wärme)	Heating	Link
29	Bredenoord	Energy as a service	Energy	Link
30	Briggs & Stratton	Landscaping as a service subscription	Manufacturing	Link
31	Bristol Siddeley	Power-by-the-hour	Aerospace	Link

32	Brütsch-Rüegger Tools	Tool management as a service	Machinery	Link
33	BSH Hausgeräte	Renting home appliances (Papillon)	Home appliances	Link
34	BSH Hausgeräte	Leasing home appliances (BlueMovement)	Home appliances	Link
35	Bühler	Laatu – pay-per-use	Process engineering	Link
36	Bundles	Washing machine as a service	Home appliances	Link
37	Bystronic Laser AG	Flexible financing	Manufacturing	Link
38	Cancom	Mac as a service	IT services	Link
39	Candela Laser Corporation	Preventative maintenance	Aesthetic device	Link
40	Canon	Managed print services	Electronics	Link
41	Capstone Metering	Water as a service	Electronics	Link
42	Car2Go	Car sharing	Mobility	Link
43	Carl Zeiss	Software as a service	Imaging	Link
44	Carpigiani	Pay-per-use	Foodservice equipment	Link
45	Carvolution	Car subscription	Mobility	Link
46	Caterpillar	Equipment management solutions	Heavy equipment	Link
47	Claas	Telematics licenses	Agriculture	Link
48	Clean Energy Global	Battery as a service	Energy	Link
49	Coborn Engineering Solutions	Pay-per-use solution	Manufacturing	Link
50	Commerzbank	Pay-per-use financing	Banking	Link
51	Continental	Conti360° fleet solutions	Automotive	Link
52	CWS International	Workwear as a service	Clothing	Link
53	CWS International	Hygiene as a service	Hygiene	Link
54	Dance	E-bike subscription	Mobility	Link
55	Dell	Pay as you go	Computer hardware	Link
56	Desso-Tarkett	Floor as a service	Carpets	Link
57	Deutsche Bahn Connect	Mobility as a service	Mobility	Link
58	Deutsche Lichtmiete	Light as a service	Light manufacturing	Link
59	Didi Chuxing Technology	Car as a service	Mobility	Link
60	DMG Mori	PAYZR (pay with zero risk)	Manufacturing	Link
61	Drive Now	Car sharing	Mobility	Link
62	Dürr	Software as a service	Plant construction	Link
63	Eisenmann	Operator model	Automotive supplier	Link
64	Electrolux	Laundry equipment as a service	Home appliances	Link
65	Electrolux	Vacuum as a service	Home appliances	Link
66	Elite	Smart lease for beds	Hotel and motels	Link
67	EM3 AgriServices	Farming equipment as a service	Agriculture	Link

68	Eneco	20°C for a fixed monthly fee	Energy	Link
69	Enel	Energy as a service	Energy	Link
70	Energy Systems Catapult	Heat as a service	Heating	Link
71	ENGIE Mobisol	Pay as you go	Electric utility	Link
72	Epiroc	Batteries as a service	Mining and infrastructure	Link
73	Ericsson	Energy as a service	Telecommunications equipment	Link
74	Ericsson	Network management as a service	Telecommunications equipment	Link
75	Fendt	Fendt care	Agriculture	Link
76	Finn	Car as a service	Mobility	Link
77	Fitbit	Premium applications via subscription	Consumer goods	Link
78	Fujitsu	Managed storage	Computer hardware	Link
79	Gebr. Heller Maschinenfabrik	Heller4use	Manufacturing	Link
80	Geely	Lynk & Co	Automotive	Link
81	General Electric	Jet engine as a service	Conglomerate	Link
82	Gerrard Street	Headphones as a service	Computer hardware	Link
83	Girl Meets Dress	Renting dresses	E-commerce	Link
84	Go4hosting	Hardware as a service	Cloud computing	Link
85	Goodyear	Tire fleet management	Auto and truck parts	Link
86	Google	Infrastructure as a service	Cloud computing	Link
87	Google	Nest camera online video subscription	Cloud computing	Link
88	Greenwheels	Car as a service	Mobility	Link
89	Grimme Group	Pay-per-use add-ons	Agriculture	Link
90	Grover	Consumer electronics as a service	Consumer electronics	Link
91	Heidelberger Druckmaschinen	Pay-per-print	Manufacturing	Link
92	Henry Mobility	E-bike as a service	Mobility	Link
93	Hewlett-Packard	Device as a service	Computer hardware	Link
94	Hewlett-Packard	Printing ink as a service	Computer hardware	Link
95	Hilti	Fleet management	Manufacturing	Link
96	Hilti	Hilti on-track, warehouse management software as a service	Manufacturing	Link
97	Hitachi	Elevator as a service	Engineering	Link
98	Hitachi Rail	Train as a service	Engineering	Link
99	Homie	Pay-per-use laundry equipment	Home appliances	Link
100	Hommel	Usage-based financing for CNC machines	Manufacturing	Link

101	Husqvarna	Toolshed as a service	Manufacturing	Link
102	IBM	Infrastructure as a service	Cloud computing	Link
104	Invia Robotics	Robotics as a service	Robotics	Link
105	Iveco	Pay-per-use service for vehicles	Manufacturing	Link
106	John Deere	Expert alerts subscriptions	Agriculture	Link
107	Jungheinrich	Full service packages	Intralogistics	Link
108	Kaeser	Compressor as a service	Compressed air	Link
109	KaffeeCenter	“Free” coffee machines	Beverage	Link
110	Clean Cooling	Cooling as a service	Energy	Link
111	Klarx	Construction machinery as a service	Machinery	Link
112	KleverKey	Access as a service	Security	Link
113	KMF Maschinenfabriken	Operator model	Heavy machinery	Link
114	Komatsu	Fleet management	Heavy equipment	Link
115	Kone	24/7 connected services	Vertical transportation	Link
116	Konecranes	Rentall cranes	Engineering	Link
117	Kuka	Smart factory as a service	Automation	Link
118	Laundrapp	Dry cleaning & laundry directly to the doorstep	Home appliances, service	Link
119	Ledlease	Light as a service	Light manufacturing	Link
120	Lenovo	Device as a service	Computer hardware	Link
121	Liebherr	4C-Power pay-per-use	Heavy equipment	Link
122	Linde Material Handling	Fleet management	Intralogistics	Link
123	Liverental	Tablet and PC rental	Computer hardware	Link
124	Lyght Living	Furniture leasing	Furniture	Link
125	Mader	Pay-per-use compressors	Compressed air	Link
126	Magazino	Pay-per-pick for robots	Robotics	Link
127	MAN Truck & Bus	Pay-per-km trucks	Automotive	Link
128	MAWERA Holzfeuerungsanlagen	Service packages for furnace systems	Furnace systems	Link
129	Medneo	Radiology as a service	Healthcare	Link
130	Metso Outotec	Lifecycle service packages for mining	Industrial machinery	Link
131	Michelin	Pay-per-kilometer tire solution	Auto and truck parts	Link
132	Microdrones	Microdrones as a service	Survey equipment	Link
133	Microsoft	Infrastructure as a service	Cloud computing	Link
134	Mitsubishi Electric	Elevator leasing according to the circular economy	Electrical equipment	Link
135	Nanox	Medical imaging as a service	Healthcare	Link
136	NavVis	Indoor digital maps as a service	Manufacturing	Link
137	NetApp	Infrastructure as a service	Cloud computing	Link

138	Nextbike	E-bike as a service	Mobility	Link
139	Nio	Battery as a service	Automotive	Link
140	Nordex	Production-based availability warranty	Manufacturing	Link
141	OCEO	Water purification as a service	Consumer goods	Link
142	ON	Running shoe subscription	Consumer goods	Link
143	OPTIMA packaging group	Total care	Manufacturing	Link
144	Otis	Elevator as a service	Vertical transportation	Link
145	Packsize	Packaging on demand	Packaging	Link
146	Panasonic	Energy as a service	Electronics	Link
147	Pay Per Wash	Pay-per-wash	Home appliances	Link
148	Pema	Pay-per-use trucks	Industrial services	Link
149	Philips Medical Capital	Finance lease for medical equipment	Medical equipment	Link
150	Philips Medical Capital	Operating lease for medical equipment	Medical equipment	Link
151	Philips Medical Capital	Pay-per-use for medical equipment	Medical equipment	Link
152	Philips	Brush head subscription	Conglomerate	Link
153	Porsche	Subscription memberships, Porsche drive	Automotive	Link
154	PubliBike	E-bike sharing	Mobility	Link
155	Reliable Heating & Air	Heating and air as a service	Heating and air conditioning	Link
156	Rent the Runway	Renting clothes	E-commerce	Link
157	Ricoh	Managed print as a service	Electronics	Link
158	Riversimple	Car as a service	Automotive	Link
159	Rolls-Royce	Power-by-the-hour	Mechanical engineering	Link
160	Sanixair	Continuous sanitation for a monthly fee	Air sanitizing	Link
161	SAP	Software as a service	Software	Link
162	Schindler	Elevator as a service	Vertical transportation	Link
163	Schneider Electric	Energy as a service	Electrical equipment	Link
164	Share Now	Car as a service	Mobility	Link
165	Siemens Healthineers	Managed equipment services	Healthcare	Link
166	Signify	Light as a service	Light manufacturing	Link
167	Signify	Circular lighting	Light manufacturing	Link
168	SKF	SKF rotation for life	Manufacturing	Link
169	Skyline Robotics	Window cleaning robots as a service	Robotics	Link
170	Solarcity NZ	Solar as a service	Energy	Link

171	STILL	Fleet management	Intralogistics	Link
172	Sunrun	Energy agreements	Solar energy	Link
173	Swapfiets	Bike subscriptions	Mobility	Link
174	Tesla	Car connectivity subscription	Automotive	Link
175	Tesla (Solarcity)	Pay for power, not panels	Solar energy	Link
176	Thyssenkrupp	Elevator as a service	Conglomerate	Link
177	Tomtom	Live services for navigation systems	Consumer electronics	Link
178	Toshiba	Managed print as a service	Conglomerate	Link
179	TrakRap	Pay-per-wrap	Packaging	Link
180	Trilux	Pay-per-use	Light manufacturing	Link
181	Trumpf	Pay-per-part	Manufacturing	Link
182	UrbanVolt	Lighting as a service	Light manufacturing	Link
183	Vaillant Group	Heat365 (heat as a service)	Heating	Link
184	Valmet	Uptime guarantees	Pulp and energy	Link
185	Viessmann	Viessmann Wärme (heat as a service)	Heating	Link
186	Vivint Solar	Solar plans	Solar energy	Link
187	Volvo Cars	All-inclusive car subscription	Automotive	Link
188	Volvo Trucks	Truck as a service	Automotive	Link
189	Wacker Neuson	OnSite Box	Manufacturing	Link
190	Waterlogic	Water dispenser as a service	Consumer goods	Link
191	Weisser	Pay-per-use artery	Manufacturing	Link
192	WeWash	Laundry machines as a service to property managers	Home appliances	Link
193	Winterhalter	Pay-per-wash dishwashers	Manufacturing	Link
194	Würth Group	C-parts management for the industry	Inventory management	Link
195	Wyatt	Toothbrush subscription	Consumer goods	Link
196	Xerox	PagePack – cost per page	Information technology	Link
197	Xfinity	Security subscription plans	Telecommunications	Link
198	Zipcar	Car as a service	Mobility	Link
199	Zity	Car sharing	Mobility	Link

Table 19: In-depth PSS case studies (weblinks accessible in PDF, all weblinks retrieved 15.09.2021)

Curriculum Vitae

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BMW AG – *Internship and master thesis* *Munich, Germany*
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