

Design of Product-Service Systems in SMEs

Exploring challenges and the influence of firm characteristics

Jennie Åkesson

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DESIGN OF PRODUCT-SERVICE SYSTEMS IN SMES
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Jennie Åkesson

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School of Innovation, Design and Engineering

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Abstract

The manufacturing industry is essential in the transition toward a circular economy (CE) and a more sustainable society. One way manufacturing companies can become more sustainable and contribute to a resource-efficient society is by offering Product-Service Systems (PSS). PSS means integrating products and services through different types of business models, such as product pooling, leasing, sharing, and other product-related services. Designing PSS considers both the tangible product offering and the design of the complete system around the product. Therefore, manufacturing companies must have a systems approach when designing PSS. The majority of studies in the PSS field have been conducted from the perspective of large companies, resulting in a limited focus considering the context and characteristics of small and medium-sized enterprises (SMEs). This thesis aims to contribute to the PSS and servitization literature by addressing the research gap and lack of insights in studies related to PSS design in a manufacturing SME context.

This research is based on a systematic literature review and empirical data from three contract manufacturing SMEs. The findings show that SMEs face both internal and external challenges when designing PSS. The challenges identified are related to several parts of the organization and are also interconnected and overlapping. SMEs' characteristics also influence these challenges, showing the importance of the context when discussing the challenges to address when designing PSS in SMEs. The study shows that characteristics such as a lack of financial resources influence more than one challenge, making it difficult for SMEs to know which challenges to prioritize when designing PSS. Furthermore, as the studied SMEs are contract manufacturers to original equipment manufacturers (OEMs), they need acceptance and support from their OEM customers, but they may not gain customer acceptance. The study indicates that SMEs need to decide if they should design PSS with their customers or find a business opportunity and design PSS independently, despite lacking vital resources needed for PSS design.

Keywords: Product-Service Systems, Small and medium-sized enterprises, Servitization, challenges, SME characteristics, manufacturing companies, circular economy

Sammanfattning

Tillverkningsindustrin är betydande i omställningen mot en cirkulär ekonomi och ett mer hållbart samhälle. Ett sätt för tillverkningsföretag att bli mer hållbara och bidra till ett resurseffektivt samhälle är genom att erbjuda Produkt-Tjänstesystem (PSS). PSS innebär integrering av produkter och tjänster genom olika typer av affärsmodeller, såsom uthyrning, leasing, delning och andra produktrelaterade tjänster. Att designa PSS handlar både om produkt-designen, men att även designa hela systemet runt produkten. Därför behöver tillverkningsföretag ha ett systemperspektiv när de designar PSS. Majoriteten av studierna inom PSS fältet har fokuserat på stora företag, med begränsat fokus gällande kontexten och karaktärsdragen hos små- och medelstora företag (SMEs). Syftet med denna avhandling är att bidra till PSS-och servitiserings-litteraturen genom att adressera detta forskningsgap och bristen på studier relaterat till att designa PSS i tillverkande SME-företag.

Studien baseras på en systematisk litteraturgenomgång och empiriska data från tre SME-företag inom kontraktstillverkning. Resultaten visar att SME-företag möter både interna och externa utmaningar när de designar PSS. De identifierade utmaningarna är relaterade till flera delar av organisationen och de är också sammankopplade och överlappande. Dessutom påverkar SME-företagens karaktärsdrag dessa utmaningar, vilket visar vikten av kontexten när utmaningar med att designa PSS i SME-företag diskuteras. Studien visar att karaktärsdrag så som brist på ekonomiska resurser påverkar fler än en utmaning, vilket gör det svårt SME-företag att veta vilka utmaningar som bör prioriteras när de designar PSS. Dessutom, eftersom de studerade SME-företagen är kontraktstillverkare till original equipment manufacturers (OEMs), behöver de acceptans och stöd från sina OEM-kunder, men att få kundens acceptans är en utmaning för företagen. Studien visar att SME-företag måste avgöra om de ska designa PSS med sina kunder eller hitta affärsmöjligheter och designa PSS på egen hand, trots att de saknar väsentliga resurser som behövs för att designa PSS.

Nyckelord: Produkt-tjänstesystem (PSS), Små och medelstora företag, servitisering, utmaningar, SME-egenskaper, tillverkningsföretag, cirkulär ekonomi

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Jennie Åkesson

Eskilstuna, September 2022

List of Papers

This thesis is based on the following papers, which are referred to in the text by their Roman numerals.

- I. Åkesson, J., Johansson, G., Chirumalla, K., Grahn, S., Berglund, A. (2022) Design of Product-Service Systems in SMEs: A review of current research and future directions to enable a circular economy. In the second review round for publication in the *Journal of Manufacturing Technology Management*.
- II. Åkesson, J., Sundström, A., Chirumalla, K., Johansson, G. (2022) Exploring Challenges to Design Product-Service Systems in SMEs—A Case Study. *Proceeding of the 10th Swedish Production Symposium (SPS2022), Skövde, Sweden, April 26-29 2022. IOS Press.*

The paper was awarded the Best Paper Award within Integrated Product-Production Development based on the reviewer's scores.

- III. Åkesson, J., Sundström, A., Johansson, G., Chirumalla, K. (2022) The influence of Small and Medium-sized Enterprises' Characteristics on Product-Service-System design challenges. Completed manuscript ready to be submitted to *International Journal of Manufacturing Research*.

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Abbreviations

PSS	Product-Service Systems
CE	Circular Economy
SMEs	Small and Medium-sized Enterprises
SDGs	Sustainable Development Goals
OEM	Original Equipment Manufacturer

1 Introduction

This chapter describes the background of the research area and the problem statement. It also presents the aim and research questions. The chapter ends with an outline of the thesis.

1.1 Background

The global extraction of natural resources has grown by more than 90% in recent years and continues to increase (Giljum et al., 2014). One solution to the sustainability issues is a transition toward a circular economy (CE) (Giljum et al., 2014; Geissdoerfer et al., 2017), which refers to closing material cycles (Michelini et al., 2017) and reserving materials' economic and environmental value for as long as possible (Den Hollander et al., 2017), leading to changes in the current production and consumption model (Camilleri, 2019). Many definitions of a CE exist (Kirchherr et al., 2017), including “*a regenerative system in which resource input and waste, emission, and energy leakage are minimised by slowing, closing, and narrowing material and energy loops. This can be achieved through long-lasting design, maintenance, repair, reuse, remanufacturing, refurbishing, and recycling.*” (Geissdoerfer et al., 2017, p.759). The manufacturing industry is essential in the transition toward a CE and crucial to sustainable economic growth (Lieder and Rashid, 2016; Kumar et al., 2019), as it significantly impacts the environment (Garetti and Taisch, 2012). In addition, improving the sustainability of manufacturing companies is becoming increasingly central for business survival and long-term success (Yang et al., 2017; Oncioiu et al., 2018).

Sustainability in the manufacturing industry has been considered in government initiatives for a CE both globally and nationally. Globally, the European Commission (2019b) adopted the ‘Circular Economy Action Plan’ in 2015, describing the importance of designing products and services to minimize resource use. Nationally, the Swedish government established a CE delegation in 2018 to strengthen society’s efforts to move to a resource-efficient CE both nationally and regionally (Government Offices of Sweden, 2018). The delegation has highlighted the need to create new business models and enhance the ability of Swedish manufacturers to design products and services for

extended product lifecycles (Delegationen för Cirkulär Ekonomi, 2021). The European Commission also proposed a sustainable product policy legislative initiative to make products fit for a resource-efficient society (European Commission, 2022b) to support the Sustainable Development Goals (SDGs) set by the United Nations (European Commission, 2022a). As part of this initiative, the European Commission suggested incorporating into legislation sustainability principles regulating the incentive of offering Product-Service Systems (PSS) or related business models in which producers keep ownership of the product throughout its life-cycle (European Commission, 2020). PSS, which is seen as one of the most effective ways for manufacturing companies to contribute to a resource-efficient society and a CE (Tukker, 2015; Michelini et al., 2017; Garetti and Taisch, 2012; Pieroni et al., 2019; Kjaer et al., 2019), is defined in this thesis as *“a mix of tangible products and intangible services designed and combined so that they are jointly capable of fulfilling final customer needs”* (Tukker and Tischner, 2006, p.1552). PSS implies combining products and services in an integrated way through different types of business models (da Costa Fernandes et al., 2020), thereby creating closed material cycles and reducing consumption and product usage (e.g., Mont, 2002; Tukker, 2015; Kjaer et al., 2019; Michelini et al., 2017). PSS leads to an increase in product use through product sharing, leasing, or renting (Mont, 2002; Roy, 2000; Goedkoop et al., 1999), and the environmental impact can be reduced by adding services during the product use phase and services when the product reaches the end of life, such as reuse, repair, remanufacturing, and recycling (Camilleri, 2019; Barquet et al., 2016; Bocken et al., 2017). One example of PSS is Rolls Royce’s Total-Care Package offer to airlines. Instead of selling the gas turbine and transferring the ownership to the airlines, Rolls-Royce leases ‘power-by-the-hour’, meaning the airline pays for each hour the engine is used. By keeping the ownership and having direct access to data on product performance and use, Rolls-Royce can improve engine efficiency and asset utilization to reduce costs and environmental impact (Baines et al., 2007). PSS is considered an attractive way for manufacturing companies to attain environmental benefits as well as economic and social ones (Adrodegari et al., 2017; Vezzoli et al., 2015) while also improving their competitive advantage (Adrodegari et al., 2017; de Jesus Pacheco et al., 2019) and increasing customer loyalty and satisfaction (Hernandez-Pardo et al., 2013; Kowalkowski et al., 2013).

However, PSS must be purposely designed as it does not automatically lead to environmental benefits (Pigosso and McAloone, 2015). To design PSS, manufacturing companies need to shift from designing and selling tangible products to designing and providing a system (Ceschin, 2013; Sundin et al., 2009; Hallstedt et al., 2020). Designing PSS covers the combined design of both products and services (Mont, 2002; Aurich et al., 2006), resulting in solutions in the form of systems instead of tangible products (Nordin and

Kowalkowski, 2010). Thus, designing PSS includes designing the complete product-service system, not just the tangible product offering (Sundin et al., 2009; Hallstedt et al., 2020). Therefore, manufacturing companies must have a system approach (Mont, 2002) and involve all actors in the value chain when designing PSS (Hallstedt et al., 2020). Given such considerations, designing PSS is more complex than designing tangible products as it requires integrating and combining product and service competence, activities and methods (Kimita et al., 2018; Sakao and Lindahl, 2009).

1.2 Problem statement

Although PSS is considered essential for manufacturing companies in the transition toward a CE (Tukker, 2015; Michelini et al., 2017; Kjaer et al., 2019), the majority of studies in the PSS field have been conducted from the perspective of a large company (Hernandez-Pardo et al., 2013; Dey et al., 2020; Bassi and Dias, 2019; de Jesus Pacheco et al., 2019), with limited focus considering the context of small and medium-sized enterprises (SMEs). The European Union defines SMEs as: “*enterprises which employ fewer than 250 persons and which have an annual turnover not exceeding EUR 50 million, and/or an annual balance sheet total not exceeding EUR 43 million*” (European Union, 2003/361/EC). The limited focus of existing research is problematic as about 90% of all global enterprises are considered SMEs and employ 50% of the global workforce (The World Bank Group, 2022). Furthermore, the approximately 25 million European SMEs represent 99,8% of all European enterprises (European Commission, 2019a) and make up a large proportion of the manufacturing industry (Garetti and Taisch, 2012). SMEs also employ almost 70% of the European workforce, produce almost 60% of the total turnover from manufacturing and services, and produce approximately 64% of the industrial pollution in Europe (Calogirou et al., 2010); hence, SMEs are the core of the CE transition (European Commission, 2019a) by designing PSS (de Jesus Pacheco et al., 2019). By designing PSS, SMEs can contribute to the transition to a CE (Prieto-Sandoval et al., 2019; Dey et al., 2020). However, their success is not guaranteed as manufacturing SMEs are unique in their efforts to design PSS. SMEs have different characteristics compared to large companies (see, e.g., Ghobadian and Galleary, 1996; Ates et al., 2013; O'Dwyer and Ledwith, 2010; Storey, 2016), and the complexity of PSS can make it difficult for SMEs to design it (Hernandez-Pardo et al., 2013; de Jesus Pacheco et al., 2019). For instance, designing PSS requires resources, and this is challenging for SMEs as they usually do not possess the same resources as larger companies (de Jesus Pacheco et al., 2019; Hernandez-Pardo et al., 2013; García-Quevedo et al., 2020; Kowalkowski et al., 2013; Adrodegari et al., 2017).

Despite the limited number of studies on challenges SMEs face when designing PSS, they present several challenges (e.g., de Jesus Pacheco et al., 2019). However, several studies in this field focus on general challenges SMEs face in relation to CE activities, addressing PSS only partially (e.g. García-Quevedo et al., 2020; Garcés-Ayerbe et al., 2019); this includes an extensive survey on European SMEs (European Commission, 2016). In addition, some challenges SMEs face when designing PSS are suggested to be related to their characteristics (de Jesus Pacheco et al., 2019), yet this is not fully researched and only briefly mentioned in a few studies (e.g., de Jesus Pacheco et al., 2019; Hallstedt et al., 2020; Besch, 2005). Therefore, a deeper understanding of the challenges SMEs face when designing PSS is needed, also exploring their specific characteristics to understand SMEs' potential to support a CE through PSS design. Researchers in this field agree that more research is needed that focuses on SMEs within the PSS area (de Jesus Pacheco et al., 2019; Ahmad et al., 2019; Bassi and Dias, 2019; Hernandez-Pardo et al., 2013) as well as their specific characteristics (Bassi and Dias, 2019).

1.3 Aim and research questions

This thesis aims to contribute to the PSS and servitization literature by addressing the research gap and lack of insights in existing studies related to PSS design in a manufacturing SME context. Based on the aim, the following research questions have been formulated:

RQ1: What are the PSS design challenges faced by manufacturing SMEs?

RQ2: How do the characteristics of manufacturing SMEs influence the PSS design challenges?

1.4 Outline of the thesis

The thesis is comprised of six chapters and three appended papers. The content of each chapter is briefly presented here.

Chapter I **Introduction** describes the background of the research area and the problem statement. The aim and research questions are also presented.

Chapter 2 **Frame of reference** presents the theoretical framework around the key topics of this research.

- Chapter 3** **Research methodology** describes the chosen research design and methods. It presents the case selection and the case companies. The data collection and data analysis are described, including a discussion of the research quality.
- Chapter 4** **Summary of the appended papers** presents how the papers and research questions are connected, followed by a description of the authors' contributions to each paper. A summary of the papers included is presented.
- Chapter 5** **Discussion** includes a discussion of the research results in order to answer the research questions.
- Chapter 6** **Conclusions, contributions, limitations, and future research** presents the conclusions, including the theoretical and managerial implications. The chapter also discusses the study's limitations and suggestions for future research.

2 Frame of reference

This chapter presents the theoretical framework for this research, focusing on Product-Service Systems, PSS design, Small-and medium-sized enterprises, and challenges.

2.1 Product-Service Systems (PSS)

Since the middle of the 1990s, PSS have been a popular theme for researchers engaged with sustainability and businesses (Tukker, 2015). The concept of PSS has evolved since it was initially established (Beuren et al., 2013), and many alternative terms have been proposed and described by researchers. Table 1 presents an overview of the related terminology.

Table 1 Terminology related to the PSS concept

Term	References
Servitization	Vandermerwe and Rada (1988), Baines et al. (2009)
Productization	Harkonen et al. (2015), Baines et al. (2007)
Integrated product and service offerings	Sakao et al. (2013), Lindahl et al. (2014)
Integrated solutions	Windahl and Lakemond (2006), Davies (2004)
Circular solutions	Camacho-Otero et al. (2018)
Hybrid offerings	Ulaga and Reinartz (2011)
Service transition	Kowalkowski et al. (2015), Oliva and Kallenberg (2003), Martinez et al. (2017)
Functional sales	Sundin and Bras (2005), Beuren et al. (2013)
Service infusion	Brax (2005), Kindström and Kowalkowski (2014)

Nonetheless, all of the terms included in Table 1 tend to refer to integrated blends of products and services (Li et al., 2020). As the PSS field covers several research disciplines (Barravecchia et al., 2021; Li et al., 2020), such as business management, economics, marketing, sustainability, product design and engineering (Brambila-Macias et al., 2018; Mont and Tukker, 2006;

Baines et al., 2017), these alternative PSS terms are mixed in the existing PSS literature and sometimes used as synonyms (Beuren et al., 2013). The use of different terminology also differs due to the graphical origin and motivation of the terms. PSS is a Scandinavian concept that is more strongly linked with sustainability (Baines et al., 2007), has a strong product connection, and is related to the manufacturing and engineering research field (Barravecchia et al., 2021). The PSS research stream not only uses a variety of terms to describe the same concepts, but also suggests different definitions of the PSS concept (Haase et al., 2017). In this study, we adopt Tukker and Tischner's (2006) definition of PSS as "*a mix of tangible products and intangible services designed and combined so that they are jointly capable of fulfilling final customer needs*" (p.1552). Goedkoop et al. (1999, p.17) further clarify that "*a **product** is a tangible commodity manufactured to be sold*", whereas "*a **service** is an economic activity that does not result in ownership of a tangible asset*" (Baines et al., 2009, p.554), and "*a **system** is a collection of elements including their relations*" (Goedkoop et al., 1999, p.17). Based on these definitions, an element is considered a product, a service, or a system.

The field of PSS is a growing research field (Barravecchia et al., 2021) due to its potential to contribute to sustainability and enable a circular economy (Kjaer et al., 2019; Pieroni et al., 2019) while also contributing to the SDGs (Hidalgo-Carvajal et al., 2021; Labbate et al., 2020) by minimizing the environmental impact of consumption by closing material cycles and reducing product usage (Mont, 2002). PSS can lead to an increase in product use by sharing or renting, and it can extend material and product lifecycle by adding services during the use phase and for end of life, such as repair, remanufacturing, reuse and recycling (Camilleri, 2019; Barquet et al., 2016). Although many researchers link PSS with sustainability (see, e.g., Camilleri, 2019; Tukker, 2015; Barquet et al., 2016; Tukker, 2004; Yang and Evans, 2019; Baines et al., 2007; Reim et al., 2015), some authors see the purpose of PSS as a competitive value proposition and instead refer to customer satisfaction and economic benefits (Baines et al., 2007; de Jesus Pacheco et al., 2019). It should be noted that PSS does not automatically lead to increased sustainability; however, it is considered a promising approach to influence sustainable production and consumption patterns (de Jesus Pacheco et al., 2019) while simultaneously benefitting the manufacturer (Garetti and Taisch, 2012). Researchers within the PSS field have studied different aspects of PSS (Barravecchia et al., 2021), such as environmental impact (Tukker, 2015), business models (Reim et al., 2015), processes (Lightfoot et al., 2013), requirement analysis (Song, 2017), and design (Vasanthan et al., 2012).

2.1.1 PSS design

PSS design plays a crucial role in successful PSS offerings (Sundin et al., 2009). Traditional product development is defined as “*the set of activities beginning with the perception of a market opportunity and ending in the production, sale and delivery of a product*” (Ulrich and Eppinger, 2012, p.2). Meanwhile, designing PSS involves adding a service dimension to these activities (Sakao and Lindahl, 2009). Designing PSS involves designing both tangible products and services and the complete system around the product (Sundin et al., 2009; Hallstedt et al., 2020). Researchers have not reached a consensus on a holistic definition of PSS design (Annamalai et al., 2011), and PSS design and PSS development are used similarly or interchangeably in the literature (c.f., Shimomura et al., 2009; Kimita et al., 2015; Morelli, 2006; Morelli, 2003; de Jesus Pacheco et al., 2019; Hernandez-Pardo et al., 2013). However, the difference between designing products and services is that products are designed to satisfy customers through their features of dimensional, aesthetical, technological and mechanical properties (Kimita et al., 2009; Roy and Cheruvu, 2009), whereas services are based on activities (Morelli, 2003; Morelli, 2006) that are performed and not produced (Baines et al., 2009). To successfully design PSS, it is important to adopt a life cycle approach (Meier et al., 2010; Vasantha et al., 2012; Matschewsky, 2017; Sundin et al., 2009) and a predefined PSS design process (Aurich et al., 2006; Morelli, 2006) with integrated product and service design procedures (Kimita et al., 2009). These PSS design tasks should be performed simultaneously, leading to the need for interdisciplinary teams (Aurich et al., 2006; Morelli, 2003; Bertoni and Larsson, 2011), as it requires competence from several parts of the organization (Vihma and Moora, 2020). Research on PSS has produced several design methods (Vasantha et al., 2012; Tukker, 2015; Clayton et al., 2012; da Costa Fernandes et al., 2020; Cavalieri and Pezzotta, 2012; Salwin et al., 2020). These methods are cyclic and iterative because of the integrative character of the PSS design process (Clayton et al., 2012), although some researchers have argued that the existing PSS design methods are not sufficiently detailed, which hinders their practical application (Salwin et al., 2020).

Both product development and product design are vital in the PSS design process (Pigosso and McAloone, 2016; Adrodegari et al., 2017), as the product design influences the environmental impact during the PSS lifecycle (Geum and Park, 2011; Pigosso and McAloone, 2016). Designing products for PSS means designing for a prolonged life cycle and designing modular products and components (Mont et al., 2006), making the products easy to repair and maintain (Adrodegari and Saccani, 2020). As such, reversed logistics (Rogers and Tibben-Lembke, 2001) is crucial for PSS design, as products need to be collected and transported back to the manufacturer to be able to reuse,

remanufacture or recycle the products (Lüdeke-Freund et al., 2019). Research has also suggested that reversed logistics needs to be aligned with the product design to deliver solutions with a lower environmental impact (Bakker et al., 2014). Hence, designing PSS means modifying the product design thinking (Andrews, 2015).

The concept of PSS design has been discussed for many years. It is one of the most discussed topics in terms of publications within the PSS field (Barravecchia et al., 2021) and one of the essential activities for enabling a CE (Prieto-Sandoval et al., 2018). However, the uptake of PSS design among manufacturing organizations remains limited (Baines et al., 2017). Consequently, research on PSS design is still not mature (Barravecchia et al., 2021; Vezzoli et al., 2015; Matschewsky et al., 2018), and requirements regarding PSS design and the sustainability opportunities in the design process are lacking (Tukker, 2015; Zeeuw van der Laan and Aurisicchio, 2020).

2.2 Small and medium-sized enterprises (SMEs)

Due to today's complex business environment, it is difficult to draw the line between a small and a large company, as SMEs may be linked to other enterprises. The number of employees, turnover, and balance sheets are not the only factors that should be considered when defining whether an enterprise is an SME. For instance, the definition of an employee varies from country to country, and if a company has seasonal workers, part-time staff, or access to significant additional resources through a larger enterprise, it could affect whether the company is defined as an SME (European Commission, 2015). As few authors within the PSS field have defined SMEs, an assumption is made that the articles included in this thesis have a similar definition of SMEs as the one set by the European Union (2003). Within this SME definition, small enterprises are firms employing fewer than 50 persons, with an annual turnover and/or annual balance sheet total below EUR 10 million (European Union, 2003).

In addition to employees, turnover, and balance sheets, prior research on SMEs in different contexts has shown that several factors differentiate small firms from large ones (e.g., Ghobadian and Gallea, 1996; Ates et al., 2013; O'Dwyer and Ledwith, 2010; Storey, 2016). For instance, SMEs have limited resources compared to larger firms (Welsh and White, 1981; Garetti and Taisch, 2012) in terms of financial, time, knowledge, and human resources (Bos-Brouwers, 2010; Bridge and O'Neill, 2012; Ates et al., 2013). In addition, SMEs may have more difficulty obtaining external funding (Freel, 2007; Freel, 1999). However, SMEs are seen as flexible firms that can decide and act quickly as their internal processes usually consist of a short decision-

making chain with a low degree of formalization and standardization (Ghobadian and Gallear, 1996; Cristo-Andrade and Franco, 2019; Bos-Brouwers, 2010). In addition, SMEs' flexibility is considered one of their major advantages over larger firms (Fiegenbaum and Karnani, 1991) as it makes them adaptable to market changes (Ghobadian and Gallear, 1996).

SMEs' organizational structures also differ from those of larger firms as SMEs lack a clear division of activities with narrow specialization (Ghobadian and Gallear, 1996). SMEs are often seen as more innovative than larger firms (Tether, 1998) as their informal processes encourage creativity and experimentation, leading them to more innovative ideas (Schilling, 2005; Heunks, 1998). Their organizational structure and informal procedures can influence SMEs' effectiveness in innovation projects and their speed in developing new products (Schilling, 2005). SMEs' lack of resources makes them focus on short-term success (Berends et al., 2014), leading to a short-term vision (Bos-Brouwers, 2010). Therefore, SMEs differ from larger firms in terms of strategic orientation and innovativeness while focusing on the existing business and avoiding unnecessary risk by searching for new opportunities and only adapting to environmental changes when forced to do so (Kumar et al., 2012). As a result, SMEs are usually reactive to environmental practice (Williamson and Lynch-Wood, 2001; Greenan et al., 1997; Brammer and Pavelin, 2008) and perceive environmental issues as threats rather than opportunities (Greenan et al., 1997). Furthermore, SMEs are usually manufacturers that supply parts and components to other businesses, such as larger companies and original equipment manufacturers (OEMs) (Garetti and Taisch, 2012; Ghobadian and Gallear, 1996; Cristoni and Tonelli, 2018), leading SMEs to be more attached to and dependent on their customers than larger firms (Bos-Brouwers, 2010; Tödting and Kaufmann, 2001). As SMEs often are suppliers, asymmetrical relationships develop with customers (Flanckegård et al., 2021), creating a power imbalance in which the customer makes use of SMEs' resources but not the other way around (Casciaro and Piskorski, 2005). In sum, SMEs are not smaller versions of larger firms as they differ in terms of characteristics (Storey, 2016).

2.3 PSS design challenges in SMEs

The terminology makes it difficult for researchers to address PSS design challenges in SMEs. As research discussing the PSS challenges are within different research fields (e.g., manufacturing, engineering, environment, business, and management), the literature also mixes terminologies such as PSS and servitization (e.g., de Jesus Pacheco et al., 2019; Ahmad et al., 2019). The terminology of PSS design and PSS development are also used interchangeably in the research literature (e.g., de Jesus Pacheco et al., 2019; Hernandez-

Pardo et al., 2013), and there is also inconsistency considering the challenges as researchers refer to barriers, challenges, and issues without clearly defining these terms (c.f., de Jesus Pacheco et al., 2019; García-Quevedo et al., 2020; Dey et al., 2020). In this study, a challenge is defined as *any issue or problem encountered by the SMEs that needs significant effort to be overcome*. Consequently, in this study, challenges, barriers, and issues are seen as synonyms.

Prior research in this context has presented several challenges for SMEs when designing PSS; see de Jesus Pacheco et al. (2019) for a comprehensive literature review. The challenges relate to, for instance, a lack of financial resources (Ghenta and Matei, 2018; Hernandez-Pardo et al., 2013), a lack of sustainability competence (de Jesus Pacheco et al., 2019), a lack of methods for PSS design (de Jesus Pacheco et al., 2019) and regulations (Garcés-Ayerbe et al., 2019). Some of the identified challenges are considered essential for manufacturing SMEs, such as financial vulnerability, resistance to change, short-term management practices, and a lack of design competence, whereas others may also apply to large manufacturing companies (de Jesus Pacheco et al., 2019).

3 Research methodology

This chapter describes the chosen research design and methods. It presents the case selection and case companies and provides an overview of the data collection and data analysis processes. Finally, the chapter discusses the research quality.

3.1 Research design and methods

Research should fill a gap in existing knowledge or add to that knowledge; therefore, it is necessary to know what knowledge already exists (Karlsson, 2016). Consequently, the research process for this research started with a systematic literature review (Paper I) to be able to contribute to existing knowledge about PSS design. Reviewing the literature is an essential supporting tool—not only for the beginning stage of the research process, but also for other stages (Seuring and Gold, 2012), because a systematic literature review provides as complete of a list as possible of the published studies in a particular area and helps describe and explain current knowledge (Fink, 2019). The initial systematic literature review showed that the research area of PSS design in SMEs is still not mature (Vezzoli et al., 2015; Barravecchia et al., 2021), and most studies have been conducted using a quantitative approach, leading to arguments for more case studies to explore in which industrial contexts the PSS design challenges appear. Hence, the systematic literature review was followed by exploratory case studies as the research within PSS design in SMEs is limited, and case studies are suitable when a new phenomenon is to be explored (Yin, 2018; Karlsson, 2016) and are also often applied when the boundaries between a phenomenon and its context may not be clearly specified (Yin, 2018). Therefore, the systematic literature review was followed by a single in-depth case study approach (Paper II). Examining a single case allows for a greater depth of exploration (Yin, 2018; Karlsson, 2016). The single in-depth case study aimed to identify and describe the challenges SMEs face when designing PSS. This thesis also includes a multiple case study (Paper III) to develop a deeper understanding (Yin, 2018), as a multiple case study design allows exploring several cases and conducting a cross-case analysis (Eisenhardt, 1989), thereby complementing the findings presented in previous

papers and further contributing to the knowledge of PSS design within an SME context.

This thesis’s empirical findings are based on semi-structured interviews and workshops. These are further supported by internal archive documents related to the company’s organization and customer offerings, which the informants provided. Table 2 presents an overview of the research methods and data collection techniques used for the three papers included in the thesis. The systematic literature review and the case studies form the basis of the thesis.

Table 2 Overview of the research methods and data collection techniques

	Paper I	Paper II	Paper III
Aim	Contribute to knowledge about PSS design by presenting an investigation of current state-of-the-art and practices	Identify and describe challenges that SMEs may face when intending to design PSS	Contribute to knowledge on SMEs' characteristics and their influence on the challenges SMEs experience when designing PSS
Research method	Systematic literature review	Single Case Study Case company B	Multiple Case study Case companies A, B & C
Relation to RQ	RQ1	RQ1	RQ2
Data collection	Literature search of journal articles	Semi-structured interviews, workshops, and internal archive documents	Semi-structured interviews, workshops, and internal archive documents

3.2 Systematic literature review

To explore the PSS design research within the SME context, a systematic literature review (Grant and Booth, 2009; Dixon-Woods et al., 2006) was conducted in Paper I. A systematic literature review can be used to describe and explain current knowledge (Fink, 2019), in order to provide an overview of the research field. Such a literature review is considered the best type of review as it identifies, evaluates, and synthesizes existing research evidence in a systematic manner. A systematic review is transparent in the reporting of the methods in order to facilitate others’ efforts to replicate the process (Grant and Booth, 2009; Karlsson, 2016). Indeed, the systematic literature review in Paper I followed the procedure suggested by Jesson et al. (2011) to identify the main themes presented in the literature currently available on PSS design in manufacturing SMEs as well as identify beneficial research routes for further

research. The search string used in Paper I is presented in Table 3, and the search was limited to abstracts, titles, keywords, and topics in journal articles published in English.

Table 3 Search string used for the systematic literature review (Paper I, p.4)

design		“product service system”		“small and medium-sized”
OR	AND	OR	AND	OR
develop*		“product service systems”		SME
		OR		OR
		PSS		SMEs
		OR		OR
		serviti*		“small firms”
		OR		
		circular*		

Literature published between 1995 and February 2021 was searched; this period was selected because the concept of PSS was established in the middle of the 1990s (Tukker, 2015). The search identified 266 articles in the Scopus and Web of Science databases. These two databases were chosen as they are considered relevant in the PSS field (da Costa Fernandes et al., 2020; Barravecchia et al., 2021), cover high-quality primary publication sources (Harzing and Alakangas, 2016), and are suitable when conducting systematic literature reviews (Gusenbauer and Haddaway, 2020). The identified articles were then screened for eligibility. The criteria set for inclusion was as follows: 1) studies investigating the transition process to PSS and/or CE; 2) studies involving SMEs; 3) studies involving manufacturing companies; 4) studies covering PSS design-related issues; and 5) studies published in English. The criteria for exclusion were 1) studies investigating the PSS transition focusing exclusively on large companies and 2) studies involving non-manufacturing SMEs (e.g., tourism, software, textile). After carrying out the screening and eligibility process, 34 articles remained and were included in the review in Paper I. At least two researchers read each paper and a total of four researchers were involved in the extraction of data. A pre-design template was developed in Excel to guide the researchers in the data extraction process, which summarized each paper (e.g., type of study, PSS issues addressed, key findings, and suggestions for future research). However, as the data extraction process was iterative, the design template was further developed during the process. By providing a structured and transparent research process in this review, bias was mitigated compared to other reviews that do not strictly follow guidelines (Grant and Booth, 2009).

3.3 Case study

As research within PSS design in SMEs is still in the early stages, explorative case studies are needed to develop research ideas and questions worthy of deeper investigation (Karlsson, 2016; Voss et al., 2002). Prior research in the field of PSS design has focused on large manufacturing companies but has been limited in terms of the SME context (de Jesus Pacheco et al., 2019; Hernandez-Pardo et al., 2013). Therefore, a case study approach was deemed appropriate. In such an approach, a real-world phenomenon is investigated and understood, and this understanding is likely to involve critical contextual conditions relevant to the phenomenon being studied (Yin, 2018). In addition, the unique strength of the case study is its ability to deal with a full variety of evidence (Yin, 2018), such as data from interviews, workshops, and documents. Case research also allows for greater accuracy and reliability than survey research, as the researchers have direct access to the origin of the original data sources (Karlsson, 2016). This research consisted of a single case study including company B (Paper II) and a multiple case study including companies A, B, and C (Paper III). The case selection and the case companies are described next.

3.3.1 Case selection

Three manufacturing SMEs were selected for the study based on the aim of the case study and for theoretical reasons (Eisenhardt, 1989) to enable contribution to existing theory. The companies were selected using three criteria:

- 1. Meet the requirements for being defined as an SME**

All three companies are categorized as small firms as they employ between 24 and just under 50 employees and have turnover ranging between 4 M EUR and 8 M EUR.

- 2. Belong to the manufacturing industry**

All three companies belong to the manufacturing industry and operate as contract manufacturers in Sweden. Contract manufacturing is an arrangement by which a manufacturing firm (i.e., an OEM) outsources some of its manufacturing processes to an outside supplier through a contractual agreement. The OEM owns the product, and the contract manufacturer supplies labor and skills to manufacture the products (Kim, 2003; Han et al., 2012).

- 3. In the transition to design PSS**

All three companies are in the transition to design PSS.

A multiple case study design is appropriate for verifying whether the contextual conditions influence the conclusions (Yin, 2018); hence, the case study selection included three SMEs representing different product types that target different customer segments and different degrees of maturity regarding PSS design. The names of the companies are not disclosed and are referred to hereafter as Companies A, B and C.

Company A is a contract manufacturer that produces metal components mainly for OEMs in the heavy vehicle industry. Its biggest customers are located in Sweden, but it also has customers in other parts of the world. It is in the early stages of exploring the possibilities of designing PSS. Its current service offerings include product development and production optimization support to its customers. However, it does not charge for these services, which are instead included in the company's product offering. The company has a turnover of approximately 8 M EUR and employs 37 individuals.

Company B is a contract manufacturer for OEMs in the electronics industry, including a service provider for electric vehicle batteries. The company has roughly a hundred customers per year, both in Sweden and in other parts of the world. The company intends to change its current offering and market itself as a full-service partner; thus, it is beginning to design PSS. The company has a turnover of approximately 5 M EUR and employs approximately 50 individuals.

Company C is a contract manufacturer of polymer components for various industries, such as automotive, commercial kitchen and medical technology. Its customers are located all over the world. The company was previously only a producer of polymer components, but today offers PSS for a limited number of products. However, it wants to expand its offering and be able to offer PSS for several components; thus, it is looking for new PSS opportunities. The company's turnover is approximately 4.5 M EUR, and it employs 24 individuals.

3.3.2 Data collection

A good case study relies on as many sources of data as possible (Yin, 2018). The current research includes several data collection techniques: interviews, workshops, and internal archive documents. A part of the data collection was made possible by a larger related research project, that focuses on investigating circular business models and possibilities to prolong the lifespan of batteries for electric vehicles, such as trains and cars. The project includes solutions for how batteries could get a second life by adding, for example, remanufacture and reuse services, thereby reducing the environmental impact.

However, the data collection presented in this thesis was conducted based on the research questions of the current thesis and by the author of this thesis.

Interviews

Interviews were selected as they are an essential source of case study evidence (Yin, 2018; Karlsson, 2016). Most case studies involve human actions, and interviews can provide important insights into these actions (Yin, 2018). Interviews were conducted with senior managers in different organizational positions at all three case companies, such as Managing Director, Sales & Marketing, Production and Logistics, and Technical. Some informants had several different areas of responsibility or had experience as a former manager in other areas of the company. For example, the managing Director of Company A was also the Production Manager, and Company C's Technical & Key Account Manager was the former Production and Logistics Manager. Thus, they had competencies in several areas. Table 4 presents a summary of the interviews. It was essential to interview several managers as PSS design requires expertise in several parts of the organization and getting different managers' perspectives on challenges within their areas of responsibility reduced the risk of overlooking critical data. For this study, semi-structured interviews were conducted (Bryman, 2016). Open-ended questions are typical in case studies and often resemble guided conversations rather than structured questions (Yin, 2018). One advantage of open-ended questions is that the interviewer can develop follow-up questions to generate more in-depth answers and information from the interviewee (Bell, 2014), thereby resulting in an in-depth interview (Yin, 2018; Bryman, 2016). The reason for not conducting unstructured interviews is that a structure is needed to ensure cross-case comparability when carrying out multiple case study research (Bryman, 2016).

Ten interviews with nine managers were held remotely via face-to-face meetings online due to the covid-19 pandemic. The interviews were held individually with each manager, apart from a group interview conducted at the request of two managers from Company C. One individual follow-up interview was conducted with one of these managers as the other had limited time to conduct an individual follow-up interview. The interviews lasted between 45 and 91 minutes. All interviews were supported by an interview guide based on theoretical concepts from the literature on SMEs and PSS design; they also included questions about the informant's background and position within the company. Appendix A presents the complete interview guide. Parts of the interview guide were used as a basis for Papers II and III. Hence, this thesis only addresses some parts of the interview guide. All interviews were recorded and transcribed. Six of the interviews were held in Swedish, and the remaining four were conducted in English. A back translation technique was used when the Swedish interviews were translated into English (Regmi et al., 2010).

Table 4 Overview of interviews from Companies A, B and C

Interview	Informant title	Type of interview	Case company	Duration
1	Managing Director	Individual	A	1hr 26 min
2	Technical Manager	Individual	A	1hr 25 min
3	Managing Director	Individual	B	58 min
4	Managing Director	Follow-up individual	B	1hr 19 min
5	Sales & Marketing Manager	Individual	B	1hr 13 min
6	Quality & Sustainability Manager	Individual	B	49 min
7	Production & Logistics Manager	Individual	B	1hr 31 min
8	Managing Director	Individual	C	1hr 21 min
9	Communication & Marketing Manager Technical & Key Account Manager	Group	C	58 min
10	Communication & Marketing Manager	Follow-up individual	C	45 min

Workshops

A workshop is defined as a group of people engaged in a meeting to share their experiences with a scientific subject. The exchange among the participants can generate new results, insights, and ideas that were not previously known. Data from workshops can also help understand data collected during interviews (Säfsten and Gustavsson, 2020). The empirical data from the workshops were collected within the related research project described herein. The author of this thesis was given access to participate and collect empirical data based on the research questions for this research project. This access made it possible to carry out two workshops with Company B and get additional data and insights into the organization.

The two workshops with Company B were held remotely online due to the covid-19 pandemic and lasted between 60 and 90 minutes, see Table 5 for an overview of the workshops. They included the researchers, the Managing Director, and the Sales & Marketing Manager. The workshops supported the researchers in understanding the company's current product and service offerings, and they gave insights into potential PSS business opportunities and challenges related to designing PSS. The workshops also provided an

opportunity to understand the company’s organizational structure and processes, which included a digital tour of the premises. The research process for this study began with Company B as a single case study and was later expanded to include two additional cases, although workshops were not conducted with Companies A and C due to the companies’ lack of time.

Table 5 Overview of the workshops

Workshop	Participants	Case company	Date	Duration
1	Researchers, Managing Director, Sales & Marketing Manager	B	28/04/2021	90 min
2	Researchers, Managing Director, Sales & Marketing Manager	B	27/05/2021	60 min

Documents

Documentary information, whether paper or electronic, is relevant to every case study topic (Yin, 2018). Informants provided documents such as process- and company descriptions during the workshops and interviews. In addition, documents such as sustainability reports and certificates were collected from each company’s website. However, documents can be biased (Karlsson, 2016); therefore, the data from the interviews and workshops were cross-checked by comparing statements and quotes with the documents.

3.4 Data analysis

The data in the study were analyzed using a qualitative content analysis (Seuring and Gold, 2012) and a thematic analysis (Braun and Clarke, 2006). The data gathered during the systematic literature review (Paper I) were analyzed using a qualitative content analysis, which is suitable when existing knowledge of the studied area is limited (Säfsten and Gustavsson, 2019). A qualitative content analysis is a suitable analysis process used for conducting rigorous, systematic, and reproducible literature reviews (Seuring and Gold, 2012), which is defined as *“a research method for the subjective interpretation of the content of text data through the systematic classification process of coding and identify themes and patterns”* (Hsieh and Shannon, 2005, p. 1278). This technique facilitates the categorization of emerging themes from the data (Bell et al., 2019) and guides the researchers in a transparent and systematic way to produce highly valid and reliable findings (Seuring and Gold, 2012). The process began with reading through all the identified articles to create an overall picture, followed by reading the articles in detail to identify salient

themes. The process was iterative, using mind-mapping techniques to cluster the themes found and compiling them into overarching themes.

The case studies were analyzed using a thematic analysis (Braun and Clarke, 2006). Yin (2018) defined the case as the unity of inquiry in a case study, thereby making it the unit of analysis. The unit of analysis in this study was PSS design in the context of manufacturing SMEs. For the single case study (Paper II), the initial codes for the thematic analysis were theoretically driven by the identified challenges found in prior research (Paper I). Furthermore, the transcriptions of the interviews were read systematically, leading to additional codes grouped into themes. These themes were then compiled into overarching themes. For the multiple case study (Paper III), the analysis began with a within-case analysis of each case. The coding was theoretically driven and supported by prior research of SMEs' characteristics and the identified challenges found in prior studies (Papers I and II). Next, a cross-case analysis was conducted (Eisenhardt, 1989) to compare the cases in terms of similarities and differences in the identified SMEs' characteristics and challenges between the cases. Blurred boundaries were discovered during the analysis of the identified SME characteristics and challenges, which led to discussions among the researchers to agree on the coding. As all interviews in the case studies were recorded and then transcribed, the analysis of the empirical data was supported using NVivo 12 to structure and code the data through the analysis.

3.5 Research quality

Yin (2018) emphasizes the difficulty in managing internal validity when conducting case study research. Although the data collection may have to rely heavily on information from individual interviews, the conclusions cannot be based exclusively on the interviews as a source of information in a case study when the case is an organization. However, using triangulation with multiple means of data collection (e.g., interviews, workshops, and documents) strengthens the internal validity (Karlsson, 2016).

A single case study generates a greater depth of exploration, yet it limits the generalizability of the conclusions drawn (Karlsson, 2016). Meanwhile, multiple cases have higher external validity than single cases, suggesting the results can be generalized beyond the specific research context (Bryman, 2016), which could be a problem when conducting a single case study (Yin, 2018). Conducting a multiple case study also increases the external validity and helps reduce biases but produces less depth per case (Karlsson, 2016; Yin, 2018). Therefore, this thesis includes both a single case and a multiple case study. The systematic literature review further supports this approach, thereby strengthening the external validity, as analytical generalization can be

achieved by comparing empirical findings and existing theory (Yin, 2018). Furthermore, this research includes companies representing different product types that target different customer segments and different degrees of maturity regarding PSS, which increases the possibility that the results from the study are applicable to different contexts (Merriam and Tisdell, 2015).

Reliability refers to the study being transparent in the sense that other researchers could replicate the research and come to the same conclusion in the same setting (Karlsson, 2016). Hence, the goal of reliability is to minimize errors and biases (Yin, 2018). To strengthen the reliability, at least two researchers were involved in the data extraction, coding, and analysis for each paper included in this thesis. In addition, the interviews were recorded with both video and audio and then transcribed. By recording and transcribing the interviews, the researchers' biases and misinterpretations could be minimized (Bell, 2014). Although the interviews were conducted online, they can be considered face-to-face interviews as the video allowed the researchers to see the informants' body language and facial expressions. Face-to-face interviews are suggested to provide a higher quality of data than a telephone interview (Bryman, 2016) by contributing to a sense of mutual trust between the interviewer and the informant (Säfsten and Gustavsson, 2020). However, it is vital not to neglect the impact of the interviewer on the informants when conducting interviews. In several interviews, the informants were indirectly influenced by the questions asked and paused the interview to note new ideas; as a result, the so-called interviewer effect may have contributed to a lower level of reliability (Säfsten and Gustavsson, 2020).

4 Summary of appended papers

This chapter presents a discussion of how the papers and research questions are connected, followed by a description of the authors' contributions to each paper. Finally, a summary of the three papers is offered.

4.1 Connection between the papers and research questions

Based on the aim of this thesis, the following two research questions were formulated:

RQ1: What are the PSS design challenges faced by manufacturing SMEs?

RQ2: How do the characteristics of manufacturing SMEs influence the PSS design challenges?

The findings from Papers I and II contribute to answering RQ1 by identifying the internal and external challenges experiences when SMEs aim to design PSS. Paper III contributes to answering RQ2 by identifying the characteristics of SMEs that influence the challenges SMEs experience when designing PSS.

4.2 Authors' contributions to the papers

Paper I was written by Åkesson, Johansson, Chirumalla, Grahn, and Berglund. The study was initiated and designed by Åkesson, who was responsible for the data collection. All authors contributed to the data extraction and conceptualization. Åkesson carried out the data analysis with the support of the co-authors. In addition, Åkesson wrote the manuscript, and the co-authors provided comments and feedback.

Paper II was written by Åkesson, Sundström, Chirumalla and Johansson. Åkesson designed the study with the co-authors and was responsible for the empirical data collection. Åkesson analyzed the data with the support of the co-authors. Åkesson wrote the manuscript and Sundström, Johansson and Chirumalla provided feedback and comments. Åkesson was the corresponding author and presented the paper.

Paper III was written by Åkesson, Sundström, Johansson and Chirumalla. Åkesson designed the study with the co-authors and was responsible for the empirical data collection. Åkesson carried out the data analysis with support from Sundström. Åkesson wrote the manuscript and Sundström, Johansson and Chirumalla provided feedback and comments.

4.3 Paper I

Introduction

The study in Paper I identifies and presents a detailed overview of the key themes in the PSS literature addressing PSS design in SMEs. The study is based on a systematic literature review and addresses the following two research questions: 1) Which prominent themes emerge from the literature on product-service systems (PSS) in SMEs to enable a circular economy? 2) How can the literature on PSS in SMEs be advanced?

Findings

Paper I identified six main themes regarding PSS design in SMEs in prior research. These themes are: 1) motives to engage in PSS design, 2) barriers to engage in PSS design, 3) methods for PSS design, 4) realization of business models through PSS design, 5) implementation of PSS design, and 6) design guidelines for PSS design. These themes are further presented in a tentative model showing their interrelations. The framework shows the complexity that SMEs face in their ambition to design PSS, as the themes are interconnected and overlapping. The barriers SMEs face in engaging in PSS design were the most mature theme found, revealing that SMEs face several barriers to designing PSS. However, prior research lacks consensus regarding the barriers and the motives for SMEs to design PSS. The findings also indicate the importance of SMEs in the CE transition, yet few studies have addressed ways to overcome the barriers SMEs face, and prior research offers limited guidance for SMEs on how to design PSS. The findings suggest that more research is needed regarding SMEs' characteristics to develop suitable methods for designing PSS in SMEs, as prior studies have mainly focused on large companies and omitted SMEs' characteristics.

Contributions to the thesis

Paper I contributes to answering RQ1 by identifying numerous internal and external challenges SMEs face in engaging in PSS design. Paper I also provides arguments suggesting the need for more case studies to understand the challenges as well as more research regarding SMEs' characteristics in relation to PSS design.

4.4 Paper II

Introduction

Paper II sought to identify and describe internal and external challenges SMEs may face when designing PSS. The study addressed the following research question: What challenges are prominent for SMEs when aiming to design PSS? The study adopted a single case study design and presents empirical data from Company B.

Findings

The study identified nine challenges an SME is experiencing when designing PSS. These challenges can be described from both internal and external perspectives. The internal challenges are related to time constraints, the current business model, lack of financial resources, organizational structure and internal processes, dedicated employees for business and service development, and competence. The external challenges are related to the SME's position in the value chain, customer interests in PSS solutions, and the handling of reversed logistics. Based on the findings, SMEs have limited resources, so they find it challenging to design PSS; this finding is consistent with prior research. The findings also identify time as another limited resource and a challenge to consider and indicate that the challenges are interwoven, causing SMEs to have difficulty prioritizing when they are designing PSS. The paper also highlights the importance of the context when discussing the challenges SMEs face when designing PSS as the organization's position in the value chain and being a contract manufacturer create additional challenges.

Contributions to the thesis

Paper II contributes to addressing RQ1 by identifying and describing the internal and external challenges SMEs face when designing PSS. It also helps address RQ2 as the findings suggest that SMEs' characteristics influence the challenges SMEs experience when designing PSS and that the context of the SMEs is important to consider when discussing the challenges.

4.5 Paper III

Introduction

Paper III describes how SME characteristics influence challenges when designing PSS, with the aim of contributing to knowledge on SMEs' characteristics and their influence on the challenges SMEs experience when designing PSS. The study addressed the following research question: How do characteristics of SMEs influence the challenges when designing PSS? The study was based on a multiple case study design approach and presents empirical data from Companies A, B and C.

Findings

Paper III presents findings indicating that SMEs' characteristics influence the challenges SMEs face when designing PSS. These characteristics include SMEs having a lack of capital, time, human resources, skilled personnel, and organizational structure as well as being a supplier to OEMs, having asymmetrical relationships with customers, being customer dependent, and having a low degree of formalization and standardization. Each of these characteristics is suggested to influence one or more challenges related to PSS design in SMEs. The results also indicate that, due to the SMEs' characteristics, a short-term horizon and a more reactive business strategy are promoted, as they influence the overall challenge when designing PSS.

Contributions to the thesis

Paper III contributes to answering RQ2 by identifying and describing the characteristics of SMEs that influence the challenges SMEs experience when designing PSS.

5 Discussion

This chapter presents a discussion of the research results, organized in relation to the two research questions.

5.1 PSS design challenges for manufacturing SMEs

This section discusses the first research question: What are the PSS design challenges faced by manufacturing SMEs? In Paper I, the challenges from the current PSS design literature in the SME context were identified and mapped, and Paper II describes the challenges based on a case study of an SME. Although Paper I demonstrated that the literature on PSS design in manufacturing SMEs is scarce, the existing literature has identified numerous challenges for SMEs designing PSS. The empirical findings from Paper II also support that manufacturing SMEs face several challenges when designing PSS. The main challenges found in Papers I and II are categorized into internal and external challenges.

5.1.1 Internal challenges

According to the findings presented in Paper I, one of the internal challenges for SMEs designing PSS found in prior research is a lack of financial resources (de Jesus Pacheco et al., 2019). A lack of resources, such as financial resources, may influence whether SMEs consider designing PSS or not (Ahmad et al., 2019). Paper II also provides empirical support for the finding that financial resources are a challenge when SMEs are to designing PSS. Furthermore, Paper II presents empirical findings that SMEs have challenges dedicating employees to service development; this challenge was also identified in Paper I. The findings indicate that the studied SMEs need employees devoted to business and service development to design PSS. However, as SMEs lack human resources (Garcés-Ayerbe et al., 2019; Ghenta and Matei, 2018; Oncioiu et al., 2018), they face challenges when designing their PSS business model (Adrodegari et al., 2017).

In addition, the informants from the SMEs included in this research indicated that they are hesitant to change their business model as they believe it requires

a shift from being a contract manufacturer to becoming product owners, meaning they need to think in a new direction if they want to design PSS. This supports prior research implying that resistance to change is a challenge as it requires adopting a new attitude (de Jesus Pacheco et al., 2019; Hernandez-Pardo et al., 2013). Empirical findings from Paper II also indicate that organizational structure and internal processes are challenging for SMEs when designing PSS. Paper I identified these challenges as well, which are associated with SMEs' lack of resources, making it difficult for SMEs to build new organizational units given their limited human and financial resources (Kowalkowski et al., 2013).

Additional challenges are related to the competence needed for PSS design, according to Paper I. SMEs are suggested to lack knowledge and competencies related to design and sustainability (Hernandez-Pardo et al., 2013; de Jesus Pacheco et al., 2019) and expertise related to designing PSS (Garcés-Ayerbe et al., 2019; Hernandez-Pardo et al., 2013). Findings from the studied SMEs support prior research and indicate that competence is a challenge, although they disagree on the competencies needed for PSS design.

5.1.2 External challenges

Empirical findings in Paper II indicate that, as contract manufacturers, SMEs' position in the value chain is perceived as a challenge as they depend on their OEM customers' acceptance to design PSS. Due to customer resistance, the studied SMEs found it challenging to transition from being a contract manufacturer to a product owner. Paper I emphasizes that not getting customers' acceptance can limit PSS design and that SMEs should strive for customer acceptance (Dey et al., 2020; Dmitrijeva et al., 2020). However, Paper II also provides empirical support that customer interest in PSS solutions is a challenge as the SMEs in the study believe the customer demand for services is low. In addition, empirical findings indicate that discussing potential PSS offerings with their customers is perceived as a challenge for SMEs. This finding supports prior research presented in Paper I, which indicated that SMEs have difficulty initiating the partnerships needed for PSS design (Vihma and Moora, 2020; de Jesus Pacheco et al., 2019).

In addition, empirical findings indicate that, due to poor communication with their customers, SMEs have difficulty handling product returns, as designing PSS leads to reversed logistics (Lewandowski, 2016; Lüdeke-Freund et al., 2019). The studied SMEs are contract manufacturers to OEMs, so they do not own the products and are usually not responsible for the products delivered to the end-customer (Dey et al., 2020); consequently, there are uncertainties about which responsibilities fall on them when it comes to after-sales services, such as repairs.

According to Paper I, one of the external challenges for SMEs designing PSS is related to regulations and administrative processes. However, unlike prior studies (e.g., Mura et al., 2020; García-Quevedo et al., 2020; Garrido-Prada et al., 2021; Cantú et al., 2021; Ghenta and Matei, 2018), the empirical findings in this study do not indicate that regulations and administrative processes are considered a challenge for SMEs designing PSS. However, prior research does not fully agree on the impact of regulations as it is presented both as one of the most critical challenges (Garcés-Ayerbe et al., 2019) and as the least critical challenge (Mura et al., 2020).

5.2 SME characteristics influencing the PSS design challenges

This section discusses the second research question: “How are PSS design challenges influenced by manufacturing SMEs characteristics?” The PSS design challenges related to SMEs characteristics are described in Paper III.

The study confirms that many challenges prevent SMEs from designing PSS and that SMEs’ characteristics influence several of these challenges. Most SMEs are characterized by limited capital (Bos-Brouwers, 2010), which influences their possibility to invest in PSS design, such as employing skilled personnel dedicated to service development, developing their current knowledge, or devoting time to develop their internal procedures. In other words, SMEs’ characteristics influence one or more challenges when designing PSS. SMEs are also characterized by limited time (Bos-Brouwers, 2010), which challenges SMEs as the studied SMEs consider designing PSS to be time consuming. In light of SMEs’ limited capital and limited time, they focus on short-term success (Berends et al., 2014) and have a short-term vision (Bos-Brouwers, 2010). As SMEs depend on few employees (European Union, 2003), their staff are occupied with the daily business to survive and cannot focus on designing PSS, which influences the overall challenge of designing PSS.

SMEs’ size and being contract manufacturers and suppliers to larger OEMs (Ghobadian and Gallear, 1996) also influence challenges related to creating a new PSS business model. SMEs are dependent on their customers’ interest in PSS design, although the SMEs in the study indicated that they lacked the possibility to increase their customers’ interest in PSS due to their asymmetrical relationships (Flankegård et al., 2021), in which the customers hold the power. This also challenges SMEs to initiate the partnerships needed for PSS

design. In addition, SMEs are considered flexible firms (Ghobadian and Gallear, 1996; Cristo-Andrade and Franco, 2019), which is perceived as one of their strengths (Fiegenbaum and Karnani, 1991). The findings in this research show that being flexible and having a low degree of formalization and standardization procedures creates challenges with reversed logistics (Rogers and Tibben-Lembke, 2001), which is a vital part of PSS design (Lüdeke-Freund et al., 2019; Bakker et al., 2014).

6 Conclusions, contributions, limitations, and future research

This chapter presents the conclusions, including the theoretical and managerial implications. The chapter also discusses the study's limitations and suggestions for future research.

6.1 Conclusions

The studies presented in this thesis show that manufacturing SMEs face several internal and external challenges when designing PSS and that SMEs' characteristics influence the challenges. The empirical findings are consistent with prior research, which emphasizes that SMEs' limited resources, such as financial and human resources, create internal challenges when designing PSS (see, e.g., Adrodegari et al., 2017; de Jesus Pacheco et al., 2019). Due to SMEs' characteristics of having limited resources, they have a short-term vision, which influences the overall possibilities of designing PSS. This study further also adds to the internal challenges by identifying time constraints as a challenge to consider when SMEs are designing PSS. Due to SMEs' short-term vision, they are occupied with daily business activities and are unable to focus on designing PSS.

Furthermore, the identified challenges for PSS design in SMEs are related to different parts of the organization and are also interconnected and overlapping. Some SMEs' characteristics, such as a lack of financial resources, influence more than one challenge. SMEs' lack of financial resources influences their possibility to invest in PSS design, such as employing skilled personnel dedicated to service development or developing their current knowledge, making it difficult for SMEs to know which challenges to prioritize. This means that SMEs must secure financial resources to design PSS. Therefore, government support programs that include financial incentives can play a critical role for SMEs to contribute to a CE (European Commission, 2022c). In addition, SMEs should strive for customer acceptance and support when designing PSS. However, as the studied SMEs are contract manufacturers, they need their OEM customers' acceptance to design PSS, but getting acceptance and support from customers is not a given. Thus, SMEs must decide if they should

design PSS with their customers or find a business opportunity and design PSS independently, despite lacking the vital resources needed for PSS design.

6.2 Theoretical contribution

Although the research on PSS design for SMEs has presented numerous challenges (e.g., de Jesus Pacheco et al., 2019), this study adds to existing PSS literature by showing that researchers disagree about these challenges and that they are interwoven and influenced by SMEs' characteristics. Second, previous research has not linked the challenges SMEs face when designing PSS to the characteristics of SMEs, and this study shows that specific characteristics, such as a lack of financial and human resources (Bos-Brouwers, 2010; Bridge and O'Neill, 2012; Ates et al., 2013), can directly be a shortcoming for SMEs when designing PSS. Third, this study shows the importance of the context and characteristics of SMEs when discussing the challenges manufacturing SMEs face when designing PSS as SMEs differ compared to large companies (Ghobadian and Gallea, 1996; Ates et al., 2013; O'Dwyer and Ledwith, 2010; Storey, 2016; Welsh and White, 1981) which contributes to increased understanding of PSS design in an SME context.

Based on these theoretical contributions, this study adds knowledge to the existing PSS literature by focusing on PSS design in manufacturing companies in an SME context, as prior research has focused on larger manufacturing companies and omitted SMEs characteristics (e.g., Baines et al., 2007; Martinez et al., 2010; Michelini et al., 2017; Isaksson et al., 2009; Barravecchia et al., 2021; Tukker, 2015). In addition, as PSS and servitization fields are strongly related (Barravecchia et al., 2021) and explore the same concept but originate from different disciplines and motivations (Baines et al., 2007; Baines et al., 2017), this study adds knowledge to the research community related to servitization.

6.3 Managerial implications

This study also provides managerial implications for SME managers who are seeking to design PSS. First, the study shows that SMEs need to consider and overcome many challenges to enable a PSS design. Hence, SMEs need to be aware of the challenges and identify them in their organizations, and the identified challenges can be used as a checklist for managers in manufacturing SMEs. Second, as SMEs lack vital resources to design PSS, such as finance, time, knowledge, and human resources (Bos-Brouwers, 2010; Bridge and O'Neill, 2012; Ates et al., 2013), they need to review their resources and prioritize among the challenges. Third, as designing PSS requires a systems

approach and involves all actors in the value chain, SMEs could benefit from involving their customers and getting their perspective during the design process to increase the chances of successfully designing PSSs and overcoming some of the identified challenges.

6.4 Limitations and suggestions for future research

This thesis focuses on PSS design in SMEs, and although the thesis presents several challenges and provides insights into the influence of SMEs' characteristics, the study has several limitations, and future research is needed. First, the systematic review has limitations in the form of the sample size as the analysis included journal articles from only two databases. Although the databases are considered relevant for the topic (e.g., da Costa Fernandes et al., 2020) and method (e.g., Gusenbauer and Haddaway, 2020), additional searches covering other literature, such as conference papers and other databases, might identify relevant literature, further contributing to the findings presented in this thesis.

Although this study includes three manufacturing case companies representing different industries and products, studying an increased number of case companies is recommended to strengthen the generalizability of the findings. This study can also be used as a basis for conducting a survey including a more significant number of companies to supplement the findings in this study. Future studies could also cover the PSS design challenges at different stages of the PSS design process to explore if and how the identified challenges change over time, as research by Garcés-Ayerbe et al. (2019) indicated that the challenges may vary depending on the degrees of PSS design maturity in the SMEs. Thus, comparing companies in different stages of the PSS design process or conducting a longitudinal study (Yin, 2018) is recommended.

Due to the covid-19 pandemic, direct observations could not be carried out at the case companies' premises in this study. Therefore, further research should include observations as a data collection technique as evidence from observations is often helpful in providing additional information and is considered a strength of qualitative case studies (Yin, 2018; Merriam and Tisdell, 2015). Additional challenges or influential character traits may have been missed due to this limitation. Another limitation is that additional data were gathered through workshops with Company B, which were not held with Company A or Company C due to the companies' lack of time. In addition, more interviews were conducted with Company B than with the other two companies. As a result, the empirical data presented in this thesis may be biased toward Company B and may not represent all three companies equally.

The three SMEs included in this thesis are characterized as small companies, as they employ fewer than 50 persons and have a total annual turnover below EUR 10 million (European Union, 2003). Hence, it would be fruitful to include medium-sized companies in future studies. It would also be valuable to include both SMEs and large manufacturing companies in future studies to make a comparison. Although the findings in this thesis suggest that many of the challenges SMEs face when designing PSS depend on their characteristics, some challenges may also be more general and apply to larger manufacturing companies, as designing PSS is considered a complex task (Beuren et al., 2017). Finally, this study focuses on the challenges SMEs face when designing PSS; this field would benefit from additional studies exploring what enables SMEs to overcome these challenges.

7 References

- Adrodegari, F. and Saccani, N. (2020). "A maturity model for the servitization of product-centric companies", *Journal of Manufacturing Technology Management*, Vol. 31 No. 4, pp. 775-797.
- Adrodegari, F., Saccani, N., Kowalkowski, C. and Vilo, J. (2017). "PSS business model conceptualization and application", *Production Planning & Control*, Vol. 28 No. 15, pp. 1251-1263.
- Ahmad, A. H., Shafaruddin, N., Masri, R., Rahman, N. R. A. and Hussin, W. S. W. (2019). "Theorizing servitisation for SME performance", *International Journal of Financial Research*, Vol. 10 No. 5, pp. 66-74.
- Andrews, D. (2015). "The circular economy, design thinking and education for sustainability", *Local Economy*, Vol. 30 No. 3, pp. 305-315.
- Annamalai, G., Roy, R. and Cakkol, M. 2011. Problem definition in designing product-service systems. *Functional Thinking for Value Creation*. Springer.
- Ates, A., Garengo, P., Cocca, P. and Bititci, U. (2013). "The development of SME managerial practice for effective performance management", *Journal of Small Business and Enterprise Development*, Vol. 20 No. 1, pp. 28-54.
- Aurich, J. C., Fuchs, C. and Wagenknecht, C. (2006). "Life cycle oriented design of technical Product-Service Systems", *Journal of Cleaner Production*, Vol. 14 No. 17, pp. 1480-1494.
- Baines, T., Ziaee Bigdeli, A., Bustinza, O. F., Shi, V. G., Baldwin, J. and Ridgway, K. (2017). "Servitization: revisiting the state-of-the-art and research priorities", *International Journal of Operations and Production Management*, Vol. 37 No. 2, pp. 256-278.
- Baines, T. S., Lightfoot, H. W., Benedettini, O. and Kay, J. M. (2009). "The servitization of manufacturing: a review of literature and reflection on future challenges", *Journal of Manufacturing Technology Management*, Vol. 20 No. 5, pp. 547-567.
- Baines, T. S., Lightfoot, H. W., Evans, S., Neely, A., Greenough, R., Peppard, J., Roy, R., Shehab, E., Braganza, A. and Tiwari, A. (2007). "State-of-the-art in product-service systems", *Proceedings of the Institution of Mechanical Engineers, Part B: journal of engineering manufacture*, Vol. 221 No. 10, pp. 1543-1552.

- Bakker, C., Wang, F., Huisman, J. and den Hollander, M. (2014). "Products that go round: exploring product life extension through design", *Journal of Cleaner Production*, Vol. 69, pp. 10-16.
- Barquet, A. P., Seidel, J., Seliger, G. and Kohl, H. (2016) "Sustainability Factors for PSS Business Models". *Procedia CIRP*. 436-441.
- Barravecchia, F., Franceschini, F., Mastrogiacomo, L. and Zaki, M. (2021). "Research on product-service systems: topic landscape and future trends", *Journal of Manufacturing Technology Management*, Vol. 32 No. 9, pp. 208-238.
- Bassi, F. and Dias, J. G. (2019). "The use of circular economy practices in SMEs across the EU", *Resources Conservation and Recycling*, Vol. 146, pp. 523-533.
- Bell, E., Bryman, A. and Harley, B. (2019). *Business research methods*, Oxford University Press.
- Bell, J. (2014). *Doing Your Research Project: A guide for first-time researchers*, McGraw-Hill Education (UK).
- Berends, H., Jelinek, M., Reymen, I. and Stultiens, R. (2014). "Product Innovation Processes in Small Firms: Combining Entrepreneurial Effectuation and Managerial Causation", *Journal of Product Innovation Management*, Vol. 31 No. 3, pp. 616-635.
- Bertoni, M. and Larsson, A. (2011). "Engineering 2.0: an approach to support cross-functional teams in overcoming knowledge-sharing barriers in PSS design", *International Journal of Product Development*, Vol. 15 No. 1-3, pp. 115-134.
- Besch, K. (2005). "Product-service systems for office furniture: Barriers and opportunities on the European market", *Journal of Cleaner Production*, Vol. 13 No. 10-11, pp. 1083-1094.
- Beuren, F. H., Ferreira, M. G. G. and Miguel, P. A. C. (2013). "Product-service systems: a literature review on integrated products and services", *Journal of Cleaner Production*, Vol. 47, pp. 222-231.
- Beuren, F. H., Sousa-Zomer, T. T. and Cauchick-Miguel, P. A. (2017). "Proposal of a framework for product-service systems characterization", *Producao*, Vol. 27.
- Bocken, N. M. P., Olivetti, E. A., Cullen, J. M., Potting, J. and Lifset, R. (2017). "Taking the Circularity to the Next Level: A Special Issue on the Circular Economy", *Journal of Industrial Ecology*, Vol. 21 No. 3, pp. 476-482.
- Bos-Brouwers, H. E. J. (2010). "Corporate sustainability and innovation in SMEs: Evidence of themes and activities in practice", *Business Strategy and the Environment*, Vol. 19 No. 7, pp. 417-435.
- Brambila-Macias, S. A., Sakao, T. and Kowalkowski, C. (2018). "Bridging the gap between engineering design and marketing: insights for research and practice in product/service system design", *Design Science*, Vol. 4, pp. e7.

- Brammer, S. and Pavelin, S. (2008). "Factors influencing the quality of corporate environmental disclosure", *Business Strategy and the Environment*, Vol. 17 No. 2, pp. 120-136.
- Braun, V. and Clarke, V. (2006). "Using thematic analysis in psychology", *Qualitative Research in Psychology*, Vol. 3 No. 2, pp. 77-101.
- Brax, S. (2005). "A manufacturer becoming service provider - challenges and a paradox", *Managing Service Quality*, Vol. 15 No. 2, pp. 142-155.
- Bridge, S. and O'Neill, K. (2012). *Understanding enterprise: Entrepreneurship and small business*, Macmillan International Higher Education.
- Bryman, A. (2016). *Social research methods*, Oxford university press.
- Calogirou, C., Sørensen, S. Y., Larsen, P. B. and Alexopoulou, S. (2010). *SMEs and the environment in the European Union*, European Commission, DG Enterprise and Industry.
- Camacho-Otero, J., Boks, C. and Pettersen, I. N. (2018). "Consumption in the circular economy: A literature review", *Sustainability (Switzerland)*, Vol. 10 No. 8.
- Camilleri, M. A. (2019). "The circular economy's closed loop and product service systems for sustainable development: A review and appraisal", *Sustainable Development*, Vol. 27 No. 3, pp. 530-536.
- Cantú, A., Aguiñaga, E. and Scheel, C. (2021). "Learning from failure and success: the challenges for circular economy implementation in SMEs in an emerging economy", *Sustainability*, Vol. 13 No. 3, pp. 1-34.
- Casciaro, T. and Piskorski, M. J. (2005). "Power imbalance, mutual dependence, and constraint absorption: A closer look at resource dependence theory", *Administrative science quarterly*, Vol. 50 No. 2, pp. 167-199.
- Cavaleri, S. and Pezzotta, G. (2012). "Product-service systems engineering: state of the art and research challenges", *Computers in Industry*, Vol. 63 No. 4, pp. 278-288.
- Ceschin, F. (2013). "Critical factors for implementing and diffusing sustainable product-Service systems: insights from innovation studies and companies' experiences", *Journal of Cleaner Production*, Vol. 45, pp. 74-88.
- Clayton, R. J., Backhouse, C. J. and Dani, S. (2012). "Evaluating existing approaches to product-service system design: a comparison with industrial practice", *Journal of Manufacturing Technology Management*, Vol. 23 No. 3, pp. 272-298.
- Cristo-Andrade, S. and Franco, M. J. (2019). "Cooperation as a vehicle for innovation: a study of the effects of firm size and industry type", *European Journal of Innovation Management*, Vol. 23 No. 3, pp. 329-347.
- Cristoni, N. and Tonelli, M. (2018). "Perceptions of firms participating in a circular economy", *European Journal of Sustainable Development*, Vol. 7 No. 4, pp. 105-118.

- da Costa Fernandes, S., Pigosso, D. C., McAloone, T. C. and Rozenfeld, H. (2020). "Towards product-service system oriented to circular economy: a systematic review of value proposition design approaches", *Journal of Cleaner Production*, Vol. 257, pp. 120507.
- Davies, A. (2004). "Moving base into high-value integrated solutions: A value stream approach", *Industrial and Corporate Change*, Vol. 13 No. 5, pp. 727-756.
- de Jesus Pacheco, D. A., ten Caten, C. S., Jung, C. F., Sassanelli, C. and Terzi, S. (2019). "Overcoming barriers towards sustainable product-service systems in small and medium-sized enterprises: state of the art and a novel decision matrix", *Journal of Cleaner Production*, Vol. 222, pp. 903-921.
- Delegationen för Cirkulär Ekonomi. 2021. *Expertgrupper 2020/2021* [Online]. Available: <https://delegationcirkularekonomi.se/om-oss/expertgrupper/expertgrupper-2020-2021> [Accessed 7 July 2022].
- Den Hollander, M. C., Bakker, C. A. and Hultink, E. J. (2017). "Product design in a circular economy: Development of a typology of key concepts and terms", *Journal of Industrial Ecology*, Vol. 21 No. 3, pp. 517-525.
- Dey, P. K., Malesios, C., De, D., Budhwar, P., Chowdhury, S. and Cheffi, W. (2020). "Circular economy to enhance sustainability of small and medium-sized enterprises", *Business Strategy and the Environment*, Vol. 29 No. 6, pp. 2145-2169.
- Dixon-Woods, M., Bonas, S., Booth, A., Jones, D. R., Miller, T., Sutton, A. J., Shaw, R. L., Smith, J. A. and Young, B. (2006). "How can systematic reviews incorporate qualitative research? A critical perspective", *Qualitative research*, Vol. 6 No. 1, pp. 27-44.
- Dmitrijeva, J., Schroeder, A., Ziaee Bigdeli, A. and Baines, T. (2020). "Context matters: how internal and external factors impact servitization", *Production Planning and Control*, Vol. 31 No. 13, pp. 1077-1097.
- Eisenhardt, K. M. (1989). "Building theories from case study research", *Academy of management review*, Vol. 14 No. 4, pp. 532-550.
- European Commission (2015). "User guide to the SME definition", *Luxembourg: Publications Office of the European Union*.
- European Commission. 2016. *Flash Eurobarometer 441. European SMEs and the Circular Economy* [Online]. Available: https://data.europa.eu/euodp/en/data/dataset/S2110_441_ENG [Accessed 29 October 2021].
- European Commission 2019a. Annual report on European SMEs 2018/2019 - Research & Development and Innovation by SMEs.
- European Commission. 2019b. *Circular Economy - Implementation of the Circular Economy Action Plan* [Online]. Available: <https://ec.europa.eu/environment/circular-economy/> [Accessed 13 December 2019].

- European Commission 2020. Communication from the commission to the European Parliament, the Council, the European economic and social committee and the committee of the regions. A new Circular Economy Action Plan For a cleaner and more competitive Europe, COM (2020) 98 final.
- European Commission 2022a. Proposal for a REGULATION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL establishing a framework for setting ecodesign requirements for sustainable products and repealing Directive 2009/125/EC, COM/2022/142 final.
- European Commission. 2022b. *Sustainable products initiative* [Online]. Available: https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/12567-Sustainable-products-initiative_en [Accessed 7 July 2022].
- European Commission 2022c. Annual report on European SMEs 2021/2022 : SMEs and environmental sustainability. Publications Office of the European Union.
- European Union. 2003. *Commission Recommendation 2003/361/EC of 6 May 2003 concerning the definition of micro, small and medium-sized enterprises* [Online]. Available: <https://op.europa.eu/s/oQOw> [Accessed 22 Mars 2021].
- Fiegenbaum, A. and Karnani, A. (1991). "Output flexibility—a competitive advantage for small firms", *Strategic management journal*, Vol. 12 No. 2, pp. 101-114.
- Fink, A. (2019). *Conducting research literature reviews: From the internet to paper*, Sage publications.
- Flanckegård, F., Granlund, A. and Johansson, G. (2021). "Supplier involvement in product development: Challenges and mitigating mechanisms from a supplier perspective", *Journal of Engineering and Technology Management*, Vol. 60, pp. 101628.
- Freel, M. S. (1999). "Financing of small firm product innovation within the UK", *Technovation*, Vol. 19 No. 12, pp. 707-719.
- Freel, M. S. (2007). "Are Small Innovators Credit Rationed?", *Small Business Economics*, Vol. 28 No. 1, pp. 23-35.
- Garcés-Ayerbe, C., Rivera-Torres, P., Suárez-Perales, I. and Hiz, D. I. (2019). "Is it possible to change from a linear to a circular economy? An overview of opportunities and barriers for european small and medium-sized enterprise companies", *International Journal of Environmental Research and Public Health*, Vol. 16 No. 5.
- García-Quevedo, J., Jové-Llopis, E. and Martínez-Ros, E. (2020). "Barriers to the circular economy in European small and medium-sized firms", *Business Strategy and the Environment*, Vol. 29 No. 6, pp. 2450-2464.
- Garetti, M. and Taisch, M. (2012). "Sustainable manufacturing: trends and research challenges", *Production Planning & Control*, Vol. 23 No. 2-3, pp. 83-104.

- Garrido-Prada, P., Lenihan, H., Doran, J., Rammer, C. and Perez-Alaniz, M. (2021). "Driving the circular economy through public environmental and energy R&D: evidence from SMEs in the European Union", *Ecological Economics*, Vol. 182.
- Geissdoerfer, M., Savaget, P., Bocken, N. M. and Hultink, E. J. (2017). "The Circular Economy– a new sustainability paradigm?", *Journal of cleaner production*, Vol. 143, pp. 757-768.
- Geum, Y. and Park, Y. (2011). "Designing the sustainable product-service integration: a product-service blueprint approach", *Journal of Cleaner Production*, Vol. 19 No. 14, pp. 1601-1614.
- Ghenta, M. and Matei, A. (2018). "SMEs and the circular economy: from policy to difficulties encountered during implementation ", *Amfiteatru Economic*, Vol. 20 No. 48, pp. 294-309.
- Ghobadian, A. and Gallea, D. N. (1996). "Total quality management in SMEs", *Omega*, Vol. 24 No. 1, pp. 83-106.
- Giljum, S., Dittrich, M., Lieber, M. and Lutter, S. (2014). "Global patterns of material flows and their socio-economic and environmental implications: a MFA study on all countries world-wide from 1980 to 2009", *Resources*, Vol. 3 No. 1, pp. 319-339.
- Goedkoop, M. J., Van Halen, C. J., Te Riele, H. R. and Rommens, P. J. (1999). "Product service systems, ecological and economic basics", *Report for Dutch Ministries of environment (VROM) and economic affairs (EZ)*, Vol. 36 No. 1, pp. 1-122.
- Government Offices of Sweden. 2018. *Regeringen utser delegationen för cirkulär ekonomi* [Online]. Available: <https://www.regeringen.se/pressmeddelanden/2018/08/regeringen-utser-delegationen-for-cirkular-ekonomi/> [Accessed 20 July 2022].
- Grant, M. J. and Booth, A. (2009). "A typology of reviews: an analysis of 14 review types and associated methodologies", *Health Information & Libraries Journal*, Vol. 26 No. 2, pp. 91-108.
- Greenan, K., Humphreys, P. and McIvor, R. (1997). "The green initiative: improving quality and competitiveness for European SMEs", *European Business Review*, Vol. 97 No. 5, pp. 208-214.
- Gusenbauer, M. and Haddaway, N. R. (2020). "Which academic search systems are suitable for systematic reviews or meta-analyses? Evaluating retrieval qualities of Google Scholar, PubMed, and 26 other resources", *Research Synthesis Methods*, Vol. 11 No. 2, pp. 181-217.
- Haase, R. P., Pigosso, D. C. and McAloone, T. C. (2017). "Product/service-system origins and trajectories: a systematic literature review of PSS definitions and their characteristics", *Procedia CIRP*, Vol. 64, pp. 157-162.
- Hallstedt, S. I., Isaksson, O. and Öhrwall Rönnbäck, A. (2020). "The need for new product development capabilities from digitalization,

- sustainability, and servitization trends", *Sustainability*, Vol. 12 No. 23, pp. 10222.
- Han, C., Porterfield, T. and Li, X. (2012). "Impact of industry competition on contract manufacturing: An empirical study of U.S. manufacturers", *International Journal of Production Economics*, Vol. 138 No. 1, pp. 159-169.
- Harkonen, J., Haapasalo, H. and Hanninen, K. (2015). "Productisation: A review and research agenda", *International Journal of Production Economics*, Vol. 164, pp. 65-82.
- Harzing, A.-W. and Alakangas, S. (2016). "Google Scholar, Scopus and the Web of Science: a longitudinal and cross-disciplinary comparison", *Scientometrics*, Vol. 106 No. 2, pp. 787-804.
- Hernandez-Pardo, R. J., Bhamra, T. and Bhamra, R. (2013). "Exploring SME perceptions of sustainable product service systems", *IEEE Transactions on Engineering Management*, Vol. 60 No. 3, pp. 483-495.
- Heunks, F. J. (1998). "Innovation, Creativity and Success", *Small Business Economics*, Vol. 10 No. 3, pp. 263-272.
- Hidalgo-Carvajal, D., Carrasco-gallego, R. and Morales-alonso, G. (2021). "From goods to services and from linear to circular: The role of servitization's challenges and drivers in the shifting process", *Sustainability (Switzerland)*, Vol. 13 No. 8.
- Hsieh, H.-F. and Shannon, S. E. (2005). "Three approaches to qualitative content analysis", *Qualitative health research*, Vol. 15 No. 9, pp. 1277-1288.
- Isaksson, O., Larsson, T. C. and Rönnbäck, A. Ö. (2009). "Development of product-service systems: Challenges and opportunities for the manufacturing firm", *Journal of Engineering Design*, Vol. 20 No. 4, pp. 329-348.
- Jesson, J., Matheson, L. and Lacey, F. M. (2011). *Doing your literature review: Traditional and systematic techniques*, Sage.
- Karlsson, C. (2016). *Research methods for operations management*, Routledge.
- Kim, B. (2003). "Dynamic outsourcing to contract manufacturers with different capabilities of reducing the supply cost", *International Journal of Production Economics*, Vol. 86 No. 1, pp. 63-80.
- Kimita, K., Sakao, T. and Shimomura, Y. (2018). "A failure analysis method for designing highly reliable product-service systems", *Research in Engineering Design*, Vol. 29 No. 2, pp. 143-160.
- Kimita, K., Shimomura, Y. and Arai, T. (2009). "Evaluation of customer satisfaction for PSS design", *Journal of Manufacturing Technology Management*, Vol. 20 No. 5, pp. 654-673.
- Kimita, K., Watanabe, K., Hara, T. and Komoto, H. (2015). "Who Realizes a PSS?: An Organizational Framework for PSS Development", *Procedia CIRP*, Vol. 30, pp. 372-377.

- Kindström, D. and Kowalkowski, C. (2014). "Service innovation in product-centric firms: A multidimensional business model perspective", *Journal of Business and Industrial Marketing*, Vol. 29 No. 2, pp. 96-111.
- Kirchherr, J., Reike, D. and Hekkert, M. (2017). "Conceptualizing the circular economy: an analysis of 114 definitions", *Resources, Conservation and Recycling*, Vol. 127, pp. 221-232.
- Kjaer, L. L., Pigosso, D. C. A., Niero, M., Bech, N. M. and McAloone, T. C. (2019). "Product/Service-Systems for a Circular Economy: The Route to Decoupling Economic Growth from Resource Consumption?", *Journal of Industrial Ecology*, Vol. 23 No. 1, pp. 22-35.
- Kowalkowski, C., Windahl, C., Kindström, D. and Gebauer, H. (2015). "What service transition? Rethinking established assumptions about manufacturers' service-led growth strategies", *Industrial Marketing Management*, Vol. 45 No. 1, pp. 59-69.
- Kowalkowski, C., Witell, L. and Gustafsson, A. (2013). "Any way goes: identifying value constellations for service infusion in SMEs", *Industrial Marketing Management*, Vol. 42 No. 1, pp. 18-30.
- Kumar, K., Boesso, G., Favotto, F. and Menini, A. (2012). "Strategic orientation, innovation patterns and performances of SMEs and large companies", *Journal of Small Business and Enterprise Development*, Vol. 19 No. 1, pp. 132-145.
- Kumar, V., Sezersan, I., Garza-Reyes, J. A., Gonzalez, E. D. R. S. and Al-Shboul, M. A. (2019). "Circular economy in the manufacturing sector: benefits, opportunities and barriers", *Management Decision*, Vol. 57 No. 4, pp. 1067-1086.
- Labbate, R., Silva, R. F., Rampasso, I. S., Anholon, R., Quelhas, O. L. G. and Leal Filho, W. (2020). "Business models towards SDGs: the barriers for operationalizing Product-Service System (PSS) in Brazil", *International Journal of Sustainable Development & World Ecology*, pp. 1-10.
- Lewandowski, M. (2016). "Designing the business models for circular economy—Towards the conceptual framework", *Sustainability*, Vol. 8 No. 1, pp. 43.
- Li, A. Q., Kumar, M., Claes, B. and Found, P. (2020). "The state-of-the-art of the theory on Product-Service Systems", *International Journal of Production Economics*, Vol. 222.
- Lieder, M. and Rashid, A. (2016). "Towards circular economy implementation: a comprehensive review in context of manufacturing industry", *Journal of Cleaner Production*, Vol. 115, pp. 36-51.
- Lightfoot, H., Baines, T. and Smart, P. (2013). "The servitization of manufacturing: A systematic literature review of interdependent trends", *International Journal of Operations and Production Management*, Vol. 33 No. 11, pp. 1408-1434.

- Lindahl, M., Sundin, E. and Sakao, T. (2014). "Environmental and economic benefits of Integrated Product Service Offerings quantified with real business cases", *Journal of Cleaner Production*, Vol. 64, pp. 288-296.
- Lüdeke-Freund, F., Gold, S. and Bocken, N. M. P. (2019). "A Review and Typology of Circular Economy Business Model Patterns", *Journal of Industrial Ecology*, Vol. 23 No. 1, pp. 36-61.
- Martinez, V., Bastl, M., Kingston, J. and Evans, S. (2010). "Challenges in transforming manufacturing organisations into product-service providers", *Journal of manufacturing technology management*.
- Martinez, V., Neely, A., Velu, C., Leinster-Evans, S. and Bisessar, D. (2017). "Exploring the journey to services", *International Journal of Production Economics*, Vol. 192, pp. 66-80.
- Matschewsky, J. 2017. PSS Without PSS Design: Possible Causes, Effects, and Solutions. *Sustainability Through Innovation in Product Life Cycle Design*. Springer.
- Matschewsky, J., Kambanou, M. L. and Sakao, T. (2018). "Designing and providing integrated product-service systems—challenges, opportunities and solutions resulting from prescriptive approaches in two industrial companies", *International Journal of Production Research*, Vol. 56 No. 6, pp. 2150-2168.
- Meier, H., Roy, R. and Seliger, G. (2010). "Industrial product-service systems—IPS2", *CIRP annals*, Vol. 59 No. 2, pp. 607-627.
- Merriam, S. B. and Tisdell, E. J. (2015). *Qualitative research: A guide to design and implementation*, John Wiley & Sons.
- Michellini, G., Moraes, R. N., Cunha, R. N., Costa, J. M. H. and Ometto, A. R. 2017. From linear to circular economy: PSS conducting the transition. In: McAloone, T. C., Pigosso, D. C. A., Mortensen, N. H. & Shimomura, Y. (eds.) *9th Cirp Industrial Product/Service-Systems*. Amsterdam: Elsevier Science Bv.
- Mont, O., Dalhammar, C. and Jacobsson, N. (2006). "A new business model for baby prams based on leasing and product remanufacturing", *Journal of Cleaner Production*, Vol. 14 No. 17, pp. 1509-1518.
- Mont, O. and Tukker, A. (2006). "Product-Service Systems: reviewing achievements and refining the research agenda", *Journal of Cleaner Production*, Vol. 14 No. 17, pp. 1451-1454.
- Mont, O. K. (2002). "Clarifying the concept of product-service system", *Journal of Cleaner Production*, Vol. 10 No. 3, pp. 237-245.
- Morelli, N. (2003). "Product-service systems, a perspective shift for designers: A case study - The design of a telecentre", *Design Studies*, Vol. 24 No. 1, pp. 73-99.
- Morelli, N. (2006). "Developing new product service systems (PSS): methodologies and operational tools", *Journal of Cleaner Production*, Vol. 14 No. 17, pp. 1495-1501.

- Mura, M., Longo, M. and Zanni, S. (2020). "Circular economy in Italian SMEs: a multi-method study", *Journal of Cleaner Production*, Vol. 245.
- Nordin, F. and Kowalkowski, C. (2010). "Solutions offerings: a critical review and reconceptualisation", *Journal of Service Management*, Vol. 21 No. 4, pp. 441-459.
- O'Dwyer, M. and Ledwith, A. (2010). "Size matters: market orientation and NPD in small and large firms", *International Journal of Product Development*, Vol. 12 No. 2, pp. 107-125.
- Oliva, R. and Kallenberg, R. (2003). "Managing the transition from products to services", *International Journal of Service Industry Management*, Vol. 14 No. 2, pp. 160-172.
- Oncioiu, I., Capusneanu, S., Turkes, M. C., Topor, D. I., Constantin, D. M. O., Marin-Pantelescu, A. and Hint, M. S. (2018). "The sustainability of Romanian SMEs and their involvement in the Circular Economy", *Sustainability*, Vol. 10 No. 8.
- Pieroni, M. P. P., McAloone, T. C. and Pigosso, D. C. A. (2019). "Configuring new business models for circular economy through product-service systems", *Sustainability (Switzerland)*, Vol. 11 No. 13.
- Pigosso, D. C. and McAloone, T. C. (2016). "Maturity-based approach for the development of environmentally sustainable product/service-systems", *CIRP Journal of Manufacturing Science and Technology*, Vol. 15, pp. 33-41.
- Pigosso, D. C. A. and McAloone, T. C. (2015). "Supporting the Development of Environmentally Sustainable PSS by Means of the Ecodesign Maturity Model", *Procedia CIRP*, Vol. 30, pp. 173-178.
- Prieto-Sandoval, V., Jaca, C., Santos, J., Baumgartner, R. J. and Ormazabal, M. (2019). "Key strategies, resources, and capabilities for implementing circular economy in industrial small and medium enterprises", *Corporate Social Responsibility and Environmental Management*, Vol. 26 No. 6, pp. 1473-1484.
- Prieto-Sandoval, V., Ormazabal, M., Jaca, C. and Viles, E. (2018). "Key elements in assessing circular economy implementation in small and medium-sized enterprises", *Business Strategy and the Environment*, Vol. 27 No. 8, pp. 1525-1534.
- Regmi, K., Naidoo, J. and Pilkington, P. (2010). "Understanding the Processes of Translation and Transliteration in Qualitative Research", *International Journal of Qualitative Methods*, Vol. 9 No. 1, pp. 16-26.
- Reim, W., Parida, V. and Örtqvist, D. (2015). "Product-Service Systems (PSS) business models and tactics - A systematic literature review", *Journal of Cleaner Production*, Vol. 97, pp. 61-75.
- Rogers, D. S. and Tibben-Lembke, R. (2001). "An examination of reverse logistics practices", *Journal of business logistics*, Vol. 22 No. 2, pp. 129-148.

- Roy, R. (2000). "Sustainable product-service systems", *Futures*, Vol. 32 No. 3-4, pp. 289-299.
- Roy, R. and Cheruvu, K. S. (2009). "A competitive framework for industrial product-service systems", *International Journal of Internet Manufacturing and Services*, Vol. 2 No. 1, pp. 4-29.
- Sakao, T. and Lindahl, M. (2009). *Introduction to product/service-system design*, Springer Science & Business Media.
- Sakao, T., Öhrwall Rönnbäck, A. and Ölundh Sandström, G. (2013). "Uncovering benefits and risks of integrated product service offerings - Using a case of technology encapsulation", *Journal of Systems Science and Systems Engineering*, Vol. 22 No. 4, pp. 421-439.
- Salwin, M., Kraslawski, A. and Lipiak, J. 2020. State-of-the-Art in Product-Service System Design. *Lecture Notes in Mechanical Engineering*.
- Schilling, M. A. (2005). *Strategic management of technological innovation*, McGraw-Hill Education.
- Seuring, S. and Gold, S. (2012). "Conducting content-analysis based literature reviews in supply chain management", *Supply Chain Management*, Vol. 17 No. 5, pp. 544-555.
- Shimomura, Y., Hara, T. and Arai, T. (2009). "A unified representation scheme for effective PSS development", *CIRP Annals - Manufacturing Technology*, Vol. 58 No. 1, pp. 379-382.
- Song, W. (2017). "Requirement management for product-service systems: Status review and future trends", *Computers in Industry*, Vol. 85, pp. 11-22.
- Storey, D. J. (2016). *Understanding the small business sector*, Routledge.
- Sundin, E. and Bras, B. (2005). "Making functional sales environmentally and economically beneficial through product remanufacturing", *Journal of cleaner production*, Vol. 13 No. 9, pp. 913-925.
- Sundin, E., Lindahl, M. and Ijomah, W. (2009). "Product design for product/service systems: design experiences from Swedish industry", *Journal of Manufacturing Technology Management*, Vol. 20 No. 5, pp. 723-753.
- Säfsten, K. and Gustavsson, M. 2020. Research methodology: for engineers and other problem-solvers. Studentlitteratur AB.
- Tether, B. S. (1998). "Small and large firms: sources of unequal innovations?", *Research Policy*, Vol. 27 No. 7, pp. 725-745.
- The World Bank Group. 2022. Available: <https://www.worldbank.org/en/topic/smefinance> [Accessed 7 July 2022].
- Tukker, A. (2004). "Eight types of product-service system: Eight ways to sustainability? Experiences from suspronet", *Business Strategy and the Environment*, Vol. 13 No. 4, pp. 246-260.
- Tukker, A. (2015). "Product services for a resource-efficient and circular economy - a review", *Journal of Cleaner Production*, Vol. 97, pp. 76-91.

- Tukker, A. and Tischner, U. (2006). "Product-services as a research field: past, present and future. Reflections from a decade of research", *Journal of Cleaner Production*, Vol. 14 No. 17, pp. 1552-1556.
- Tödting, F. and Kaufmann, A. (2001). "The role of the region for innovation activities of SMEs", *European urban and regional studies*, Vol. 8 No. 3, pp. 203-215.
- Uлага, W. and Reinartz, W. J. (2011). "Hybrid offerings: How manufacturing firms combine goods and services successfully", *Journal of Marketing*, Vol. 75 No. 6, pp. 5-23.
- Vandermerwe, S. and Rada, J. (1988). "Servitization of business: Adding value by adding services", *European Management Journal*, Vol. 6 No. 4, pp. 314-324.
- Vasantha, G. V. A., Roy, R., Lelah, A. and Brissaud, D. (2012). "A review of product-service systems design methodologies", *Journal of Engineering Design*, Vol. 23 No. 9, pp. 635-659.
- Vezzoli, C., Ceschin, F., Diehl, J. C. and Kohtala, C. (2015). "New design challenges to widely implement 'Sustainable Product-Service Systems'", *Journal of Cleaner Production*, Vol. 97, pp. 1-12.
- Vihma, M. and Moora, H. (2020). "Potential of circular design in Estonian SMEs and their capacity to push it", *Environmental and Climate Technologies*, Vol. 24 No. 3, pp. 94-103.
- Voss, C., Tsikriktsis, N. and Frohlich, M. (2002). "Case research in operations management", *International Journal of Operations and Production Management*, Vol. 22 No. 2, pp. 195-219.
- Welsh, J. A. and White, J. F. (1981). "A small business is not a little big business", *Harvard business review*, Vol. 59 No. 4, pp. 18-32.
- Williamson, D. and Lynch-Wood, G. (2001). "A new paradigm for SME environmental practice", *TQM Magazine*, Vol. 13 No. 6, pp. 424-432.
- Windahl, C. and Lakemond, N. (2006). "Developing integrated solutions: the importance of relationships within the network", *Industrial Marketing Management*, Vol. 35 No. 7, pp. 806-818.
- Yang, M. and Evans, S. (2019). "Product-service system business model archetypes and sustainability", *Journal of Cleaner Production*, Vol. 220, pp. 1156-1166.
- Yang, M., Evans, S., Vladimirova, D. and Rana, P. (2017). "Value uncaptured perspective for sustainable business model innovation", *Journal of Cleaner Production*, Vol. 140, pp. 1794-1804.
- Yin, R. K. (2018). *Case study research and applications: Design and methods*, SAGE Publications.
- Zeeuw van der Laan, A. and Aurisicchio, M. (2020). "A framework to use product-service systems as plans to produce closed-loop resource flows", *Journal of Cleaner Production*, Vol. 252.

Appendix A - Interview guide

Introduction

- The purpose of this study is to conduct interviews exploring how SMEs manage challenges related to PSS design and how the characteristics of SMEs influence these challenges.
 - This data will only be used for this research project and will not be distributed to anyone else. All answers will stay within the small team of the research group.
 - Is it okay for you if we record this meeting?
 - You will have the opportunity to approve the publication of the final version of the article.
-

Information about the informant

- What is your position within the company? What are your tasks?
- How long have you been working at the company?

General information about the company

- What do the company offer to customers today?
Both in the form of products and services.
- What are the strengths of the company's current offer, according to you?
 - i) In what way do you compete with other companies in the same industry?
- What are the weaknesses of the company's current offer, according to you?
 - i) Are there any challenges or downsides with the product offerings today?
- What would the company like to offer to the customers in future (or next five years), considering the emerging trends such as circular economy and digitalization etc.?

Motives

- What is your perception of the concept of “sustainability” and how does it influence your work?
- What benefits or opportunities do you see in changing the current offering and adding more services considering sustainability or circularity?
- What do the customers demand today? What do you think are the reasons for their demands?
- Do customers inquire or set any requirements regarding sustainability or adding more services?
 - i) If yes, please describe those.

Challenges

- What challenges have you faced in this transition to offering PSS?
- What would you say are the biggest obstacles for the company to change the current offer and add more services considering sustainability or circularity?
 - a. How have you handled this challenge?
- In your perspective, what is necessary for the company to overcome these challenges?
- What risks do you see in adding more services considering sustainability or circularity?
- What disadvantages do you see being a smaller company in comparison to a large company when adding more services considering sustainability or circularity?
- What advantages do you see being a smaller company in comparison to a large company when adding more services considering sustainability or circularity?

PSS offerings

- What type of offers, including products and/or services, are of most relevance to your customers?
- How do you deal with sustainability in relation to products, manufacturing, and facilities, e.g., reducing waste by recycling or reusing?
- What does the company need (e.g., capabilities in terms of resources and competencies, infrastructure, organizational structure, and supply chain integration) to design more services considering sustainability or circularity?

Business model

- What types of business models do you work with currently?

- How do you work with increasing customer value?
- Which type of business models are you planning to work with in the future?
 - i) Please describe why you are planning to develop these business models.
- How will the sustainability requirements affect your business model in the future?

Customer communication

- How do you get feedback from customers?
- How do you find out about the unknown needs of your customers?
- How is customer feedback used internally?
- What are the strengths of how you communicate with your customers today?
- What are the weaknesses of how you communicate with your customers today?

Design process

- How do you currently run a typical product development project?
- How do you collaborate internally in new product development with different functions?
- How do you collaborate in new product development externally with customers and suppliers?
- How are you involved in the customers' product development process?
- Considering adding more services around sustainability on some products, do you see any changes required on how the company work with:
 - i) Customer's product development process?
 - ii) Your internal new product development process?
- How do you work with the development of services?
 - i) Do you have any specific development process for services?
 - ii) If not, why? Do you need one?
 - iii) If yes, what will it look like?
- How do you like to work with your customers/suppliers when developing new service offerings on products in the future?
- Would it be possible for you to offer sustainability expertise as a service to your customers in your product development projects?
 - i) What would you need to offer such expertise?
- How do you work with sustainability requirements in your product development projects with customers?

- How would you describe the dream scenario for the company in the future?

Closing questions

- Is there something you want to add to the questions?
- Is it okay to contact you for any follow-up questions?
- Would it be possible for us to interview more people within the company?

Thank you for your time!