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The Role of Life Cycle Costing in the Servitization Process of Manufacturing Businesses

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Abstract

Aim: This study investigates the role of life cycle costing the process of servitizing the value proposition of manufacturing businesses. The aim is to increase the understanding of potential utility of life cycle costing in the servitization process of manufacturing businesses. Additionally, the potential challenges within the process of life cycle costing process are explored.

Method: To contribute to a greater understanding, a qualitative case study was conducted at a manufacturing company that is operating in the rail transport industry. A total of ten semi-structured interviews with experts within the case company were conducted.

Result: The results of this research imply that life cycle costing can offer great utility in the servitization process of manufacturing businesses. Life cycle costing can support in identifying servitization potential and align internal and external incentives, which are crucial in enabling servitization. The key challenges of life cycle costing are the change in perspective towards a product centric LCC perspective. This requires a change in the design and measuring processes of life cycle costing, while also requiring increasing collaboration with stakeholders in the value chain.

Keywords: *Servitization, Product-Service System, Life-Cycle Costing, Business Model, Manufacturing,*

Abbreviations

BML – Build Measure Learn
IPS2 – Industrial Product-Service System
LCC – Life-Cycle Costing
LCCA – Life-Cycle Cost Analysis
MRO – Maintenance, Repair, Overhaul
OEM – Original Equipment Manufacturer
PLM – Product Lifecycle Management
PSS – Product Service System
RAMS – Reliability, Availability, Maintainability and Safety

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1. Introduction

This chapter serves the purpose of introducing the overall topic of the research proposal and highlighting the relevance of this topic. At the end of this chapter the research aims, and research questions are specified for the context of this thesis.

1.1. Background

Manufacturing companies worldwide are facing increasingly complex challenges, driven by globalization and digitalization (Witt & Gross, 2020; Helo, Gunasekaran, & Rymaszewska, 2017). Addressing these challenges requires manufacturing companies to rethink their role in globalized value chains and the way they interact with their customers. An essential part of this process is the evaluation and redesign of the organization's business model (Ries, 2011). While manufacturing companies have traditionally focused on developing and producing products, many manufacturers are introducing a service aspect to their value proposition (Olivia & Kallenberg, 2003; Wise & Baumgartner, 2000). This integration of a service component into a product-dominated value proposition is referred to as servitization and is already well established in several industries (Annarelli, Battistella, & Nonino, 2016). Most manufacturing companies still offer a primarily product-dominated value proposition, but there is a growing trend to explore and implement servitization in manufacturing business models (Mont, 2002).

For many manufacturing companies, a servitized business model can be a successful way to establish a sustainable competitive advantage in the increasingly competitive economy (Baines, Lightfoot, Benedettini, & Kay, 2009). Integrating a service component often provides greater value to the customer, allowing them to focus more on their core competencies. Examples such as the Power-By-The-Hour approach of Rolls-Royce have clearly demonstrated the potential to transform an entire industry by adopting a servitized business model (Smith, 2013). In the traditional value proposition, the customer is paid for the transfer of ownership of the product. In a servitized value proposition, in most cases, the customer pays for the benefits of the product rather than the ownership (Annarelli et al., 2016). While this shift in the business model towards a servitized value proposition undoubtedly offers new opportunities for manufacturing companies, its practical implementation presents new challenges (Benedettini, Neely, & Swink, 2015; Neto, Pereira, & Borchardt, 2015). Offering a service-oriented value proposition is often associated with increasing product responsibility of the manufacturing company in the operational life cycle phase. While increasing responsibility adds value to the customer, it leads to an increasing internalization of technical and commercial risks by the manufacturing company (Keine & Steven, 2012; Herzog, Meuris, Bender, & Sadek, 2014). Particularly in the case of complex manufactured

products with long life cycles, the risk associated with the operational phase can be of significant importance in shaping the overall value proposition. A key technical risk in the operational lifecycle phase is linked to the reliability of the provided product. The risk associated with reduced utility due to reliability issues is only partially covered by the manufacturing company through warranty or pre-agreed life cycle cost estimates. In the servitized business model, this risk is usually transferred to the manufacturing company, shifting the responsibility for the risk and associated costs to the provider of the product (Helo et al., 2017; Tukker, 2004).

This implies that a manufacturing company that wants to change towards a servitized business model should be aware of the risk associated with increasing product responsibility in the operational life cycle phase (Reim & Sjoedin, 2016). One way to conceptualize the associated risk is to analyze the costs associated with the different life cycle phases. If the manufacturing company is able to accurately estimate the costs during the operational life cycle, it can more accurately assess the associated risk as responsibility increases (Benedettini et al., 2015). In assessing and evaluating the total cost associated with the product life cycle, the process of life cycle costing plays an important role in many manufacturing companies (Farr & Faber, 2018). While it is already used in many manufacturing companies, the shift to a service-oriented business model is changing the requirements for life cycle costing. As the manufacturing company expands responsibility for the costs associated with operating the product, the accuracy of the estimate becomes an integral part of managing the company's bottom line. While the additional costs during operation were previously borne by the operator of the plant, the supplier itself internalizes these costs in a servitized business model (Aurich, Fuchs, & Wagenknecht, 2006; Adrodegari, Saccani, & Kowalkowski, 2016).

In the academic literature, servitization in the manufacturing context is receiving increasing attention as practical applications of servitization increase (Kiruma, Matoba, & Mitsui, 2007). The application of life cycle costing in servitization has received rather little attention from researchers in recent years (Kambanou, 2020). Given the integral role of life cycle costing in the shift to a servitized business model, there is a need to increase the understanding of the role of life cycle costing in a servitization context (Benedettini et al., 2015; Reim & Sjoedin, 2016). Although there is some research that suggests that life cycle costing can be useful in the servitization process of manufacturing companies, further research is needed to evaluate this (Kambanou, 2020).

1.2. Research Aim and Questions

As mentioned earlier, the ongoing trend of shifting towards a service-based business model is an increasing challenge for manufacturing companies. Existing academic literature does not provide sufficient practical guidance on the application of life cycle costing in a servitization context. Therefore, the objective of this paper is to increase the understanding of the role of life cycle costing in the servitization process of manufacturing companies. Since there is relatively little research on the application of life cycle costing in this process, this research focuses on investigating the potential benefits of life cycle costing in the servitization process. Based on the objective of this research, the following research question was defined:

RQ1: What utility can Life Cycle Costing provide in the servitization process?

Answering this research question will increase the understanding of life cycle costing. The manufacturing company is likely to face challenges as it shifts to a service-oriented value proposition, and life cycle costing could provide benefits associated with solving some of these challenges. The results of these research questions could support the idea of an increased need for research in this area of knowledge. The potential benefits of life cycle costing could assist manufacturing companies to investigate the implementation of new life cycle costing processes. In addition to exploring the potential benefits, the research will seek to generate valuable insights into the potential challenges of using life cycle costing in the context of servitization. As discussed, life cycle costing requirements are likely to change in a servitized business model, which may be associated with additional challenges. Therefore, the second research question of this study was defined as follows:

RQ2: What are the challenges associated with Life Cycle Costing in the servitization process?

Answering these research questions can help companies looking to use life cycle costing in a servitized business model by preparing them for potential challenges. This information can then be used to assess whether the company is likely to face challenges associated with the conversion of the life cycle costing process. Answering these two research questions will directly contribute to closing the research gap and could assist manufacturing companies in transitioning to a servitized business model.

1.3. Case Company

A case study approach is used to fulfill the research objective and answer the research questions. The case company for this research is an international manufacturing company operating in the railway transport industry. This industry is characterized by complex ownership structures and highly interdependent stakeholders that operate on a shared railway infrastructure. Driven by digitalization and increasing pressures from road bound transportation, the railway transport industry is undergoing drastic changes. In order to

proactively develop the company's business model and value proposition based on the changing market environment, the case company is interested in investigating the potential benefits of life cycle costing. At the same time, the case company is interested in understanding the challenges associated with changing its life cycle costing approach. The company operates in a complex market environment with long product life cycles and a high focus on safety and reliability. At the same time, overall optimization of life cycle costs is critical to successfully compete in the market. With an increasing focus on servitization and expertise in life cycle costing, the case company provides a unique opportunity to explore the benefits and challenges associated with life cycle costing in a manufacturing context.

1.4. Delimitations

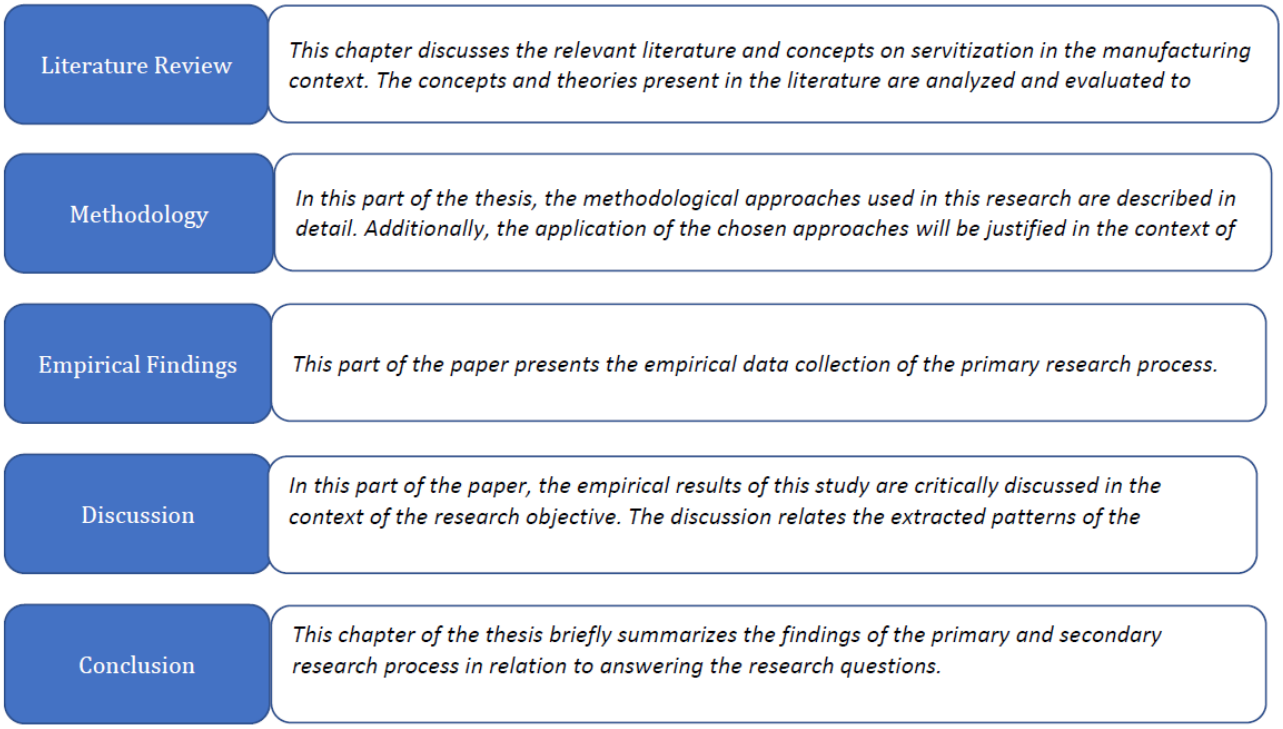
This research will focus on servitization and life cycle costing in a manufacturing context. While there are other contexts in which these concepts could be analyzed, these will not be the focus of this research process. For the purpose of this research, manufacturing companies are defined as companies that produce technological products with a life cycle of at least five years. While producers of products with a shorter life cycle can be considered manufacturing businesses these are not the focus of this research. Furthermore, there is extensive variety in the application of servitization, and this research will not analyze and compare the utility and challenges of these different applications. Similarly, the different applications of life cycle costing will not extensively be analyzed and compared. This research aims to provide a general understanding of how these two concepts are interlinked and establish a foundation for further research to analyze if life cycle costing can be of utility in the servitization process and which challenges might be connected to the practical implementation.

As this research is based on a case study approach of only one single case company, the results of this research process should not be generalized without careful consideration. While there might be generalizable patterns in the results of this research, this research is merely aiming on providing understanding of the relevant concepts in a narrow application area. This choice is based on the limitations on resources and timeframe for this research process and will be further addressed in the methods section of this thesis.

1.5. Disposition

This thesis is structured into six different chapters that will provide the reader with the necessary information to understand the entire research process. In the first chapter the overall topic and the research setting have been described to enable the reader to get an

understanding of the relevance of the topic and the current state of research. The remaining five chapters of this research process are following:



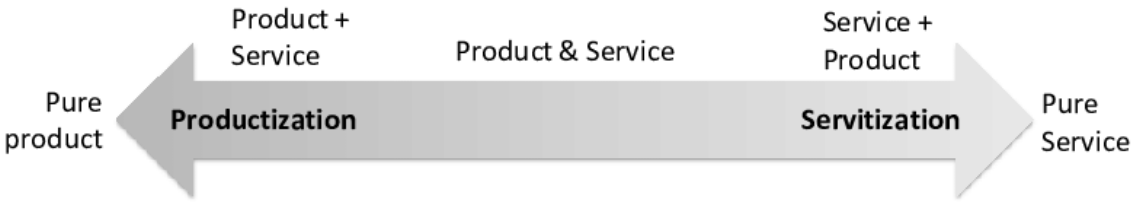
1.1 Disposition

2. Literature Review

This chapter discusses the relevant literature and concepts on servitization in the manufacturing context. The concepts and theories present in the literature are analyzed and evaluated to provide a basis for a broader discussion of the topic. The literature review begins by analyzing the concepts and frameworks of servitization in manufacturing. It then examines the challenges of servitization in relation to the business model. Then, the reader is introduced to the overall concept of life cycle costing. After that, the processes involved in the concept of life cycle costing are discussed in the servitization context. Finally, the overall structure of the life cycle costing concept is discussed to provide a broader understanding of the importance of active life cycle costing.

2.1. Servitization

In developed countries around the globe, the importance of service-based offerings has been growing since the second half of the twentieth century. Although the causes of this development are complex and difficult to define, it is undeniably relevant to all parts of the developed world (Witt & Gross, 2020). The speed of this overall evolution is even increased since the development of the internet and the increasing digitization of the workforce (Muro, Liu, Whiton, & Kulkarni, 2017).



2.1 Product-Service Continuum (Tukker, 2004)

Pure service-based offerings and product-based offerings are often conceptualized as two endpoints on a continuum. The characteristics of a service-based offering are that they are perishable, intangible, and inseparable from the service provider (McManus, Winroth, & Angelis, 2019). In contrast, product-based offerings are described as tangible, storable, and separable from the provider. While some companies focus on purely service-based or product-based offerings, most value proposition include a combination of both (Mont, 2002). Companies can position their value proposition to customers on the service product continuum to differentiate themselves from competitors and create a competitive advantage in the marketplace. This makes the combination of product and service

elements in their value proposition a critical part of their strategy (Ulaga & Reinartz, 2011). Although this concept of combining products and services is not a new phenomenon, many companies are increasingly being forced to reshape their position on the product-service continuum (Osterwalder & Pigneur, 2010).

2.1.1. Servitization in Manufacturing

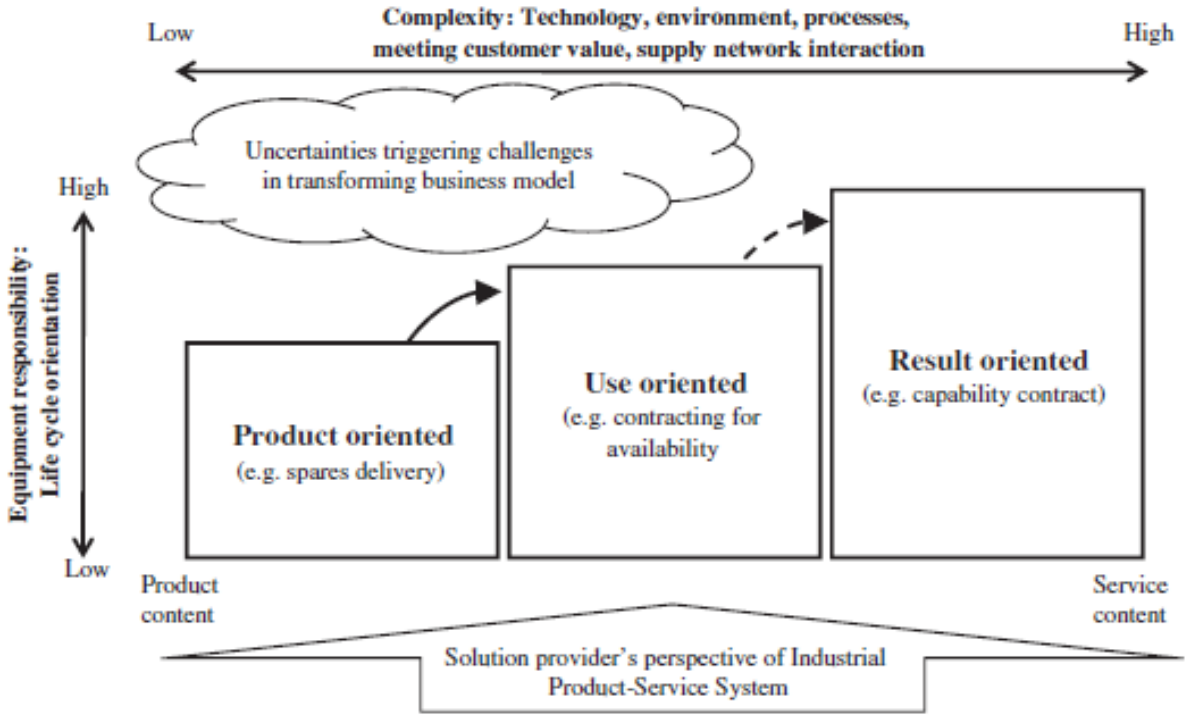
The increasing importance of services and the advance of digitization pose a particular challenge to companies that have historically relied on product-based offerings with little or no service component in their value proposition to customers. This is particularly the case for manufacturing companies that produce technological products. While industrial manufacturing firms have historically focused on delivering products, there is an increasing demand for differentiation in the value proposition that includes service aspects (Olivia & Kallenberg, 2003; Vandermerwe & Rada, 1988). There are many aspects influencing this development, increasing competition and customer expectations being the main drivers for this change. Manufacturing companies that exclusively supply products with little or no service features are coming under pressure from competitors that offer superior value propositions to the market (Baines et al., 2009). Therefore, to ensure long-term profitability and create a sustainable competitive advantage, a shift towards a combination of product and service aspects in the value proposition is inevitable for manufacturing companies that want to compete successfully in the 21st century. The overall concept of a company shifting its value proposition to include service offerings that complement its main product offering is referred to as servitization. The opposite movement of a service provider that begins to include product elements in its value proposition is called productization (Dimache & Roche, 2015; Tukker, 2004).

Since the value propositions of manufacturing businesses are predominantly product-based, the key changes are connected to servitization. However, it is important to emphasize that not all manufacturing companies that begin to offer services engage in servitization. In servitization, there is a clear link between the product and service offered to provide greater value to the customer. Instead of than separate offerings, servitization requires a bundling of product and service that are connected (Wise & Baumgartner, 2000). Most often, the concept of servitization in manufacturing is discussed on a general level without addressing the practical applications of the theory. While servitization can take many forms, there are patterns in its practical application that can help provide detailed understanding of the underlying theoretical concept of servitization in manufacturing. One of the best-known cases of servitization in manufacturing is the power-by-the-hour approach of the aircraft original equipment manufacturer (OEM) Rolls-Royce (Smith, 2013). The core of Rolls-Royce's value proposition is the aircraft engine, which is a product-offering. Due to several interrelated reasons, the company has servitized by offering additional services related to maintenance repair and operations (MRO).

By adding MRO services to its product offering, the company has successfully diversified its value proposition and built a strong position in the aircraft engine market. While servitization in manufacturing can take many different forms, offering of MRO services that support the core product offering is a commonly used strategy by manufacturing companies. On the one hand, increasing customer demand for complementary services in the MRO sector is driving this development. On the other hand, increasing digitization and the shift towards Industry 4.0 are enabling manufacturing companies to provide comprehensive MRO services that increase the reliability, availability, maintainability, and safety of the delivered product. For companies to successfully enter servitization, a holistic understanding of the theoretical concept of servitization is necessary. For this purpose, the concept of Technical Product-Service Systems can be a helpful conceptualization of servitization in the manufacturing context (Farr & Faber, 2018).

2.1.2. Product-Service Systems

The Product-Service Systems (PSS) is a conceptualization of the integration of value propositions with product and service content. Although not necessarily applicable only to the manufacturing context, it provides guidance for the servitization process for manufacturing companies. As described, there are various forms of servitization that can be used by the manufacturing firm to generate a sustainable competitive advantage.



2.2 Comparison across IPS2 value propositions (Erkoyuncu, Durugbo, & Roy, 2013)

The PSS refers to the product-service continuum, as it represents different combinations of product and service content of a firms' value proposition rather than either a product or a service offering. PSS can be applied to manufacturing companies that are trying to move from a product-only offering to a combination of product and service offerings. There are three major categories of value proposition that reflect the proportion of product and service content of the offering (Tukker, 2004). In the context of these three main categories, the complexity and the equipment responsibility of the value proposition is increasing. While a product-only offering has relatively low complexity and minimal equipment responsibility, an increase in service content often leads to an expansion of equipment responsibility over the life of the product and an increase in complexity in delivering the value proposition (Annarelli et al., 2016).

In the *Product Oriented* approach, the companies value proposition is predominantly product-centric. The company offers additional services that are directly related to the product, such as providing MRO services or advice to the user of its product. In this value proposition, ownership of the product is transferred to the user and the responsibility for performing the MRO activities rests entirely with the user. The vendor is simply offering additional MRO services that are not necessarily part of the original product sales transaction (Brax, 2005). This offering has a relatively small service component because the user performs the MRO activities themselves and may choose not to outsource any of these activities to the vendor. A product-oriented approach is relatively common in manufacturing companies and presents relatively minor challenges on the provider for implementation (Keine & Steven, 2012). The next step towards a greater share of service content in the value proposition is the *Use Oriented* approach. In this approach, the provider of the product keeps part or the entire ownership of the product during the operational stage of the product. The most common contractual agreements are forms of rental or lease contracts in which enable the customer to use the product without obtaining ownership of the product. In this case, the OEM is owner of the machine and takes full responsibility for the MRO activities related to keeping the product on a desired availability level. This transition has critical implications for the provider, as the internalization of the MRO activities requires additional capabilities. While the product sale transfers the cost and risk of operation to the customer, the provider is now directly responsible to maintain the product and internalizes all major risk associated with the lifetime of the product (Azarenko, Roy, Shehab, & Tiwari, 2009). This makes the transition from a pure product offering to a use-oriented approach a complex process which requires careful planning and execution. The most service-based approach in the PSS is the *Result Oriented* approach on which the OEM of the product effectively takes responsibility for delivering the desired output of the product rather than the means of producing this output. The customer does effectively outsource the activity to the manufacturing business that provides the products of the products activities. This approach is similar to the use-oriented approach in terms of risk and operation cost

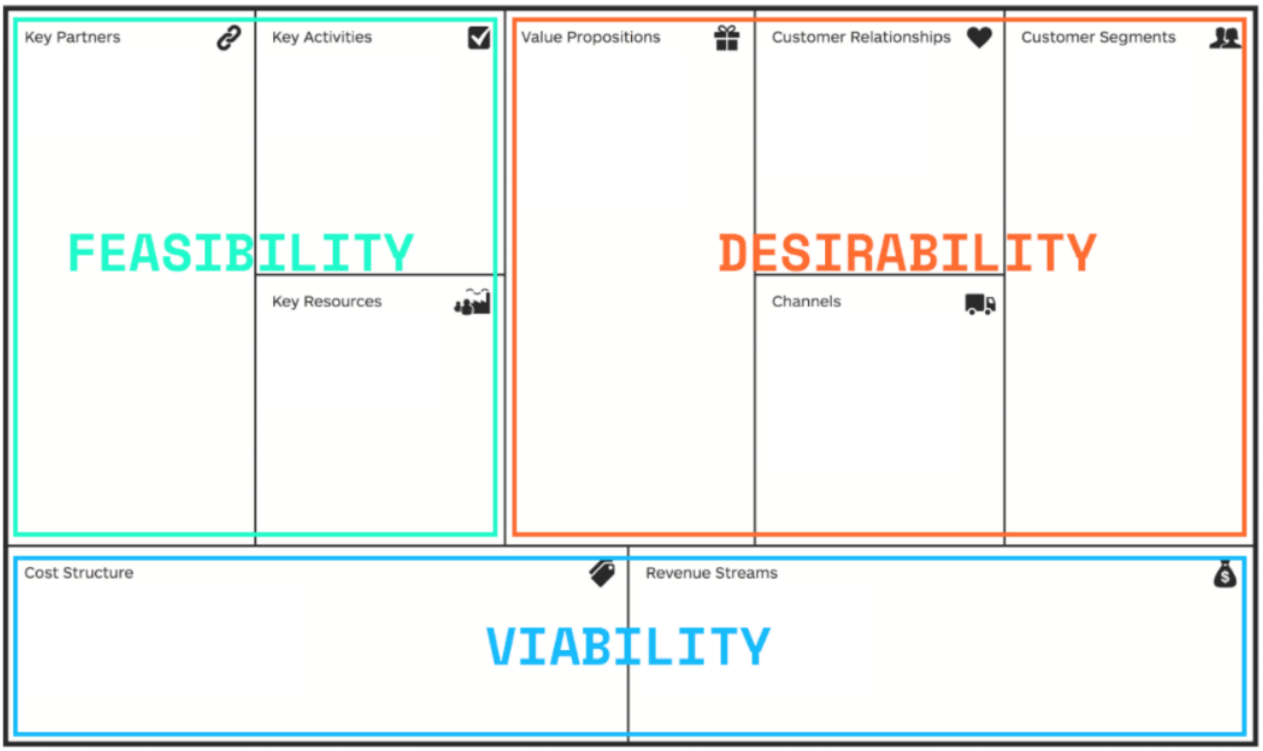
transfer to the provider. The provider is now responsible for the performance of the product and not only the availability. This requires additional expertise and competencies in operating the product to deliver the desired outcome. When a manufacturing business seeks to shift from a pure product offering to a result-based approach, the implications for the entire business are enormous (Spring & Araujo, 2009; Tukker, 2004; Ng, Maull, & Yip, 2009).

The PSS framework provides a general conceptualization of the servitization outcomes that might be chosen from manufacturing companies. Ranging from a pure product offering to a pure service offering with intermediate stages of shared product and service offerings. However, the PSS framework does not provide guidance for companies on which approach might be most suitable for them to generate a sustainable competitive advantage (Mont, 2002). It does not provide a holistic picture of the required activities and processes to actually implement servitization in manufacturing businesses. The framework can serve as a starting point for discussion of servitization processes but does not provide support in the practical transitioning process. While the opportunities of servitization are often discussed extensively, as delivering increased value and leading to a sustainable competitive advantage, there are several major challenges connected to an increasing share of service offering. Especially for companies that are currently offering a pure product value proposition, the servitization process will require drastic changes to their organization (Brax, 2005). When the provider of a product changes towards an approach in which the ownership and the related responsibilities for MRO activities are not transferred to the user, there are entirely new challenges and risks to be assessed and solved. Eventually, a change towards a more service-based PSS offering will inevitably require the manufacturing business to review and adjust their business model entirely (Azarenko et al., 2009; Aurich et al., 2006).

2.2. Transforming the Business Model

While many companies are trying to increase the service portion of their offerings to compete in an increasingly digital economy, many companies are failing to successfully transition their value proposition to an integrated product-service offering. Companies looking to implement a PSS business model should therefore be aware that there are significant challenges to consider when servitizing their value proposition. As described earlier, an increasing proportion of service content in the value proposition requires a careful rethinking of the provider's entire business model (Olivera, Mendes, Albuquerque, & Rozenfeld, 2018). Since an organization's business model is a complex entity with many layers, it is useful to use the Business Model Canvas as a conceptualization of the essential parts of a business model. The Business Model Canvas divides the business model into three main categories that together describe the company's value proposition and how

the company delivers that value proposition while receiving value in return. (Osterwalder & Pigneur, 2010).



2.3 Business Model Canvas (Osterwalder & Pigneur, 2010)

To successfully transition to a PSS value proposition, the provider must be aware of the opportunities and challenges associated with the transition process. Careful consideration of the transformation challenges and opportunities can increase the chances of successful servitization with increased profitability and sustainable competitive advantage for the provider (Benedettini et al., 2015). As highlighted earlier, the key changes in the shift towards a PSS offering are related to the increase in complexity and extended product responsibility of the provider. While the opportunities and challenges largely depend on the current value proposition and the desired outcome of the value proposition, there are obvious patterns that should be considered (Keine & Steven, 2012; Wallin, Chirumalla, & Thompson, 2013).

2.2.1. Desirability

The desirability of a business model defines what the company has to offer its customers. Defining the value proposition, customer segments, customer relationships, and distribution channels are at the core of creating a desirable business model. Moving to a PSS offering is a direct change to the value proposition that is at the core of desirability. In a manufacturing PSS context, the shift in desirability is often associated with an increase in device responsibility by the provider. This allows the customer to focus on

their core competencies as equipment responsibility decreases. In many cases, the supplier takes responsibility for the availability or performance level of its product and performs some or all of the necessary MRO activities (Osterwalder & Pigneur, 2010; Matschewsky, Kambanou, & Sakao, 2018). For suppliers, it can be challenging to identify customer demand for additional service offerings and to anticipate willingness to pay for these services. It is also crucial to segment customers according to these insights and to design a value proposition with a clear target customer orientation, which does not necessarily have to match the pure product value proposition (Meier, Völker, & Funke, 2010). Furthermore, the PSS approach often leads to a more intense interaction between supplier and customer, which most likely has an impact on the customer relationship. In most cases, a product-based value proposition is associated with a transaction-based relationship with the customer, where interaction is limited to the sales process. As the service content of the offering increases, a closer long-term relationship with the customer emerges with more meaningful interactions that can lead to mutual benefits between the provider and the user of the product (Wallin et al., 2013; Osterwalder & Pigneur, 2010).

2.2.2. Feasibility

Once the company has defined how it will create value and design a desirable value proposition with clearly defined customer segments, relationships, and channels, the practicalities of delivering that value must be clarified (Osterwalder & Pigneur, 2010). Business model feasibility refers to the processes and resources used by the provider in delivering the value proposition to the customer. In this business model category, the key resources, key activities, and key partners are considered. In a PSS approach, the resources required to deliver the value proposition often need to be adapted. The resources of the business range from physical assets to intellectual property to financial resources to continue to deliver value to customers. Based on the level of servitization and related activities, there may be a need for new competencies among employees or new structures to manage the integrated service-product offering (Annarelli et al., 2016). Additionally, the firm must consider the required activities associated with the value proposition. As mentioned earlier, a shift towards a PSS value proposition has implications for the complexity of internal processes and resources. As the level of servitization of the value proposition increases, additional value is provided to the customer. Companies attempting to meet more demanding customer needs often face increasing challenges in coordinating and designing internal processes (Osterwalder & Pigneur, 2010; Meier et al., 2010). In many cases, supply chain coordination requirements become increasingly complex as the service component of the service offering grows. This may require collaboration with external organizations, some of which are integrated into the company's value chain. Therefore, the company needs to have a well-defined picture of which processes and activities should be handled internally and which should be outsourced to third parties (Erkoyuncu et al., 2013).

2.2.3. Viability

The third part of the Business Model Canvas corresponds to the viability of the business model. While the first two categories deal with what is delivered to the customer and how it is delivered, viability deals with the profitability of the business model. A business model must consider the ability to generate revenue streams and recover the costs of doing so in order to generate a profit for the value proposition provider (Osterwalder & Pigneur, 2010). For PSS value propositions, the revenue streams generated are often a much debated topic. For providers offering value propositions with a high product content, switching to a PSS approach often drastically changes revenue streams. While product-based offerings often involve a large one-time payment for the transfer of ownership, service offerings often involve recurring revenue streams linked to product utility. The ability of companies to maintain their value proposition often results in more stable and consistent cash flows, which is generally a benefit for financial planning. At the same time, the company's pricing model is often challenged, as the PSS approach may require more careful segmentation and different pricing, as well as diversification of the value proposition. It is important to understand that these challenges often come with opportunities to extract additional value from customers. In PSS offerings, the level of servitization is often directly linked to the availability or performance of the product. This creates incentives for the vendor to deliver a reliable product, as revenue streams are no longer associated with just selling the product, but also with operating it. This link poses a risk to the revenue streams of suppliers as they are directly linked to the reliability of the product during its lifetime (Adrodegari et al., 2016; Erkoyuncu et al., 2013). In addition to the revenue streams generated, the company must also consider the cost structure. Sourcing of components in a product dominated value proposition differs significantly from the sourcing in an integrated value proposition. To establish a profitable business model in a servitization context the entire supply chain needs to be considered in managing the cost structure. It is one of the main challenges of manufacturing companies to handle a servitized value proposition while acting in a value chain that is mainly operating in a product-based cost and revenue structure (Baines et al., 2009). With a shift towards a more stable cash flow, the financial ability to allocate costs internally becomes greater. Therefore, to fully realize the potential of a PSS business model, the firm must consider the allocation of costs and the deployment of capital to its value proposition.

2.2.4. Challenges for manufacturing companies

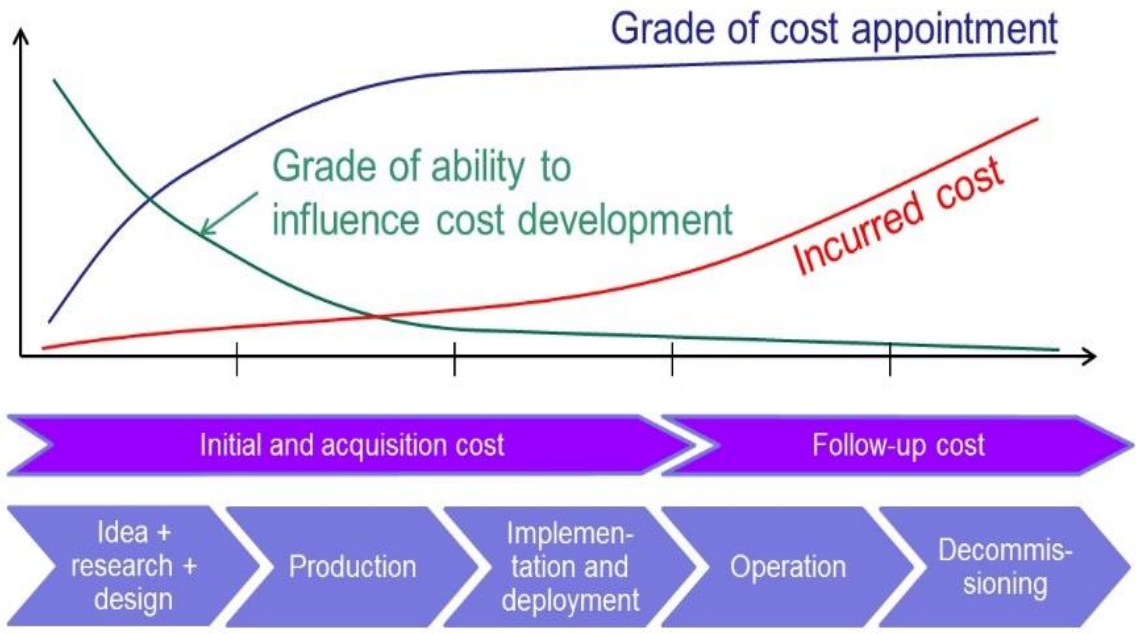
As discussed, changing the value proposition from a product-dominated to an integrated product and service-based approach requires careful consideration of the challenges associated with the business model. Developing an appropriate business model that enables the delivery of an integrated value proposition faces particular challenges in the manufacturing context. While the above considerations are applicable to manufacturing companies, there are recurring challenges that increase the complexity of transitioning to

a PSS offering for manufacturing companies. The challenges in the servitization process are often closely related to the lack of capabilities in manufacturing companies to develop and deliver competitive service offerings. Since manufacturing companies, which are predominantly product-oriented, usually lack experience with services, there is an obvious knowledge gap that can lead to failed servitization efforts. Internal processes and resources require extensive restructuring, which must be carefully considered in the transition process (Olivera et al., 2018; Helo et al., 2017, Neto et al., 2015). At the same time, there is a challenge associated with the transition of ownership of the product, especially for manufacturing companies that offer products with long life cycles. In a traditional product-dominated value proposition, ownership of the product transfers to the customer, who thus also assumes responsibility for the operation of the product. While there are often contractual warranty agreements that compensate the customer for failure to perform as agreed, these usually do not cover the entire life of the product. This leaves the customer responsible for the maintenance and operation of the product during its lifetime, including all technical and operational risks of failure (Baines et al., 2009). The customer must then manage the activities and resources associated with the MRO services based on their own decisions and bear all costs associated with these processes. In a PSS approach, the transfer of ownership and responsibility for the product is drastically changed. Depending on the type of PSS offering, the vendor may take full responsibility for the maintenance and even the operation of the product over its lifetime. When the vendor offers outcome-based contacts to its customers, it essentially internalizes all the risks associated with the life of its product. In handling all relevant MRO activities to ensure a desired benefit from the product, the supplier is responsible for all costs associated with these processes. For products with a long life cycle and a high proportion of MRO costs, this transfer of ownership and responsibility can have a critical impact on the company's business model. As a result, manufacturing companies that are changing their business model towards a more service-oriented approach need to make a more holistic assessment of the risks and costs associated with the whole life of the products they sell. This trend increases the relevance of life cycle management tools that help the company manage the entire life cycle of their products (Galar, Sandborn, & Kumar, 2020; Farr & Faber, 2018).

2.3. Life-Cycle Costing

The shift towards a PSS requires the organization to consider the importance of a broader lifecycle perspective in managing its value proposition. As mentioned earlier, servitization leads to a change in ownership and responsibility for product lifecycle phases. Because of this change, those responsible for internalizing the costs associated with these lifecycle phases often change as well. Therefore, the provider of a PSS value proposition needs to have a clear understanding of how costs are allocated across the different lifecycle phases

of the value proposition. Especially in the context of manufacturing companies that produce complex products with long life cycles, an understanding of the underlying cost structure of the offering is essential to achieve long-term profitability of the business. Life-cycle costing (LCC) can be a helpful tool to design and evaluate the costs associated with the life of the product (Farr, 2011). In establishing an overview of total cost associated to a products life, the company can compare different products in relation to the customers requirements and the achievable sales price. This makes LCC an important tool in assessing different product options and managing the profitability of manufacturing companies. The LCC model focuses exclusively on the costs associated with a particular product, from the initial development of the idea to the end of the product's useful life. The life of the product is divided into five distinct phases associated with different activities that most commercialized products go through in their lifetime. In the process of life cycle costing, there are various conceptualizations and focus areas that are coined to get an understanding of the costs associated with any of the stakeholders. It is relatively common for producers of manufactured products with a product-dominated value proposition to focus on the life cycle costs associated with the direct costs to them. Operational costs are not necessarily part of life cycle costing from the producers' perspective (Aurich et al., 2006; Foussier, 2006).



2.4 Life cycle cost phases and cost appointment (Mydin, 2017)

The first stage of the LCC model begins with the initial ideation process of the product to the final design of the product. In this stage of the product life cycle, the committed life cycle costs are relatively low and there is a high possibility to influence the cost structure of the product over its lifetime. In certain scenarios, this phase is further divided into

conceptual design and final design, especially in a manufacturing context. This can be helpful in narrowing the scope of design when resource allocation is critical to the overall LCC design. This phase is therefore considered the most important for the business provider, as the most influential decision regarding the LCC design is made during this phase. At the same time, the actual costs incurred are relatively small compared to the total lifetime costs of the product. In this phase, the influence on the LCC design is the highest, while at the same time the uncertainty of the total cost of ownership is very high. After the design of the product is complete, the production life cycle phase occurs where the key decisions for the distribution of life cycle costs have already been made. This leaves relatively little room for change and improvement in the LCC design (Westkämpfer & Osten-Sacken, 1998). At this stage, a relatively high proportion of life cycle costs relative to total life cycle costs is invested in the product. In a traditional product-oriented value proposition, the supplier transfers ownership of the product to the customer after this life cycle stage. This means that the supplier of the product internalizes the costs and risks of the first three life cycle phases. In the last phase of the product's life cycle, the product is in service until its final disassembly at the end of its life. As mentioned earlier, prior to this phase, ownership is usually transferred to the user of the product, thus transferring the associated life cycle costs of this phase. In many cases, the life cycle costs in this phase are mainly driven by energy costs and MRO activities to maintain the usability of the product. In this phase, the influence on the distribution of life cycle costs is relatively small, as the most important decisions have already been made in the previous life cycle phases of the product (Aurich et al., 2006; Peruzzini, Germani, & Marilungo, 2014).

The overall concept of life cycle costing is helpful in gaining an understanding of the total cost of ownership of a product. In addition, the LCC perspective provides an understanding of how the transfer of ownership and responsibility for the product is associated with different cost phases of a product's life cycle (Farr, 2011). Particularly in the context of manufactured products with a long life cycle, there are significant differences in how life cycle costs are allocated to different phases. While this concept provides an overview of cost allocation, it does not provide direct guidance on the processes required to enable effective life cycle costing. In order to use this concept in relation to a business model change, the processes and challenges involved need to be analyzed and understood by the provider. (Stark, 2015; Farr & Faber, 2018; Wallin et al., 2013).

2.3.1. LCC in the Business Model Context

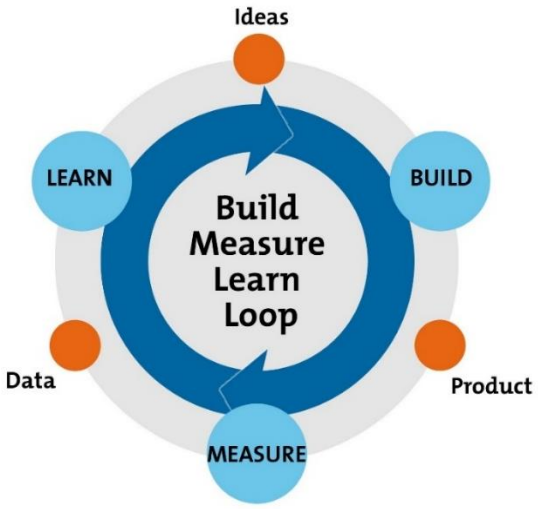
The overall concept of LCC assists the business in gaining an understanding of the costs associated with the various life cycle stages of the product. In the context of a traditional product-based value proposition, LCC can assist the company in making design decisions and in designing an appropriate life cycle cost allocation for the products offered. In this decision making, they consider the initial and purchase costs as internalized costs, while the subsequent costs are borne by the user of the product. Since ownership of the product

usually passes to the buyer before the operational phase, the price charged for the product must consider the initial and acquisition costs already incurred. Since the subsequent costs of the product are not directly related to the product provider's revenues, it is important to price the initial and acquisition costs according to the profitability requirements and the acceptable price level for the product. This combination of interrelated factors provides the product provider with an incentive to minimize initial and acquisition costs while not necessarily focusing on subsequent costs. In particular, in scenarios where the product provider is selling to a buyer who is not the actual end user of the product, subsequent costs are not the primary focus of negotiations. As a result, the total life cycle cost of the product is actively designed to be higher than it could be in order to reduce the share of initial and purchase costs (Ambad & Kulkarni, 2013; Westkämpfer & Osten-Sacken, 1998; Reim, Lenka, Frishammar, & Parida, 2017). In a PSS business model, the dynamics and incentives change due to the change in ownership structure. While there are different levels of servitization, the general trend in servitization is the extension of responsibility and ownership of the product by the provider. Because servitization can result in the provider retaining ownership of the product throughout its life, there is no need to match initial and acquisition costs with profitability requirements and accepted price levels. Instead, the provider of the system can match the total life cycle cost of the system with commercial market requirements. This change in incentives leads the provider to view both initial and subsequent costs as internal costs that should be minimized to maximize profitability. Therefore, the concept of life cycle costing is an integral part of the company's business model design (Matschewsky et al., 2018; Kiruma et al., 2007).

2.3.2. LCC Process

The complexity of life cycle costing can often be a challenge leading to a reactive life cycle costing approach. This refers to a system in which the company does not actively engage with life cycle costing processes until external forces make a change to the status quo in the company inevitable. Often, the external forces that trigger the change involve a change in customer demand or a change in the competitor's business model. In this reactive scenario, the firm misses the opportunity to be the market leader by proactively designing a life-cycle cost structure that enables it to make superior value propositions (Osterwalder & Pigneur, 2010; Foussier, 2006).

As a contextual framework, the Build-Measure-Learn (BML) cycle can be a helpful tool in structuring life cycle cost processes at the organizational level. This framework does not necessarily provide guidance on the detailed processes involved in life cycle costing, but it does provide a holistic structure for how the organization can achieve an iterative process of actively controlling the life cycle cost of its value proposition. While most organizations have some form of life cycle costing process in place, the servitization process requires a larger scope and more detailed analysis and control of the costs incurred throughout the life cycle of the product (Blank, 2013; Ries, 2011).



2.5 Build-Measure-Learn Cycle (Ries, 2011)

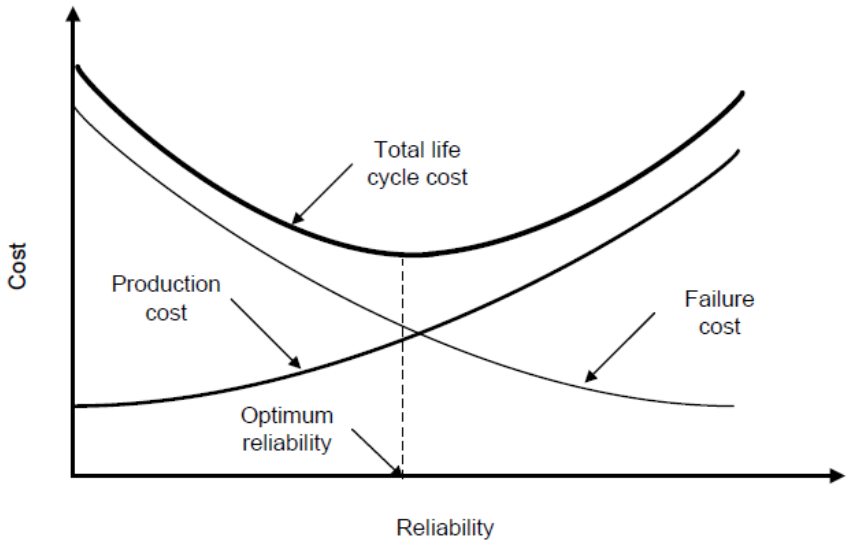
In the context of servitization of a manufacturing company, the starting point of the BML cycle is often an existing value proposition, namely the product. The company needs to clearly define the product being offered and the scope of the analysis. This can be a complex part as the quantity of products offered and the differences between them can be associated with significant differences in the life cycle costs incurred (Westkämpfer & Osten-Sacken, 1998). Once the product offering is clearly defined, the company needs to measure the actual costs incurred throughout the life cycle of the product. This can be a difficult part of the BML cycle, as the costs incurred up to the point of transfer of ownership are often well measured, while the costs incurred during operation and disassembly are not directly internalized by the organization. Nevertheless, the organization needs to establish structured processes to track the actual total cost of ownership of its products (Farr, 2011; Galar et al., 2020).

The result of this measurement process is referred to as data in the BML cycle. In this process, it is essential to establish a structured database to store the collected data. Since data collection is the basis for further steps in the life cycle costing process, the quality and quantity of the data must be carefully checked. Poor quality or low quantity can be misleading for the further processes and collecting a sufficient quantity of high quality data is therefore essential for the accuracy of the results. To prepare the data for further analysis, the data can be visualized and structured to facilitate the handling of large amounts of data (Farr & Faber, 2018). The next step in the life cycle costing process is to analyze the collected data. In this step, the organization needs to revise the data collection and get an understanding of the total life cycle cost of its products offered. In further iterations of this process, the learning process often involves comparing the projected life cycle costs to the actual life cycle costs. This allows the company to create a feedback loop that guides further action to increase the accuracy of the life cycle cost estimate (Aurich

et al., 2006). Based on the data analysis and the desired life cycle cost of the product, the organization can generate ideas to improve the life cycle cost processes. This part of the BML cycle depends to a large extent on the actual data collected and the quantitative data analysis. At the same time, qualitative factors that cannot be quantified without great imprecision influence the idea generation process in this iterative process. In this regard, the choice of business model is a key input to the life cycle costing process, as the desired distribution of total cost of ownership is highly dependent on the business model used (Baines et al., 2009). Once the organization has analyzed the collected data and compared the actual total life cycle cost with the planned total life cycle cost, it can begin to build a desired life cycle cost model. In this process, the organization must make a significant decision about the intended distribution of costs over the life of the product. Since the BML cycle is an iterative process, the build phase does not necessarily mean that the desired life cycle cost allocation must change from the previous iteration. It could be the case that the desired allocation has not been achieved with the current processes and that the underlying processes need to be revised to reduce the variance between the actual life cycle cost allocation and the desired life cycle cost allocation (Stark, 2015; Peruzzini et al., 2014).

2.3.3. LCC Design

As described earlier, the life cycle cost of the product provided is an integral part of managing the overall profitability of the business. The LCC planning phase is associated with the construction phase of the BML cycle and is often a theoretical calculation and planning of life cycle costs over the life of the product. In the context of complex manufactured goods with a long life span, the concept the actual design of life cycle cost is a complex process that requires holistic knowledge of the life cycle phases of the products. One concept that helps to actively shape the life cycle cost of the product is reliability optimization. Especially in systems where subsequent costs are mainly associated with MRO activities, active management of product reliability is a key concept to minimize total life cycle costs (Herzog et al., 2014).



2.6 Total cost and optimum reliability (Dimache & Roche, 2015)

In the early stages of product development, the systems provider must make key decisions about the total costs associated with the product and how those costs are distributed among the various life cycle phases. Complex manufactured products with a long life cycle are often associated with high total life cycle costs. To effectively manage total cost, a holistic perspective is required that incorporates the costs associated with the entire life of the product from the earliest stages of ideation and design. The concept of optimal reliability management focuses on total life cycle costs relative to production costs and failure costs. Production costs in this model include both the costs associated with conceptual and final design and the actual costs of producing the product. These costs are typically incurred before the product becomes the property of the user, at least in traditional product-dominated value propositions. In the context of life cycle costing, these costs are referred to as acquisition and manufacturing costs (Kiruma et al., 2007; Smith, 2013).

The second factor affecting total life cycle costs is failure costs, which are referred to as consequential costs in life cycle costing. Not all consequential costs of the system are necessarily directly related to MRO activities, energy consumption and recycling costs are other cost factors in the consequential costs (Dimache & Roche, 2015). However, for many manufactured products with long life cycles where there is no active energy consumption, the follow-on costs are mainly caused by MRO activities. The costs associated with MRO activities are directly related to the reliability and failure rate of the system, making reliability management a core activity in life cycle cost design. A system with low reliability results in an increased failure rate, which reduces the utility of the product below an acceptable rate. Restoring the product's utility requires MRO activities that contribute directly to the total life cycle cost. As this model suggests, an increase in

production costs may be directly related to an increase in product reliability. While this is not necessarily the case, assuming a well-structured design phase, an increase in dedicated resources will correlate positively with system reliability. On the other hand, a decrease in production costs will lead to an increase in the failure rate and associated costs for MRO activities. Again, this relationship is not necessarily true for all cases, but it can be assumed to hold true in many scenarios (Farr, 2011). The essence of this model is that the given relationships imply that there is an optimal balance between the costs associated with the design and production and the costs associated with the operation and decomposition of the product (Smith, 2013). If the company decides to increase spending on resources in the early stages of the life cycle, the reliability of the product will increase, leading to a decrease in failure costs (Castaneda, Majic, Ostrosi, & Stjepandic, 2019). This is effective until the increase in resources in the initial life cycle phases leads to an increase in the total life cycle cost. To effectively determine the optimal reliability of the systems, an effective estimation of the consequences of increased resource use is required. This model helps the manufacturing sector to understand the complexity of life cycle cost design and reliability decisions. At the same time, the actions to be taken regarding the definition of optimal reliability are complex and highly context dependent (Peruzzini et al., 2014; Meier et al., 2010).

2.3.4. LCC Design Strategy

In the resource allocation during the product life cycle there are different strategies in minimizing the total cost of ownership. The most suitable LCC design strategy needs to be evaluated in the wider business model context of the manufacturing company (Baines et al., 2009). The design-out approach refers to a life-cycle cost design strategy in which the product is designed to eliminate costs associated with MRO activities. This approach can result in an increase in design and production costs while decreasing the overall costs associated with operating the product. Overall, the design-out approach to life cycle costing increases cost allocation in acquisition and manufacturing costs while reducing the system's subsequent costs. Although there are technical limitations in reducing failure costs, this approach has the goal of eliminating all failure costs in the operation of the system. The advantages of this approach are mainly high availability and low failure cost (Erkoyuncu et al., 2013). As this approach seeks to eliminate the failure costs, the uncertainties associated with the operation of the system are minimized, making the variable costs associated with MRO activities relatively fixed and low (Azarenko et al., 2009). In this scenario, most of the life cycle costs are allocated to the design and production phases, which represent a significant portion of the total life cycle costs of the product. The disadvantages are that the design and production costs and the length of these phases can be higher than in other approaches, which increases the time to market of the product. As the design and production costs are relatively high, there is a high level of risk for the systems provider as the revenue required to break even is high. If the market demand is not proven or the technological development speed of the market is

high, this approach can lead to significant losses for the provider if the expected sales targets are not achieved (Zhang, Guo, Gu, & Gu, 2018; Reim & Sjödin, 2016). In contrast to the design-out approach, the design-for-maintenance approach is mainly focused on optimizing the maintainability of the system. In terms of cost allocation, this approach does not necessarily aim to eliminate consequential costs, but rather to achieve an optimal level of costs associated with MRO activities. There are several approaches that address the optimization of MRO activities, such as condition monitoring and predictive maintenance. The advantage of this approach is that it optimizes total life cycle costs, as the design for maintenance approach often considers initial, acquisition, and subsequent costs in the design phase. Which approach is more appropriate for the life cycle costing of a system is strongly influenced by technical and commercial factors that need to be considered when designing the cost allocation (Erkoyuncu et al., 2013; Farr, 2011).

2.3.5. Life Cycle Cost Analysis

To effectively apply life cycle costing in the context of complex manufactured products with a long life cycle, the actual life cycle cost of the system must be measured and analyzed. This phase of the life cycle costing process is referred to as a measure in the BML cycle and is concerned with actually tracking and measuring the costs incurred over the life of the product. While life cycle costing deals with the theoretical desired cost distribution over the life of the product, the actual costs incurred must be considered to effectively reach the target cost (Kambanou, 2020). To effectively start the improvement process, the supplier of the product must evaluate the current situation in relation to the theoretical estimates. In this process, a deep life cycle cost analysis (LCCA) will be a necessary tool to evaluate the current status of the total life cycle cost and the allocation to the different life cycle phases. Therefore, before deciding on a reliability strategy, the vendor must perform LCCA on the products provided. Since LCCA is a critical part of optimizing product reliability and total cost of ownership, the provider must select an appropriate approach to cost estimation based on product characteristics and total life cycle length. Once the current life cycle cost distribution has been evaluated with reasonable accuracy, the company needs to make decisions on how to achieve the desired distribution established in the life cycle cost definition (Farr, 2011; Kiruma et al., 2007; Zhang et al., 2018). Evaluating and measuring the actual costs incurred in relation to the different life cycle stages can be a complex process for manufacturing companies. In a traditional product-dominated value proposition with ownership transfer prior to the operational lifecycle stage, there is often relatively inaccurate data on the follow-on costs of the products. Since follow-on costs are not directly linked to costs at the vendor, there is no incentive to have very accurate data on the actual costs incurred in connection with MRO activities. Although MRO activities might be linked to provider revenues, this is not necessarily the case in all business model configurations. In a PSS approach, the required accuracy of the measurement of subsequent costs is an integral problem to effectively

manage the life cycle costing of the products provided (Farr & Faber, 2018; Kambanou, 2020).

2.3.6. Challenges of Life Cycle Costing

As mentioned above, the LCC design of a complex product can have a significant impact on the total cost of ownership and the cost allocation in the different life cycle phases. Especially in the first two phases of the life cycle, there is a great potential to influence the LCC of the product without much effort. However, it is a complex process to effectively decide on a desired LCC distribution in the early stages of the product (Baines et al., 2009). While the company decides on an appropriate life cycle cost design for the product, there are challenges to overcome to deliver the proposed value proposition while capturing enough value to be profitable. The life cycle cost design process is usually associated with the start of the product design, preferably already at the conceptual design stage. This allows the greatest influence over LCC with the lowest cost effort. This inevitably leads to some challenges, especially when the total life cycle of the product is longer than 15 years (Ambad & Kulkarni, 2013). When the value proposition provider is in the design phase of the product, the uncertainties associated with the product life cycle are usually extremely high. The direct costs associated with the first two phases are a relatively simple process because the design time period is relatively short in relation to the overall product life cycle period. In addition, all costs associated with the design phase are borne directly by the supplier itself. Although there are uncertainties associated with conceptual design and the final design phase, the uncertainties and risks are usually manageable and the amount of actual costs incurred is low (Galar et al., 2020; Kambanou, 2020). When designing the costs associated with producing the product, there is a greater amount of uncertainty and risk. This makes the accurate estimation of the LCC associated with the production phase a more complex process, as the uncertainty and risk in the production phase can significantly affect the overall LCC of the product. However, compared to the total lifetime of the product, this phase is a relatively small part of the lifetime. Although the estimation of LCC in this phase may be based on assumptions, the responsibility for this process still lies with the supplier, who provides a direct feedback loop from the actual costs incurred back to the estimate. This can assist the supplier in adjusting production processes based on actual costs incurred (Olivia & Kallenberg, 2003; Westkämpfer & Osten-Sacken, 1998).

In determining the life cycle cost of the product, the greatest uncertainty is associated with the last phase of the life cycle, the operation of the product until it reaches the end of its useful life. Especially for products with a long lifetime, this phase accounts for the largest part of the life cycle period. At the same time, this phase is usually associated with a change in ownership and responsibility for the product, with ownership transferring to the buyer or user of the product. This leads to an increase in uncertainty and risk associated with shaping the life cycle cost of the operational phase.

In addition, the entire timeframe from starting the operation until the end of the useful life of the product is directly linked to the LCC of this phase. While often predefined lifetime is set based on customer expectations and producer estimations, there is high uncertainty if the product will effectively be in use until the end of its lifetime. The costs incurred in this phase of the life cycle are directly related to the total benefits derived from the product by the user of the product. At the same time, the derived benefits of the product may not only be a function of the benefits of the product compared to the costs associated with the product, but also a comparison to other existing alternatives in the market. For products with a long lifespan, technological development can be a crucial point in the design of LCC to deliver the most benefits for a relatively short lifespan and manage the potential obsolescence due to technological development (Olivia & Kallenberg, 2003; Stark, 2015).

3. Methodology

In this part of the thesis, the methodological approaches used in this research are described in detail. Additionally, the application of the chosen approaches will be justified in the context of answering the research questions. At the beginning of this chapter, the general research strategy is outlined to provide an overview of the research process. The research design and research methods are then discussed in detail to provide an insight into the individual processes involved in this research. Next, the methods of data analysis are discussed to provide an understanding of the importance of the analysis process in this research. Finally, the limitations of this research process will be discussed to provide a perspective on the validity of the data collected.

3.1. Research Strategy

The starting point for this research project was a general interest in the topic of life cycle cost analysis. Then, internal communication in the workplace showed an increasing demand for life cycle cost assessments requested by potential clients, which presented a new challenge for the company. This challenge served as a catalyst to focus the overall research objective on the area of life cycle costing and how this concept can be applied in practice. The decision of the research strategy is mainly based on the objective of this research and the related research questions. The strategy of the research process must be designed to serve the purpose of arriving at an answer to the research questions and ultimately fulfilling the research objective. The research objective of this project is to increase the understanding of life cycle costing in the servitization process of manufacturing companies. This research objective is attempted to be fulfilled by answering the research questions. While the overall research objective was defined at the beginning of the research process, the explicit research questions to answer the objective could not be finalized without further exploring the knowledge area of life cycle costing through primary and secondary research (Schick & Vaughn, 2013).

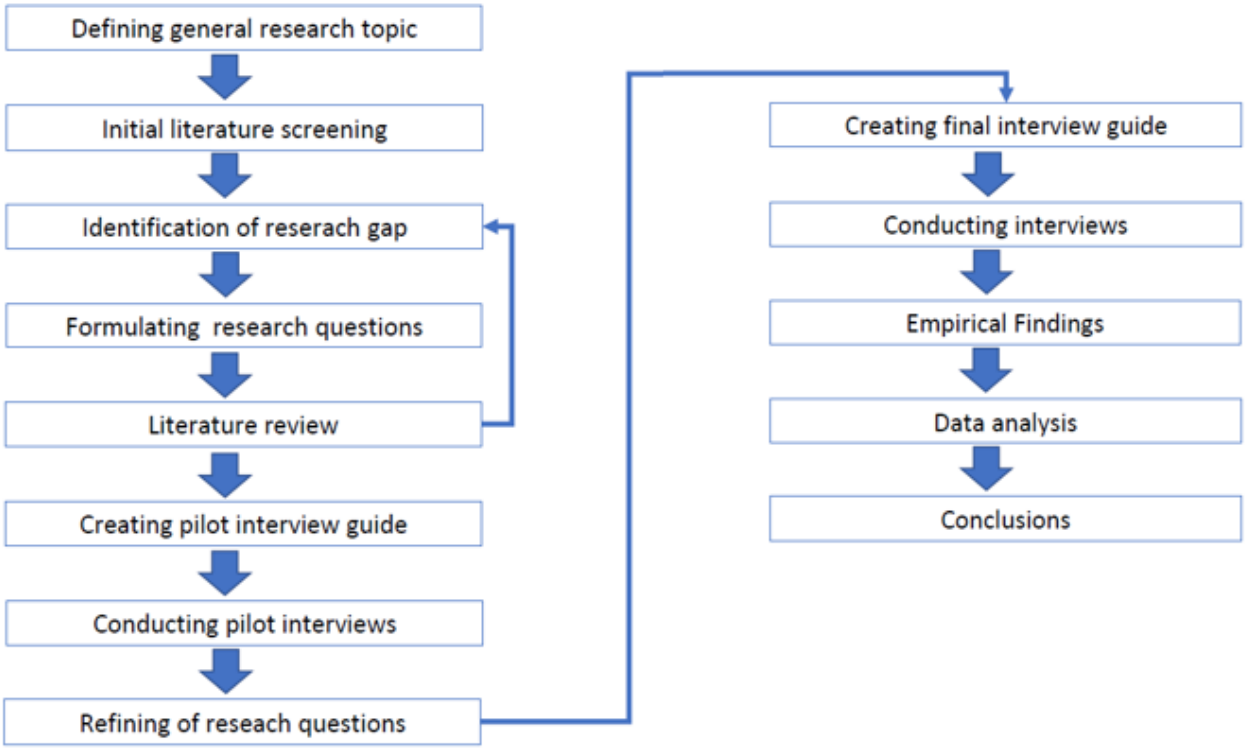
Both the objective and the research questions are exploratory in nature to provide answers to knowledge areas that are not currently well explored. The aim of this research is not of a validating form, where existing research is tested in a different scenario to validate pre-existing concepts and frameworks. For the exploratory nature of the aim and questions, only an exploratory research strategy is appropriate. Therefore, the entire research strategy and process is developed on the premise that exploratory methods increase the likelihood of answering the research questions and meeting the objective. The most appropriate strategy for exploratory research is the use of qualitative research methods. A qualitative research strategy allows for the use of various research methods that provide great insight into complex scenarios where there is no clear quantifiable

nature of the problem (Bryman & Bell, 2011; Betz, 2011). While the overall topic of life cycle costing seems to be based almost entirely on quantitative data, the use and challenges of life cycle costing are more associated with qualitative factors and assessments. A quantitative research strategy, on the other hand, would require the use of quantitative methods, which are very powerful in validating concepts where the essential data is quantitative or easily quantifiable. To fulfill the aim of this research, the use of quantitative methods was deemed inappropriate as there are no clear quantifiable findings that can help answer the research questions (Tracy, 2020).

3.2. Research Design

Based on the chosen research objective and the general research strategy, an appropriate research design was chosen. In this exploratory context, it was decided to use an iterative research design that begins with preliminary research questions that guide the research process in the early stages. Findings during the research process then led the researcher to refine the research questions as the context and research gap became clearer. Additionally, it was deemed appropriate to use the researcher's workplace company as a case company for this research project. This approach allows access to internal resources as well as knowledgeable individuals who can serve as a resource for primary research. Because the overall topic of life cycle costing is a highly contextual area of knowledge, the case study approach allows for an in-depth examination of a given scenario, rather than a superficial examination of multiple contexts that may conflict (Betz, 2011).

The case company agreed to actively participate and support the research process, which helped to create a research approach that will have both academic and practical relevance. The overall research process is structured as shown in Figure 3.1. The steps of this research process are described in detail in the following sections of this thesis. The research process starts with a general narrowing of the topic and an initial literature screening to increase the knowledge about the overall topic of life cycle costing and servitization. Then, the research gap is defined through an iterative process of reviewing the academic literature and formulating research questions. This secondary data collection serves as the foundation for the primary research and the overall goal of increasing knowledge about life cycle costing in the context of servitization. In the following steps, an initial pilot interview guide is designed and tested on individuals within the case company to increase understanding of the relationship between the academic literature and the practical application of the topic. This process leads to a refinement of the research questions, which serve as the basis for an improved research guide to be used in the main primary data collection. The data collected will then be analyzed and discussed in relation to the academic literature. At the end of the research process, the conclusions of this research project will be presented.



3.1 Research Process

3.3. Research Methods

The primary and secondary research methods used are defined and discussed in this section. As this is an exploratory and qualitative research strategy, the methods used are exclusively qualitative in nature. The selection of appropriate methods is based on determining the potential contribution to answering the research questions and the overall aim of this study. At the same time, the resources available and the time frame of this research project influence the choice of appropriate methods. Finally, the selection of primary and secondary methods will consider the limitations of the chosen research strategy and design, with a focus on methods suitable for a case study approach.

3.3.1. Secondary Data Collection

With the general goal of expanding the understanding of life cycle costing in the context of servitization, the process of secondary research begins with an exploration of the existing academic literature in this area of knowledge. In this research, there are two main knowledge areas, one is Life Cycle Costing and the other is Servitization. These two

knowledge areas can be discussed in a variety of contexts, but for this research a manufacturing context is chosen as the focus. As can be seen from the research design, the literature review in this research consists of two separate parts, differing in form and scope. At the beginning, an initial literature screening was conducted in a more narrative form. Then, after the research objectives and questions were more narrowly defined, a structured literature review was conducted. This approach allowed for a free exploration of existing knowledge in the context of creating initial research questions and narrowing down the overall research topic. The narrative approach was chosen as appropriate at this stage as it allowed freedom and flexibility in reviewing the existing literature, which was supportive in defining the overall research gap (Bryman & Bell, 2011; Lancaster, 2012).

The second part of the secondary data collection is the actual process of literature review, which was conducted using a systematic approach. This approach provides a scientific structure to the literature review process that can reduce the researcher's personal bias in selecting literature to review. Although this approach provides structure, it requires a well-defined research objective and research questions as there is little flexibility to proactively select literature outside of the predefined boundaries. The choice of a structured literature review process was made to enhance the scientific quality of the secondary research and to minimize the potential bias of personal and emotional involvement in the literature review process. Especially since this research project is associated with a company that is the researcher's workplace, personal bias could be an issue that may be reflected in the selection of literature reviewed to confirm preconceived notions about the topic (Lancaster, 2012). There could be a conflict in using an exploratory research approach and using a structured literature review as there is a contradiction in the underlying assumptions about the research process. Whilst exploratory research acknowledges a lack of well-defined research and seeks to explore all academic literature, the structured literature review requires clearly defined research questions and characteristics for the selection of appropriate literature. This conflict is addressed by implementing a narrative literature screening prior to refining the research questions and narrowing the research gap (Betz, 2011; Tracy, 2020).

3.3.1.1. Initial Literature Screening

In the narrative literature review, the following keywords were chosen as the starting point for the secondary research: "Servitization", "Product-Service System", "Business Model Servitization", "Industrial Services" and "PSS design". On the one hand, these keywords were used for screening the overall topic of servitization in the manufacturing context. On the other hand, the following keywords were used to search for life cycle cost literature relevant to this research: "Life Cycle Costing", "Life Cycle Cost", "LCCA", "Cost Analysis", "Cost Modeling", "Product Lifecycle". Additionally, keywords from these two categories were combined to identify research that covered both topics. The resulting

literature then served as a starting point for further exploration of the topic based on scientific evidence related to the defined research objective of this project. This process suggested that there is a significant research gap in the academic literature regarding the application of life cycle costing in the context of servitization in manufacturing companies. While there is academic research on life cycle costing and servitization, the combination of these two concepts is a relatively unexplored area of knowledge. At the same time, the process of life cycle costing has been used in a variety of contexts, suggesting that there is a lack of clearly defined terms, which complicates the literature search process. In addition, the academic literature on servitization in manufacturing was found to be highly contextual with relatively little generalizable data. Even within the field of servitization, the terms and definitions used tended to be vaguely defined, creating a challenge when screening and reviewing the academic literature. The literature screening process proved valuable in refining the research objective and focusing the research on life cycle application in the servitization context as a context-dependent case study that does not focus on producing generalizable data (Tracy, 2020; Lancaster, 2012).

3.3.1.2. Systematic Literature Review

Based on the narrative literature review and the research aim and research questions, a structured literature review process was conducted to gain a comprehensive understanding of the underlying academic literature for this research process. The original keywords chosen for the narrative literature review process were adjusted according to the results of this iterative process. In this process, the two overarching themes of this research were divided into "Servitization" and "Life Cycle Costing". The systematic search was divided into two categories to find in-depth articles on both knowledge areas. The initial literature screening revealed that the overlap between these two knowledge areas is relatively small, which limits the amount of appropriate research for this study. By dividing the systematic literature review into two knowledge areas while appreciating the totality of existing research, a solid foundation for primary research can be established. The articles to be included were selected from the keyword articles with additional inclusion and exclusion features discussed for each of the two knowledge areas. The headings, abstracts, and introductory chapters of the articles were reviewed for their suitability for this research process. For the Servitization category, the following keywords were used: "Servitization", Product-Service System", "Industrial Product-Service System", "Industrial Services" and "Business Model". The main focus in this part of the systematic literature review was to find literature related to servitization in a manufacturing context. Therefore, articles with a manufacturing and industrial context were included, while articles focusing on other contexts were excluded from the literature review. For the second part of the literature review, the topic of life cycle costing was defined with the following keywords: "Life Cycle Costing", "Optimum Reliability", "Reliability Modeling", Life Cycle Cost Analysis", "Total Cost of Ownership" and "Total Life Cycle Cost". In this part, the focus of the literature has been on the process of life cycle

costing as a holistic process. Articles dealing exclusively with quantitative life cycle cost modeling and statistical cost estimation were excluded from this review. At the same time, articles focusing on cost management through maintenance optimization were excluded as they were outside the scope of this research process.

3.3.2. Primary Data Collection

The review of secondary literature served as the basis for the primary research process in this project. As previously mentioned, it was decided to use a case study approach for this research, allowing for in-depth primary research of the case company. The process was built iteratively to increase the likelihood of gaining valuable insights that would help answer the research questions. In the following parts, the primary research process is further discussed and justified in accordance with the research objective of this project.

3.3.2.1. Case Study Selection

As argued earlier, a case study approach was deemed appropriate for the primary research process as the topic of life cycle costing and servitization is a highly contextual system. Whilst generalizable research findings would be of great value in this area of knowledge, the scale and resources of this research are inadequate to generate sufficient high quality data to enable generalizability of findings. The case study approach, on the other hand, allowed for in-depth primary research in a case company. This allows the researcher to gain detailed insight into the dynamics of life cycle costing and servitization in a practical context. Furthermore, access to primary research sources is greatly facilitated as internal references provide an easy way to access high quality resources (Betz, 2011; Lancaster, 2012).

The case company was selected as a suitable case study subject as it meets the contextual requirements of this research. The company operates in the manufacturing sector and offers a highly product-dominated value proposition. At the same time, there are market dynamics that reflect a need to rethink the business model in the near future. In addition, the company's life cycle costing and servitization efforts are largely unstructured and not yet well established. This allows for an exploratory research process as the structure is not yet defined and individuals within the company are given conceptual freedom. A well-established product-service-system approach in the company might have been a preferred research scenario for a different research approach, but that is not necessarily the case for this exploratory research. As the case company has some interest in evaluating the servitization potential and the role of life cycle costs in this process, there was a great deal of collaboration between the company and the researcher. This helped to identify a research question that has academic and practical relevance. At the same time, it was emphasized that the researcher acted as an independent entity that took an unbiased and academic approach to data collection and analysis. This was clearly communicated in order to generate qualitative data that critically assesses the situation in the company and the role of life cycle costing in servitization efforts.

3.3.2.2. Semi-Structured Interviews

Semi-structured in-depth interviews were chosen as the appropriate research method for the primary research process. This qualitative research method is a commonly used interview form that allows for a balance of freedom and structure necessary for exploratory research approaches (Whiting, 2008). Interviews are an effective research method for gaining insight into the perceptions and knowledge of individuals that are a significant part of gaining an understanding of the potential benefits of life cycle costing in the servitization process as perceived by individuals within the organization. At the same time, individuals within the company are aware of the internal processes and could have valuable insights into the challenges associated with the life cycle costing process of their products. The semi-structured approach was chosen because a predefined set of questions without flexibility would limit the exploratory potential of the research. At the same time, an unstructured research approach could lead to unstructured and complex data that would be of little help in gaining a clearer insight into the life cycle costing and servitization processes in the company. Therefore, a semi-structured interview was chosen with an interview guide containing the most general questions. This allows the researcher to ask follow-up questions throughout the research process based on the interviewee's input. In this way, the interview guide does not necessarily have to include all the relevant questions that can help answer the research questions and meet the objective (Betz, 2011). Since the literature review essentially defines the interview guide, a structured interview guide would limit the researcher to validate existing literature. In summary, the semi-structured approach allows the researcher to consider questions based on existing academic literature while acknowledging that individuals in the case company may be valuable sources of data not yet captured in existing literature. Particularly as the topic of servitization in manufacturing companies is not well researched, this approach is essential to facilitate a high quality exploratory research process (Schick & Vaughn, 2013).

3.3.2.3. Selection of Interviewees

In view of the research topic and the scope of the research, it was considered necessary to conduct at least 10 interviews with people in the case company. This was necessary to gain a solid understanding of the life cycle costing and servitization processes in the case company, taking into account the limited time frame of this research. During the literature review there was a clear separation between Life Cycle Costing and Servitization, with relatively limited overlap of academic knowledge. Although the aim of the primary research is to conduct interviews with individuals who have significant knowledge in both areas, it was recognized that it may be difficult to identify and reach individuals who are experts in both areas. Therefore, it was decided to divide the selection of interviewees into groups of five individuals who were experts in each area of knowledge. At the same

time, available interviewees with expertise in both areas were prioritized for the primary research process (Whiting, 2008; Bryman & Bell, 2011).

Therefore, for the selection process, it was not appropriate to rely on random sampling techniques as individuals for this process require expert knowledge that is not evenly distributed across the workforce of the case company. Therefore, a non-probability sampling method was chosen for the primary research process of this project. The organizational structure of the case company does not contain a specialized department or team for the purposes of life cycle costing or servitization. As the literature review suggested, specialized knowledge of life cycle costing processes is usually distributed throughout the organization, as different steps of the life cycle are associated with different departments or teams. At the same time, the servitization processes and the business model decision of the company are very complex and cannot necessarily be narrowed down to one team or individual. Since the required knowledge and expertise for this research is spread across the company, a snowball approach was chosen as appropriate. In this approach, interviewees can refer to other suitable interview candidates who could be helpful resources for this research. In this way, the chances of reaching the most appropriate individuals are greatly increased. At the same time, the snowball system is susceptible to personal bias in the selection of interviewees. The interviewee might be more likely to recommend another person with a similar view of life cycle costing and servitization than another person with opposing views. This could lead to a biased sample group of people representing only a part of the case company. A pilot study was conducted to avoid this bias and to obtain the most appropriate sample of respondents for this research (Betz, 2011).

3.3.2.4. Pilot Interviews

Prior to conducting the semi-structured interviews for the primary research of this project, a pilot study was conducted. The purpose of the pilot study was to identify appropriate interviewees for this research and to gain a deeper understanding of the topic of life cycle costing and servitization in a practical context. For the pilot study, two individuals were identified within the company who are actively involved in processes related to the research topic. At the same time, the selected individuals are experienced employees who have an established network of contacts within the company. This allows access to a general introduction to the research topic and at the same time access to valuable leads within the organization. This iterative and exploratory research approach also used the findings from the pilot study to refine the research questions. For the pilot study, individuals who were knowledgeable but not necessarily the assumed core targets for this research were intentionally selected so as not to deplete the most valuable resources prior to the actual interview process (Whiting, 2008; Schick & Vaughn, 2013).

The interviews for the pilot study followed a semi-structured approach with an interview guide containing general questions about the life cycle costing activities in the company.

In addition, the servitization of the company was the topic of the interview guide, while staying at a general level to avoid bias or leading questions. While the original plan was to conduct the interviews in a physical meeting, they were eventually conducted via MS teams at the request of the interviewees.

Interviewee	Function	Date	Duration	Language	Form
C1	PLM Responsible	2021-01-18	38 minutes	Swedish	MS Teams
C2	Service Engineer	2021-02-04	42 minutes	Swedish	MS Teams

Table 1 Pilot interview respondents

Both interviews were initially scheduled to last approximately 30 minutes, which was considered appropriate for an initial interview for the pilot study. The first person selected was working in PLM (Product Life Cycle Management) and mainly contributed on the life cycle costing side in the case company. The other interviewee was selected because of his role in the after-sales market, which is a potential area for servitization efforts in the case company. Both individuals were instrumental in refining the research questions and pointing to suitable interview candidates in the case company. The process of conducting a pilot study helped refine the research question based on practical feedback from the pilot interviews. At the same time, this process was a helpful part in designing the final interview guide used in the primary research process. It was found that there is a significant difference in the definition and terms used in academic research compared to the practical application of life cycle costing and servitization. As these theoretical concepts are not necessarily part of the daily activities of the workforce at the case company, it was decided to briefly introduce the relevant theories in the interview process when it was deemed necessary to explain a specific part of the relevant life cycle costing or servitization processes.

3.3.2.5. Interview Guide

As described, the interview guide was the result of an iterative process of secondary research and the results of the pilot study. In the semi-structured interview process, the interview guide serves as a guide in the interview while leaving room for questions not included in the interview guide. At the same time, the interview guide does not specify an order of questions to be asked, allowing for a natural flow of conversation. The aim of this primary research was to achieve a natural flow of conversation while using the interview guide to structure the conversation when necessary. This allows for high quality exploratory primary research that can help answer the research questions (Whiting,

2008; Tracy, 2020). While the primary research process targeted two different areas of knowledge, it was decided to formulate a general interview guide that was used in all interviews conducted for this research. While experts were selected based on their knowledge in their respective knowledge areas, a potential overlap of knowledge could be overlooked if questions were only asked about one knowledge area. At the beginning of the interview guide, a brief introduction to the research process was given to the interviewee to explain the aim of this research. At the same time, it was clearly stated that the data collection would be treated anonymously and no link to their personal information would be made in any of the research documents. This was done to ensure an ethical research process and to allow respondents to speak freely about internal processes in the case company. Introductory questions were then used to create a formal understanding of the interviewee's role in the company and length of service. This was helpful in getting into the interview process and gaining an understanding of the interviewee's background, which had a significant impact on the focus of the interview process. After the initial introduction, the theoretical background of this research process was briefly defined for the interviewee to ensure a common understanding of the terms and definitions used. Specifically in the area of life cycle costing, the perspective of cost over the life of the product was clarified as the focus of this study. As described earlier, the pilot study found that there was confusion about the exact definitions and terms used, which presented a challenge to clearly communicating relevant ideas. The questions specified in the interview guide were not necessarily asked in all interviews. Depending on the context and function of the interviewee, the focus of the interview guide was shifted to different aspects. At the same time, it was important to maintain a natural flow of conversation rather than formally asking all stated questions directly to the interviewee (Bryman & Bell, 2011).

After structuring the background of the interview guide, it initially focused on the life cycle costing processes. To provide a simple structure to this complex process, the BML cycle served as the basis for the interview guide. The questions were structured to refer to a stage of the BML cycle in the life cycle costing process to provide guidance in the interview process. The questions were formulated in an open-ended manner to allow the interviewees to freely express their knowledge and share their expertise without being constrained by closed questions. The aim of the questions related to the life cycle cost process was to answer the research question about the challenges in the life cycle cost process. Therefore, the questions first focused on getting an overview of the structure of the processes involved in the whole life cycle cost process in the company. Then, questions were asked directly about the challenges that the respondent perceived in the current structure of the processes. In this way, it was possible to identify the overall structure of the processes as a source of challenges while obtaining direct input on the actively perceived challenges.

The second part of the interview guide focused on answering the research question about the benefits of life cycle costing in the servitization process of the case company. As the ongoing servitization processes are relatively unstructured and in an exploratory stage, it was assumed that knowledge about already obvious servitization challenges is rather low among the people in the case company. Nevertheless, by including a wide range of individuals with different functions and backgrounds, the perceived challenges and opportunities of servitization can be explored. To determine the benefits of life cycle costing in the servitization process, it was assumed that life cycle costing processes can help solve problems that arise in the servitization process. Therefore, questions about the perceived and expected challenges of servitization were included. In this way, these challenges could be related to the overall benefits of life cycle costing and any overlap could serve as a possible answer to the research question. In order to stimulate the creativity of the interviewees and to explore the application field of servitization using the company as an example, additional questions regarding the possibilities of servitization were included in the interview guide. This allowed for an understanding of the potential applications of servitization, which could then be analyzed to understand the benefits and role of life cycle costing in each application. As the literature suggests a strong link between product reliability and the life cycle costing process, questions were also asked about product reliability in the case company. These questions were included to gain a deeper understanding of the potential for servitization that may not be directly perceived by the interviewees in this primary research process.

3.3.2.6. Semi-structured Interviews

As described earlier, the main part of the primary research process will be based on semi-structured interviews with people from the case company. Based on the pilot study and the recommendation of the pilot interviews, a number of 12 individuals were contacted to participate in the interview process. Initial contact was made either by face-to-face interview or by email if face-to-face contact could not be made prior to the interview. During the initial interview contact, the overarching theme associated with the aim of the research process was briefly introduced. Then, the relevant details were discussed over the estimated duration of 45 minutes to allow for practical planning of meetings to conduct the interviews. Additionally, it was mentioned that the interviews should preferably be conducted in a physical meeting as this allows for more nuanced conversation and data collection. As an alternative to a physical meeting, the intra-company channel MS teams was suggested as an alternative way to conduct the interview. It was also communicated that the interview should preferably be recorded so that the data can be analyzed after the interview. In terms of data analysis, it was noted that the results of the study would be treated anonymously and would not be shared with others unless the interviewee consented (Whiting, 2008; Bryman & Bell, 2011). In response to the initial interview invitation, a number of 10 individuals responded positively and were available to be interviewed in the allotted time frame for primary data collection.

Although the remaining two interview candidates also agreed to be interviewed, an appointment could not be arranged within the desired time frame. It was decided to exclude these candidates from the interview process as the primary data collection process was to be completed before the data analysis began. Therefore, for the time frame of this research, the priority was to complete the data collection with 10 interviewees rather than delay the data analysis portion due to two additional interviews. The 10 interviewees for this primary data collection represent five individuals for each of the two main knowledge areas essential to this research process. It was important to include the perspective of different functions and departments within the company, which was achieved through the total number of interviewees that could actually be interviewed.

Interviewee	Function	Date	Duration	Language	Form
A1	Procurement	2021-03-09	46 minutes	Swedish	MS Teams
A2	RAMS/LCC	2021-03-15	57 minutes	Swedish	Face-to-face
A3	Customer Service	2021-03-17	45 minutes	Swedish	MS Teams
A4	Test Manager	2021-03-18	49 minutes	Swedish	Face-to-face
A5	R&D Manager	2021-03-17	49 minutes	Swedish	Face-to-face
B1	Sales Engineer	2021-03-16	55 minutes	Swedish	Face-to-face
B2	Engineer Manager	2021-03-18	47 minutes	Swedish	Face-to-face
B3	Portfolio Manager	2021-03-22	77 minutes	German	MS Teams
B4	Key Account Manager	2021-03-24	57 minutes	Swedish	Face-to-face
B5	Global Support	2021-03-25	55 minutes	Swedish	MS Teams

Table 2 Interview respondents

Individuals were grouped into A and B respondents to allow for a more structured portion of the data analysis and to analyze whether there were patterns within the two groups and how significant the overlap of knowledge was. Group A was selected based on expertise and experience related to the field of life cycle costing. All respondents are directly involved in activities related to one of the steps of the whole life cycle costing process. The second group B was selected as suitable interviewees based on the competence and experience in the field of business model change activities and

servitization. While the actual servitization progress in the company is not formalized, the individuals are engaged in activities identified in the literature as key areas for servitization potential in manufacturing companies.

The interview process itself was structured through the use of the interview guide described earlier. As discussed, the focus of the interview was aligned with the general skill areas of the interviewee to maximize the quality of the primary data collection. The majority of the interviews were conducted face-to-face, which was helpful for a natural flow of conversation. For the remaining interviews, the software MS Teams was used to conduct the primary research. In both settings it was possible to obtain audio recordings of the interview process as all interviewees agreed to be recorded during the interview. This allowed for a clear focus on the conversation and a nuanced picture of the interviewees' responses. At the same time, key words were recorded as notes to support the post-interview data analysis part of the process. However, it was kept to a minimum in order to focus on the actual conversation with the interviewee and to gain a deep understanding of the interviewee's perceptions of life cycle costing and servitization. All interviews were conducted in the interviewee's native language to allow individuals to have an easy flow of conversation and express their perceptions in the most accurate form (Tracy, 2020). This required additional effort at the data analysis stage of this research as the resulting data was translated into English. To reduce the possibility of miscommunication and misinterpretation leading to translation issues, the results of the data collection were sent to the interviewees to verify that the translated data collection accurately reflected the data entered by the interviewees (Schick & Vaughn, 2013). Given the relatively limited time frame of this research project, interviews were scheduled within a four-week period. This allowed for a large amount of data collection to be completed in a short amount of time, which was helpful in allowing additional time for in-depth data analysis. For this research, it was chosen to complete the primary data collection before beginning the data analysis. While an iterative data analysis approach could allow for restructuring of the interview guide and research approach during the primary data collection phase, this approach makes it difficult to structure the data collected. This would lead to an increase in the complexity and time taken to analyze the data collected and was therefore deemed unsuitable for this research. Data input during the interviews was very helpful in answering the research questions. Although it was initially assumed that the overlap between the two main areas of knowledge might be relatively small, most interviewees were able to make a valuable contribution to both areas. The estimated duration of approximately 45 minutes was exceeded for most interviews, largely due to additional follow-up questions. Overall, the semi-structured interview approach generated a large amount of data that was very valuable in fulfilling the aim of this research.

3.4. Data Analysis

This thesis is characterized by an exploratory approach and seeks to gain a deeper understanding of the role of life cycle costing in the servitization process. In order to contribute to filling the research gap in the academic literature on this topic, primary data collection is essential. The primary data collection process of this research resulted in nearly nine hours of audio recordings covering the topic of life cycle costing and servitization in the context of the case company. In order to maximize the value that can be derived from the audio recordings of the semi-structured interviews in the context of the research objective, an appropriate data analysis process must be selected. In this research design, the process of primary data collection was completed prior to the commencement of the data analysis section, which simplifies the data analysis process as the structure of the interview guide can be used as a starting point for further analysis of the data collected. For the data analysis of this research, a thematic analysis approach was chosen as an appropriate means of extracting values from the primary data collection (Bryman & Bell, 2011).

The thematic analysis approach was chosen because this exploratory research requires flexibility in the data analysis processes to generate valuable insights. In cases where the data is being used to validate existing theories, this may be inappropriate, but for the purpose of this research, thematic analysis provides the flexibility needed while providing a structured approach that allows for scientific data analysis. Initially, a grounded theory approach was evaluated as a suitable data analysis method for the purposes of this research. In the context of an exploratory case study research process, a grounded theory approach would require generalization of the primary data to generate a theory that can be applied in other contexts. As the data collected in this research does not necessarily provide the generalizability required to apply this approach universally, the process of thematic analysis was chosen instead. The process of thematic analysis is a structured process in which the apparent patterns and themes of the primary data collection can be extracted without being constrained by existing theoretical assumptions that may limit the researcher in the analysis process (Braun & Clarke, 2006). Since the data collection was conducted to provide answers to the stated research aim and research questions, a theoretical thematic analysis was adopted. This approach attempts to fit the primary data collection into predefined themes and patterns. Although this may limit the researcher's freedom in data analysis, the interview guide for this research was not altered during the process of primary data collection, so the primary data is already predefined by the chosen structure of the interview guide. Where the apparent data patterns differed greatly from the structure of the interview guide, the theoretically predefined themes were supplemented with inductively created themes. This allowed for the analysis of all relevant data that directly contributed to answering the research aim and research questions, while covering recurring themes from the primary data collection that were not directly intended to be part of the data collection. Additionally, the thematic analysis

was based on a semantic approach, where the collected data is analyzed at an explicit level. While there may be underlying implicit intentions and perceptions of respondents in the qualitative research process, these are complex and difficult to extract. In the process of latent thematic analysis, the researcher's bias is often much more involved in the data analysis as the analysis of implicit data requires at least some level of assumptions and interpretations. This would reduce the scientific validity of the data and further increase the complexity of the data analysis process. The potential benefits of latent analysis were considered to be low in the case of identifying challenges and benefits of life cycle costing in this case study context, therefore a semantic level of analysis was used (Betz, 2011).

3.4.1 Thematic Data Analysis

The process of thematic analysis of the audio recordings of the semi-structured interviews followed a six-step model that provides guidance and structure in the data analysis process (Braun & Clarke, 2006):

3.4.1.1. Familiarization

As a starting point for the thematic analysis, the collected audio recordings of the interviews were transcribed using an AI-based software (Scriptme.IO). The transcript generated by the software served as the starting point for the incorporation into the dataset. Because the software-generated transcript was not an accurate transcription, the text was corrected based on reading the transcript and simultaneously listening to the actual audio recordings. This process helped to gain a deeper understanding of the data collected and served as a starting point for further analysis. At the same time, the written notes taken during the interviews were reflected upon in light of the overall interview transcript. At the same time, the familiarization process helped to provide an initial sense of recurring patterns and themes within the data set (Braun & Clarke, 2006).

3.4.1.2. Coding

After the initial familiarization with the data set the initial coding process was started. The coding was carried out for each of the ten interview transcripts with a focus on relevant codes for the research aim and research questions. At the same time, recurring codes that are not directly linked to the questions have been highlighted to capture additional findings in the data set. The coding was assisted by a key-word search in the transcripts of the interviews to identify an overlap of codes already early in the coding stage. At the same time, the transcripts were highlighted with color codes to visualize the content of the data collection. In this stage, the chosen codes were all in English language, while the transcripts were in Swedish and German language. It was carefully reflected upon if the chosen translation might dilute the value of the code, to maximize the derived value of the primary data collection. As it was decided that direct quotes might be helpful in

communicating the content of the interviews, suitable passages in the transcripts were identified in this stage of the analysis (Tracy, 2020).

3.4.1.3. Generating themes

Once the initial coding phase had been carried out to a sufficient level of detail, the overarching themes were used as the structure for sorting the codes. As described earlier, thematic analysis is a semantic-theoretic type that uses the predefined themes of the interview guide as a starting point for structuring the codes of the interview. At the same time, the codes that did not fit into any of the predefined themes were initially sorted into the "other" theme to capture insights that did not directly contribute to answering the research questions. The themes are structured into "Challenges of Life Cycle Costing" and "Benefits of Life Cycle Costing" with several subthemes describing the themes in more detail. This approach combines a top-down literature-based thematic analysis with a data-driven approach that provides deep insight into primary data collection. In this step, codes were first assigned to general themes and then grouped into various subthemes identified during data collection (Betz, 2011; Braun & Clarke, 2006).

3.4.1.4. Reviewing themes

Following topic generation, the topics and subtopics were reviewed for their usefulness in conveying the content of the primary data collection. This involved reviewing the patterns at the code level once again in relation to the chosen subtopic and theme to ensure a holistic presentation of the data. At the same time, the subthemes were reviewed to ensure an accurate representation of what the interviewees actually said. In this process, the subthemes were restructured to ensure clear communication of content while reducing redundancy among subthemes. While some degree of subtopic overlap was deemed appropriate, efforts were made to avoid it where possible. In addition, the codes that did not fit within the themes and subthemes directly related to the research objective were reviewed in order to present the additional findings in a structured manner. The additional findings in the theme "Benefits of Life Cycle Costing" were analyzed and grouped into subthemes. When deriving the benefits of life cycle costing, the distinction between intended and additional data was complicated, as the perceived benefits were mostly communicated explicitly. At the same time, the interviewees mentioned challenges in servitization that could be related to a possible benefit of life cycle costing (Braun & Clarke, 2006).

3.4.1.5. Defining and naming themes

In this phase of the analysis, the reviewed themes and subthemes are further defined to extract the essence of the primary data collection. At the same time, the final naming and structure of the themes and subthemes was reviewed to effectively communicate the content of the interviews in the context of this research process. Naming was revised to

provide a clear indication of content, while subthemes were framed within the context of this research objective.

3.4.1.6. Writing up

The last part of the data analysis is related to the decision on how to present the results of the analysis process. This part is crucial to the research process because it is in this process that the communication of the data analysis to the reader takes place. Therefore, it was critical to document the results of the primary data collection in a logically coherent flow without interpreting latent assumptions into the data set. Themes directly related to each research objective and research questions were chosen as the starting point for presenting the primary data collection. Additional findings that were not directly related to the research questions were presented in a structured manner to highlight the perceived benefits of LCC while addressing servitization challenges that may imply potential benefits of LCC. To effectively communicate the findings, direct quotes were embedded in the empirical findings section as deemed appropriate. These quotes were translated into English and verified by the interviewee to ensure an accurate translation of the interview content. The outcome of the data analysis process is presented in the empirical findings section of this thesis below (Tracy, 2020; Bryman & Bell, 2011).

3.5. Research Quality & Limitations

The final part of the methodology is a discussion of research quality and limitations. As with any qualitative research process, there is an inevitable interference of the researcher as an individual with preconceived ideas and assumptions with the data. In order to minimize the dilutive and biased influence of data collection, the methodology of this research has been designed in a structured and scientific manner. Although qualitative research does not necessarily lend itself to a purely objective and scientific evaluation of data, a structured qualitative research process has its merits. As this research aims to expand the understanding of life cycle costing in the servitization process, human participation is required to understand the perceptions and conceptualizations in a practical context. From the choice of the research topic to the decisions regarding the interview guide and the selection of interviewees, the researcher is a major factor that determines the outcome of the data collection. This may reduce the validity of the data in an objective and quantitative sense, but still provides an insight into a real life application of life cycle costing. As mentioned earlier, this research does not aim to conceptualize reality in a universal framework that can be used to generalize the findings to a different context. The research findings should be interpreted in the research context and can help to gain an understanding of the potential challenges and benefits of life cycle costing in the servitization process. The nature of servitization processes is highly context dependent and the existing literature does not necessarily provide a universal concept

that can be applied to all contexts. Similarly, this research might not be useful for all contexts, but for companies in a similar environment to the case company, the findings of this research could provide a starting point for internal discussion and action (Bryman & Bell, 2011; Leung, 2015).

3.5.1. Reliability

One consideration for validating the data collected is the concept of reliability. The reliability of a data set is considered high when the process and results are highly replicable. In the case of this research, the primary data collection focuses on a single organization as the case study subject. The results of this research process are difficult to replicate because the research findings are not necessarily suitable for generalization to other organizations. At the same time, the process of secondary and primary research has been discussed and outlined in detail, which enables the researcher to design a similar research setting if desired. In this case, the reliability of the results cannot be replicated, while the process and context can be replicated, resulting in significant reliability of the data (Leung, 2015).

3.5.2. Validity

In assessing the data set and the methodology chosen, the notion of validity is a helpful variable. The methods used in this research were discussed in detail to clarify the intention and justification of the choice of methods and procedure. The methods should be evaluated in the context of the exploratory nature of the research as they cannot be effectively evaluated without the research context. The overall research process and methods were carefully documented to provide a detailed picture of the research process as part of the overall findings of this thesis (Bryman & Bell, 2011).

3.5.3. Generalizability

The concept of generalizability is another consideration when evaluating the data set of this research process. As mentioned earlier, this research process is based on a case study approach with a relatively narrow scope. Combined with a theoretical thematic analysis of the data, the overall potential for generalizability is relatively low. The topic of this research is highly contextual, making generalization to another context a complicated task. When attempting to generalize the findings of this research, the context and scope of the research should be considered before drawing conclusions. In a similar context, after careful consideration, there may be potential to generalize the findings of this research to some extent (Leung, 2015).

4. Empirical Findings

This part of the paper presents the empirical data collection of the primary research process. The empirical data is structured based on the relevant themes that emerged during the course of primary data collection. First, the empirical findings regarding the benefits of life cycle costing in the servitization context are presented. Then, the findings regarding the challenges of life cycle costing in the servitization context are presented. In all sections, the interviewees are quoted with their identification code, which was given in the methodology section.

4.1. Utility of Life Cycle Costing in Servitization

The following section presents the empirical findings on the usefulness of life cycle costing in the context of servitization. As described earlier, the themes relevant to the potential usefulness of life cycle costing were defined as the directly perceived benefits and challenges of servitization associated with life cycle costing more broadly. The benefits theme is divided into subthemes based on the Business Model Canvas sections of desirability, feasibility, and viability. While not all outcomes are explicitly related to the benefits of life cycle costing in servitization, there may be implicit connections that are discussed later in this thesis.

4.1.1. Desirability

When asked about the potential utility of life cycle costing in the servitization process of the case company, most respondents (A2, A3, A5, B1, B2, B3, B4, B5) referred to topics related to the desirability of the case companies' business model.

4.1.1.1. LCC as a Sales Argument

One point raised by several of the interviewees was the importance of life cycle costs in the process of selling products. While the main negotiation in terms of price is related to the initial selling price, the total cost of ownership of the product is a question often asked by the customer (B4, B1, A2). In these sales negotiations, the total cost associated with the life of the product is often discussed over a period of 30 years or longer. According to one interviewee, the importance of life cycle costs as a selling point are highly context dependent (A2, B2). In addition, the importance of life cycle costs as a factor in the sales process seems to have increased in recent years (B4).

> *"We are seeing an increasing pressure on LCC requirements already in the offer stage of our projects." – B4*

Several respondents indicated that the increased focus on LCC in the sales process is increasingly challenging the corporate processes of life cycle cost estimation (A2, A3, A5, B1, B2, B4). According to one respondent, the required level of detail in LCC estimation in the early stages leads to slower bidding work and complicated internal discussions (B1). Several respondents argued that the increased LCC requirements in the sales process lead to lost projects because the customers' requirements are not met (B1, B4, A2). One respondent argued that LCC requirements are sometimes not based on technical factors but rather on economic wishful thinking (A3).

> *"Last year we lost a project with a customer that has been working with us in many projects. They stated that the LCC requirements were not met and that this was part of the reason for rejecting our offer for this project." – B1*

Overall, most respondents indicated that they expect LCC requirements to increase in the coming years (A2, A3, A5, B1, B2, B3). One point mentioned by several respondents is that competitors in the market often have a different approach in dealing with LCC requirements, as a vague estimate rather than an exact calculation (B4, B5, A2). It was mentioned by some respondents that although LCC requirements are often strict and set over a period of several decades, the actual life cycle costs are rarely tracked by the customer (A1, A2, B4, B5). One respondent indicated that some of the customers are aware of this discrepancy and are working on developing a better cost tracking structure (B4). It was indicated by several respondents that this development is not necessarily a challenge for the case company as LCC estimates are usually slightly higher than actual costs incurred (A4, A2, A3, B5). In addition, it was indicated that the actual LCC of the products are often highly dependent on the actual treatment of the product during operation. In many cases, the actual LCC of the products have been shown to be lower than the originally estimated costs due to rather conservative safety margins (A2, A3, B5).

> *"We are rather conservative in estimating the LCC of product in the offer stage. We try to focus on safety and quality which often leads to increased safety factors in the initial LCC calculations." – A2*

It was also noted that showing the life cycle cost benefits of certain products can be very effective. The interviewee stated that if the company can provide reliable data on the actual life cycle costs of its systems, the sales process would become easier with certain customers (B4).

4.1.1.2. Customer ≠ Buyer

When asked about the usefulness of life cycle costing in relation to the desirability of the case companies' business model, many respondents referred to complexity in the sales process (A2, A5, B1, B2, B3, B4, B5). While there is an interest in the LCC of the products sold, this interest is not necessarily shared by all customers of the case company. As mentioned by several interviewees, the customers of the case company are rarely the actual owners of the product over a longer period of its lifetime (A2, A5, B1, B2, B4, B5). The interviewees argued that the customers, who do not actually pay the costs associated with the operation of the product, do not drive the LCC requirements themselves in the bidding or project phase. In almost all cases, the LCC requirements discussed in the bid or project phase are initiated by the actual owner of the product and not by the direct customer of the case company (A2, B2, B4, B5).

> *"In the discussion regarding LCC requirements the actual owner of the system is mostly driving the requirements. Our customers are not the ones actually paying the operational cost of the product." – B4*

This often complicates negotiations with the direct customer, as LCC requirements are only a secondary factor for them. Other interviewees mentioned that there are some customers who are also the operators of the plant, who have invested a lot in understanding the LCC of the products several years ago (A2, B3, B4, B5). In the actual negotiation process of the case company, there is rarely direct contact with the operator of the product. While there is an attempt to establish direct communication at the bidding stage to discuss LCC requirements, the product is not seen as a major cost driver of the operator's overall system (A2, A4, A5).

> *"We have, tried to communicate the LCC advantages of our products directly to the operator but this turned out to be complicated. Our system is not a big cost driver for the operator and is only slowly getting more attention." – B5*

Some interviewees mentioned that direct communication with the operator is currently a challenge, but there are increasingly better processes to bring in LCC requirements at the sales stage by the operator (A2, B4). This is expected to increase the importance of LCC as a selling point in the coming years (B4, B5, A5). Another point mentioned by several interviewees is that servitization efforts often failed in the past because the customer of the product was not interested in new business model ideas. Since the customer is not responsible for the operation, servitization of the offering was not in the best interest of the customer, while it added value for the operator. It is argued that a

closer connection to the operator could be the first step to try out new business models (A2, B1, B3, B4).

4.1.1.3. Collaboration

In relation to the role of LCC in servitizing the case company, the issue of co-development was mentioned by several interviewees (A2, A5, B3, B5). In LCC, the actual development of products and associated services often takes place with little or no collaboration with the customer and the operator. While market requirements shape the value proposition, interviewees argue that there is limited collaboration in the development process (A2, A5). In most cases, development collaboration is usually initiated when a challenge arises in an ongoing project (B3, B5).

> *"In most development projects there is no direct collaboration with the operator of the systems. This is making costly development prior to a project sale a difficult activity for us." – A5*

Several respondents mentioned that closer collaboration in the product development process would be helpful to optimize the total life cycle cost of the products (A2, A4, A5, B3). Respondents argued that defining the desired cost allocation earlier would be an easy way to design suitable products for customers. A potential problem with this was mentioned by one respondent as collaboration would reduce the customer's bargaining power (B4). The process of LCC could be an opportunity to effectively track the effectiveness of collaboration and serve as an argument for further collaborative development projects (A5, B3, B5).

> *"Being able to demonstrate the overall cost reduction for the operator through collaboration would be a very helpful process for all parties involved." – B3*

Some respondents argued that this cooperation must be initiated mainly by the company's operators and customers. While the company itself can approach the customer and propose a joint development to reduce LCC, this process is not the norm in the industry (A2, A5, B3, B5). At the same time, it was emphasized that the company should actively signal to the customer that collaboration is possible and mutually beneficial (B2, B3, B4). It was highlighted that this collaborative trust building could be helpful to offer more servitization value propositions. One interviewee stated that a servitized value proposition also requires a trusting relationship with the customer, as there are close connections over several years instead of a short interaction during the sales process (B3).

4.1.1.4. Segmentation

When discussing the desirability of the business model and the life cycle costing requirements of customers, the need to segment customers was raised by several interviewees (A2, A5, B3, B4, B5). There are customers who are strongly interested in the total life cycle cost of products in the sales phase. These customers tend to have advanced internal processes that track and evaluate the life cycle costs of different alternatives for each subsystem (A2, B4). These customers are very interested in having accurate LCC estimates in the sales phase to evaluate the offering and optimize the total cost of ownership and reliability (A2, A3, A4, B3). In order to effectively meet the customers' requirements regarding the LCC of the products, the internal processes are already challenged in terms of accuracy and speed (A2).

> *"We have certain customers that are very engaged in discussing the LCC of our products and trying to optimize the cost. Other customers on the contrary have very little interest in any LCC optimization at all." – A2*

Some respondents indicated that there are other customers who do not actively work with an LCC estimate and are not interested in changing their internal processes (A2, B3, B4). These customers do not consider an LCC perspective as a value-adding activity and will most likely not start doing so if operators do not bring their demands to them (A2, B5). Several interviewees stated that servitization of the business model needs to consider customer demands as they effectively choose the most appropriate of their options. Servitizing all customer segments could be counterproductive and lead to dissatisfied and confused customers who choose a competitor instead (A5, B3, B4, B5). At the same time, interviewees argue that it is not sufficiently defined which customer segments value which type of servitized value proposition. Defining customer segments in different servitization suitability was suggested as a desirable internal process (B3, B4).

> *"Getting an understanding of which customers are open to servitization offers would help us a lot to develop our value proposition to certain market segments." – B3*

4.1.1.5. Degree of Servitization

In relation to the previous subthemes of desirability, many respondents mentioned the complexity of defining an appropriate level of servitization (A2, B2, B3, B4, B5). While most respondents agreed that some kind of servitization of the business model is desirable in the future, the explicit form of servitization was unclear. Most respondents argued that the current value proposition is highly product-dominated and that service aspects in the value proposition could provide a competitive advantage for the company (B3, B4, B5). While there are some parts of the servitized value proposition in the after-

market area of the case company, these are not integrated with the original value proposition in the sales phase (B5). At the same time, these servitization efforts are mostly customer-driven and not well connected to a broader understanding of the implicit challenges of cost allocation (A3, B4, B5).

> *"We are focusing on selling the product to our customer, the additional services required to maintain the system are then negotiated once the operator is in charge of the product." – B5*

This product-dominated value proposition was cited as the most desirable solution from the perspective of the case companies (A2, B3, B4). Several respondents said that this value proposition is the status quo in the industry and that most customers are satisfied with the current model. At the same time, several respondents acknowledged that digitization in the industry is changing the requirements for the case company and that there is an increasing focus on low lifecycle costs rather than a low purchase price with high operating costs (B3, B4). Some respondents mentioned that it seems to be unclear for the case company what a future business model of a more service-oriented business model could look like (A2, B1, B3, B4, B5). Most respondents mentioned that a gradual increase in the service component might be most desirable for the company to slowly introduce the new processes into the business (B2, B3, B4, B5). Other respondents mentioned that servitization should be a reaction to customer requests rather than actively pushing for more servitization as there are many ambiguities related to servitization (A3, A5).

> *"Deciding on a service based offering is very difficult in this early stage. We are not fully aware of the implications of extended ownership of the product." – A2*

It was cited by respondents that deciding on the level of servitization at this stage is very difficult as there are many factors that are not well known. One challenge mentioned was that the cost of actually running the product depends heavily on the daily use of the product (A1, A2, A3, B5). At the same time, several respondents mentioned that they were convinced that the reliability of the product would most likely not be a problem in a servitized value proposition (A3, B2, B3, B5). It was argued that there is a potential to increase the case company's reliability for their products if they can receive adequate compensation for this service (B4, B5). Several respondents argued that a better understanding of the actual total life cycle cost of the products would help in deciding what to propose to the customer.

"By understanding the actual cost of ownership, we would gain an advantage in designing our market offering. But for this to happen we need more accurate return of experience of our product life cycle cost." – B4

4.1.2. Feasibility

Another sub-theme related to the usefulness of life cycle costing in the servitization process is linked to the feasibility of the business model. All respondents interviewed in the primary research phase mentioned that there is a potential benefit or challenges of LCC in processes related to the feasibility of the case company.

4.1.2.1. Supplier Collaboration

It was mentioned by several interviewees that the servitization efforts of the case company strongly depend on the supplier network (A1, A2, A4, B2, B3, B5). In many cases, the existing business model of a product-focused value proposition is the industry standard across the value chain (A1, A2). One interviewee argued that changing the business model to a service-focused offering would also require a change in the supplier network (A2). This change would require suppliers to provide products and services that are more tailored to the needs of the business than standard products (A1). Some respondents mentioned that changing the supplier network could be a challenge that could reduce the servitization potential (A1, A2).

"If we want to change the offering to our clients, we also need to make sure that our suppliers can handle this. There might be some suppliers that cannot deliver the required products to good price." – A1

Some respondents mentioned that the supply chain could become a challenge if the case company wants to offer a service-oriented value proposition. It was argued that if life cycle cost optimization is the focus, this must also be the case for all suppliers in the network (A1, A2, A3, B2). Some respondents mentioned that although there are suppliers that can deliver very reliable products, they are often significantly more expensive than the standard solutions (A1). If the company wants to move to a service-based service offering, the internal requirements need to be well understood and clearly communicated to the suppliers (A1, A2, B3). It was discussed that although this is possible, it could be more expensive as it deviates from the industry standard (A1, A2, A5). Some respondents argued that there needs to be close collaboration with suppliers to get the desired product quality with a reasonable lead time (A1). In addition, some respondents mentioned that it is important to include the supply chain perspective in the servitization process.

Respondents argued that suppliers determine what the case company can deliver and at what price. While the case company can define the desired value proposition, suppliers are essentially a bottleneck for opportunities (A1, A2, A3, B1, B2, B3).

> *"We can talk to customers to understand what they want. But we need to talk to the suppliers to check what we can possibly supply to the customers." – A1*

4.1.2.2. Life Cycle Costing Expenses

When asked about the process of LCC, most respondents indicated that there was room for improvement (A2, A4, A5, B1, B2, B3). At the same time, respondents argued that the potential benefits of LCC must be considered in relation to the costs associated with the required processes (A2, B1, B2, B3). Some respondents mentioned that the costs associated with LCC processes to deliver a service-oriented value proposition are currently unknown and complex to estimate. In order to get a clear picture of the costs for LCC, the internal requirements for accuracy need to be defined more precisely (A2).

> *"If we want to get a better understanding of the life cycle cost of our products, we need to invest more resources in the internal processes. At the same time, we do not know the potential benefit of these investments for the company." – A2*

Several respondents argued that it is important to understand the costs of life cycle costing in order to determine an appropriate value proposition. The advantage of the current business model is that the cost of LCC processes is relatively low as the accuracy required is low (A2, B3). If the business model were to be adapted to a service-oriented offering, this would require an increased effort for LCC processes. Some respondents argued that the costs should be compared with the benefits of increased LCC accuracy, but this was not straightforward as experience with similar situations was low (A2, B3). It was also argued that the costs associated with LCC would require a significant initial investment in data infrastructure and development, making a transition process rather difficult (A2, A5, B2, B4). It was argued that significant scale should be achieved in a relatively short period of time to cover the initial costs, with the added benefit of multiple projects with a serviced offering (B4, B5).

> *"Developing a new life cycle costing process is a complex process which we have little experience with. The potential benefit must be big enough to justify the cost of the development." – B3*

This situation complicates the transition process because significant need must be identified before internal processes can be changed. The interviewee further stated that this is a recurring challenge in development projects of novel ideas with which the case company has little experience (B3). Accurately estimating the costs versus benefits of LCC will be one of the key internal discussion points in the implementation process (A2, B2, B3, B5).

4.1.2.3. Product Development

Another recurring pattern in the interview data relates to the concept of target costing in development. In internal company development processes, the target cost factor is an essential part of the required input data (A1, A5, B2, B3, B4). Respondents indicated that internal development processes are often triggered by a perceived market need or by a direct customer request to the case company (A5, B4). In other cases, internal new product development may be triggered by technological changes that are believed to enable new product development (A5, B3, B4). Respondents mentioned that an integral part of the development process is determining the desired target cost of new development (A1, A5, B3, B4).

> "When we develop a new product or module, we internally discussing a target cost for this development. This is the cost we internally want to achieve for the product to be competitive in the market." – *A5*

In the current target costing process, the initial cost of the product is defined in a collaborative process (A5, B4). In this process, the life cycle cost perspective is included by a cross-functional team with most of the functions involved (A2, A5, B3, B4, B5). At the same time, respondents mentioned that there is no clear target cost over the lifetime of the product (A2, A5, B4). One respondent argued that servitization would require a direct input for considering target costs in the operational phase. However, in the current business model, these costs are not borne by the case company and are therefore only partially of interest in the development process (A1, A2, A5, B4).

> *"It would be interesting to consider the target cost of the product over the entire life time, but we currently do not have the data to make these decisions." – A5*

One respondent mentioned that a well-structured LCC process would help to develop new products considering the whole life cycle costs. However, in the current LCC structure and product structure, estimating life cycle costs in development would be very complex (A2, A3, A5). At the same time, respondents indicated that in the current business model, target development costs are not the highest priority. This is partly because product life cycle

costs are rarely perceived as a challenge in the operational life cycle phase of products (A2, B4, B5).

4.1.2.4. Product Portfolio

Another topic that was widely discussed was the current product portfolio and product structure in the case company. Several respondents mentioned that the current complexity and quantity of products makes it difficult to estimate the life cycle costs of certain products (A1, A2, A3, A4, A5, B2, B3). It was argued that there are often many similar products for a desired functionality, which hinders effective estimation of life cycle costs. Since life cycle cost estimates often depend on life cycle testing in internal test facilities or field experience, new products are often started with low reliability data (A2, A4, A5, B2, B3).

> *"When we estimate the life cycle cost of a product for a 30-year period we need reliable data. If we change the product structure for every product the return of experience is unfortunately relatively low." – B2*

At the same time, the product portfolio is mainly determined by customer preferences. It was argued that the alternative to the current portfolio could be a standardized product structure that does not meet specific customer requirements (A4, B3, B4). Some respondents argued that a better understanding of the product portfolio is necessary to offer a service-oriented value proposition (B2, B3, B4, B5). Respondents stated that the current product portfolio may be too complex to get a good understanding of what the life cycle costs of the products actually are (A1, A2, A4). Several respondents mentioned that there is an ongoing process of modularization and standardization in the case company, which helps to simplify internal processes (A1, A2, A3, B1, B2, B3, B5). While standardization and modularization are ongoing processes, some interviewees stated that it has already contributed to a much better understanding of the life cycle costs of the products (A2, A3, A4, B2, B3).

> *"A modularized and standardized product portfolio can enable us to understand the life cycle cost a lot better. Reducing redundancy and unnecessary complexity is a key focus in shaping the product portfolio." – B3*

One respondent argued that a structured LCC process would help the case company to get a better understanding of the product portfolio. In addition, the LCC process could provide active decision support in the development of the future product portfolio (B2). Especially for understanding the operating cost part of the life cycle cost, it is necessary to implement a holistic LCC process. It was mentioned that the current understanding of operating costs

is not a main factor in product portfolio design as there is little relevant data (A2, B2, B3, B5). At the same time, there is a need to get better coverage of whole life cycle costs in order to further develop modular and standardized products and subsystems (A2, B1, B3).

> *"Having a LCC process that is covering the entire life cycle from a product perspective would be a helpful to get a better understanding of our product portfolio. This would definitely help us to understand cost-drivers in our system better." – A2*

4.1.3. Viability

As another sub-theme the field of viability of the case companies' business model emerged as relevant to the respondents. Several respondents mentioned topic related to viability when asked about the potential challenges of servitization and the utility of life cycle costing in this context.

4.1.3.1. Revenue Structure

Several respondents mentioned that it is challenging to capture value in the form of revenue from customers in the servitized business model (A2, B1, B2, B3). Although there seems to be a demand for integrated product-service offerings, there are no established revenue models to capture value (B2, B3, B4). In the current business model, customers are charged for ownership of the product, which is often a large portion of the total cost. This revenue covers the internal product costs of the case company, while operating costs are not necessarily considered relevant (B3, B4, B5).

> *"It is interesting to think about servitization of our product offering. We have many ideas of how to design new offerings but actually capturing value from the customer is a difficult aspect of the servitization process." – B3*

Several respondents mentioned that it would be necessary to understand and design operating costs in more detail. This would help to understand the revenue and profit potential of a servitized offer (A2, B2, B3, B4). At the same time, the shift towards a servitized offering is highly dependent on what revenue streams are generated. The case company needs to cover its internal costs through the generated revenue streams (B4, B5). A servitization offering that charges a recurring amount instead of a larger initial sales price would require a restructuring of the internal financial structure (A2, B3, B4). To gain an understanding of the limitations and potential benefits, the actual revenue potential needs to be better understood. Some respondents argued that revenue potential

is highly dependent on customers' willingness to pay, which is difficult to estimate (B3, B4, B5). It was argued that a structured LCC process could be a helpful tool to estimate the revenue potential in relation to the lifetime cost of the product (A2, A5, B1, B2).

> *"There is a need to identify new ways of charging our customers for the products. A good knowledge of the life cycle cost might help us to check what is possible internally. At the same time, we need to communicate with customers to understand their needs." – B4*

It was argued that the decision of which degree of servitization can be achieved largely depends on the revenue streams that can be generated (B3, B4, B5). Some respondents mentioned that the change of revenue model might be beneficial in the long run but might cause a loss in the short run (B4, B5). Therefore, servitization might also be perceived as undesirable in the current business environment which is based on generating growth (A2, B1, B3).

4.1.3.2. Customer Cost Structure

When asked about the servitization process of the case company, some respondents cited the cost structure of customers as a potential challenge. While there could be potential for reducing the total lifecycle cost of the system, the customer needs to adjust internal processes to benefit from these changes (B2, B3, B4, B5). In some cases, the customer focuses on optimizing short-term costs rather than focusing on the costs associated with the whole life cycle of the product (A2, A3, B4). It has been argued that this focus on short-term costs is difficult to reconcile with a servitization offering that focuses on whole lifecycle costs (B4).

> *"We once worked with a customer on a cost optimization process for our products. After further discussion we understood that the aim of the customer was not reducing the overall life cycle cost of the system but rather to reduce the initial sales price. This was hardly a real cost optimization, but many customers have this focus." – B4*

Several respondents mentioned that there might be a problem with servitization when it comes to the cost structure of customers. It was argued that customers operate on the basis of traditional product-based offerings, with relatively little flexibility (B3, B4, B5). Offering a revenue model with lower lifecycle costs but a different cost allocation for the customer would be desirable but not practically possible in larger companies. Some respondents mentioned that customers are often large companies that are slow to adapt to new offerings in the market (A2, A5, B1, B3, B5). This was perceived as a challenge to actually implementing a servitization offering in the current market. Although there have

been efforts in the past to change the way customers are billed, these could not be managed by the customers' purchasing department (B3, B4).

> *"Even if we can offer a product with lower life cycle cost and higher reliability, the customers might be unable to change their internal cost structure based on our offer. Only if this becomes more of a norm there is a realistic chance to charge the customer with a monthly fee." – B4*

This dynamic is further complicated in cases where the buyer is not the operator of the system. It was discussed that the buyer of the system often needs to charge an initial sale price rather than a monthly fee in order to benefit from the sales process (B1, B2, B4). It was argued that suppliers of systems that are perceived as cost drivers of the overall system are much more likely to negotiate special terms. As a supplier of a relatively small part of the overall system, suppliers often do not offer much flexibility (A1, B3, B4).

> *"To effectively leverage the lower life cycle cost there needs to be a better integration and coordination of the cost structures in the supply chain." – B5*

4.1.3.3. Supplier Cost Structure

Similar to the previous point, several respondents mentioned that implementing a servitized offering is challenging due to the internal cost structure. As the company relies on a complex supplier network, its cost structure is dependent on several other cost structures in the supply chain (A1, A2, B2). It was argued that changing the internal cost structure might be possible but changing the supplier network cost structure seems almost impossible (A2). The interviewees argued that even if the customers agreed to a new way of paying for the product, the suppliers would have to agree as well. Otherwise, the case company will have to pay all material and production costs before the operation phase, while it will only start to generate revenues once the product is in operation (B3, B4).

> *"We are dependent on our supplier network when it comes to payment conditions. While there is flexibility there are not many suppliers that are able or willing to change their cost-structure based on our demands." – A1*

In most cases, suppliers' LCC processes do not address the operating costs of their systems. It was argued that this difference in LCC perspective can lead to challenges in product costing (A1, A2, B3). One interviewee mentioned that by working more closely and co-developing with suppliers, a more holistic view of LCC could be achieved by other

companies in the supply chain (B3). This would help to communicate the benefits of reduced LCC to suppliers and customers, which could increase the willingness to collaborate more (A1, A2, A5).

> *"If we want to implement servitization we need to get together with suppliers and customers to get on the same page. If we try to do this alone, we will have a problem to cover our expenses." – A2*

It was discussed that there needs to be an LCC process that involves suppliers in the design and estimation of LCC costs. As many parts of the product are manufactured by external suppliers, this is essential for an appropriate cost structure (A1, A2, A5, B4). In the current procurement and discussion with suppliers, life cycle costs are usually not the focus of the discussion (A1).

4.2. Challenges of Life Cycle Costing

In this part of the empirical findings section, the themes and subthemes related to the challenges of life cycle costing are discussed. The findings are structured into themes based on the BML cycle, which is the foundation of the LCC process in a product perspective. The empirical findings relate to actual experienced challenges in the company and perceived potential challenges that may occur in the process of LCC in a servitization context.

4.2.1. Designing the LCC Model

The first sub-theme discussed by respondents was the design process of a desired LCC model for the case company's products. Many respondents mentioned that there are several challenges associated with actually defining a desirable allocation of life cycle costs among the different life cycle phases of the products.

4.2.1.1. Conceptual Design Phase

Several respondents mentioned that the actual design of the life cycle cost of a product seems to be a complicated process. It was argued that while there are often several different life cycle cost allocations available, there is little freedom in deciding on the most appropriate LCC model (A1, A2, A5, B1, B2, B3, B4). Respondents argue that the life cycle cost of the product is mainly determined by the modules used, which themselves have different life cycle cost models (B1, B2, B4). At the same time, the life cycle costs of the product are also determined by the operating variables, which are mostly defined by the customer (A2, B1, B2).

"When we are designing the life cycle cost model for our products, we need to consider the parts that we are using as well as the intended use characteristics by the customer." – B1

In projects where life cycle cost is not a main negotiating point in the sales process, the subsystems used are mainly based on internal cost preference and technical specification (A2, B1, B2). While the life cycle cost of the system is still relevant, the LCC model is built in a reactive way once the components are selected based on other characteristics (A2, B3). Some interviewees argued that this approach could be suboptimal, but that the resulting LCC models are often sufficient for the customer, at least in the initial bidding phase (A2, B1, B2, B4). According to several interviewees, the LCC model is often driven by the customer requirement for a low selling price rather than a low life cycle cost (B1, B2, B3, B4, B5). This gives little scope to proactively design the LCC model differently, at least with the current business model (B4).

"We are trying to propose the most suitable solution based on the customer requirements. If the customer requires a certain cost allocation, we often have little room for changes." – A2

Some interviewees mentioned that although there is potential to optimize total life cycle costs, customer requirements for low acquisition costs limit design efforts (A2, B1, B2). Another point mentioned by several respondents is that even if there is scope, the LCC model is rarely the driving force in the conceptual design phase (B1, B2, B3). It was argued that while the LCC model is of theoretical interest, the practical value in capturing value is perceived to be low in many cases (B3, B4). In the current LCC modelling, the costs related to the operational phase are not actual costs for the case company (A1, A2, B1, B3). Therefore, the accuracy of modelling in the design phase is not considered essential (B1, B2). In many cases, life cycle costs in the operational phases are often related to the revenues of the case company, which are a source of revenue for the company (B3, B4, B5).

"In the LCC modelling we are taking a mainly internal perspective. The cost during the operation is cost that are not covered by our company. These costs are linked to revenues for our company in the form of spare parts and overhaul." – B5

Several interviewees mentioned that the combination of these factors leads to a reactive LCC modelling process rather than proactive LCC modelling (B1, B2, B3). It was mentioned that since the main decisions are made in the design phase, changes in later phases are often complicated and require additional resources (B1, B2, B3, B4, B5).

4.2.1.2. Product Portfolio

Several respondents cited the product portfolio as the main challenge in the LCC design process when designing a life cycle cost model for a project. When LCC modeling for new projects, the existing product portfolio is the starting point for development as new developments are often costly (B1, B2, B3, B4). Several respondents mentioned that although they know the product portfolio, they do not always know the life cycle cost of each product (A2, A3, B1, B3). It was argued that life cycle costs depend on various factors that are not well understood, making clear design a complicated task (A2, A5). It was further argued that while the current portfolio is optimized for a product-dominated offering, adjustments to the portfolio may be necessary for a servitization offering (B1, B2, B3).

> *"When designing new concepts, we are relying on the current product portfolio. This might be hard to combine with drastic changes in the LCC modelling without changing the product portfolio." – B1*

At the same time, respondents argued that the use of proven products from the product portfolio is often necessary to obtain accurate life cycle cost estimates. When using products that deviate from the standard, life cycle costs are often difficult to estimate and a commercial and technical risk in the project (A1, A2, A3, B1, B2, B3, B4). The combination of a limited standardized product portfolio and a complicated LCC estimation process for new developments often results in a product with suboptimal LCC allocation (A2, B1, B3). Several interviewees mentioned that the design of a system with LCC consideration is complex because the life cycle costs of the different parts of the product cannot be estimated independently. In order to get a clear picture of the actual LCC of a product, the individual parts have to consider the whole system configuration, which complicates the LCC design process significantly (A1, A2, A4, B3, B4, B5).

> *"The estimation of the LCC of our products needs to consider the interdependence of the sub-systems. Each individual part of the system has an impact on the overall fatigue and wear of the system." – A2*

Several respondents mentioned that the design of a standardized and modularized product portfolio offering customization and flexibility would be a desirable development. It was argued that this would help to obtain a better quality of LCC estimates in combination with many other benefits (A1, A2, A4, B1, B2, B3, B4). At the same time, most respondents agreed that there was no clear idea of how this could be achieved (A1, A2, A5, B1, B3, B4, B5).

4.2.1.3. Non-recurring Cost

Another complexity in designing the LCC of products that was frequently mentioned is the factor of one-off costs. Several respondents mentioned that when designing the technical concepts and the associated LCC of the system, the role of non-recurring costs can be a challenge to achieve a desirable LCC design (A1, A2, A4, B1, B2, B4). The aforementioned non-recurring costs mostly related to the company's development costs or individual testing of product functionality or reliability (A1, A2, A3, B2, B4). In cases where a project requires one of these tasks, there are often relatively high initial costs associated with the life cycle costs of the product, which then need to be factored into the company's value creation process (B3, B4, B5). Several respondents mentioned that this complicates the sales process for low-volume projects, as the sales price is significantly influenced by the life cycle costs associated with the development phase (B1, B2, B3, B4).

> *The life cycle costs of the products are much lower when we do not need to develop any new features. But if there is development required to meet the customer demands this is often drastically increasing the internal cost at our company." – B4*

At the same time, respondents argued that this potentially hinders product development and business development. In cases where development could be used in other projects, costs should be spread across the different applications of development (B1, B3, B4). Several respondents mentioned that while this is the desirable solution, it is often difficult to estimate the future need for the developments or testing procedures (A2, A5, B1, B3, B5). This challenge often leads to a complicated LCC design process that needs to consider current and future demand in accurately allocating one-off costs across different projects (A1, A2, B3, B4).

> *"Considering the non-recurring cost in the LCC process is relatively complicated. But in the current business model we usually need to break-even with the initial sales price." – B5*

Some respondents mentioned that changing the business model would make it easier to spread the one-off costs over the lifetime of the product (A2, B3). However, in the current business model, the one-off costs are often directly related to the sales price, which makes new developments economically undesirable for the case company (A2, B1, B2, B3).

4.2.1.4. Maintenance & Operation

Several respondents mentioned that the LCC design process is highly dependent on the decisions and actions of customers and operators in the operational phase of the life cycle (A2, A5, B1, B2, B3, B5). The total life cycle cost of the system is highly dependent on the

intended maintenance strategy of the operator (A2, B3, B5). It was mentioned that the customer essentially decides on appropriate maintenance and overhaul periods based on the main cost drivers of their systems. As the product of the case companies is not considered as the main cost driver, the LCC design has to be adapted to the customers' requirements (A2, A5, B2, B4, B5). Some respondents mentioned that customers often set the overhaul and maintenance periods at the system level, with little flexibility for major changes later in the operational phase. This requires the case company to develop the LCC reactively based on customer specifications (A2, A4, B2, B4, B5).

> *"The operator is often designing the overhaul periods based on the cost-drivers of the system. We cannot actively influence that choice as we deliver a relatively small part of a big system." – B5*

Some respondents mentioned that even if the company could reduce the total life cycle cost by increasing the overhaul interval, the operator may not consider this in the overhaul planning. This makes the actual design of the LCC highly operator dependent, limiting the freedom of optimal life cycle cost allocation (A2, B3, B4, B5). In some cases, operators try to work with suppliers to share the desired reliability and LCC models for their systems, which can help the company to develop an appropriate LCC model internally (A2, B4). It was argued that although this is the case for some development projects, the majority of operators do not work with suppliers of smaller systems (B3, B4, B5).

> *"If the operator shares their desired overhaul and maintenance periods early in the development, we can benefit from that. Unfortunately, this is the exception rather than the norm in our industry." – A2*

This dynamic was mentioned by many respondents as the main challenge in designing appropriate LCC models. It was also mentioned that there is a move towards earlier and more intensive industry collaboration (A1, A2, A5, B1, B3). At the same time, the majority of LCC models need to be designed reactively based on the customer specification. Similarly, the intended mode of operation of the system is often directly linked to the LCC modeling of the case company's product (A2, B2, B3, B4, B5). It has been argued that the operating forces and usage characteristics are a significant factor in the overall LCC design phase of the products. At the same time, the case company has no significant influence on these factors (A2, A3, B1, B2, B4). Several interviewees believe that closer collaboration in the specification phase would be helpful to optimize the whole life cycle costs of the product and the whole system (A1, A2, B3, B5).

"The utilization of our product in the operational stage is a main factor in determining the life cycle cost of our products. The operators are shaping the boundaries for the LCC in the specification stage of the overall system level." – A2

4.2.2. Measuring LCC

The second theme in the challenges of life cycle costing in a servitization context was the process of measuring the actual life cycle cost of products, which was mentioned by all respondents. There were several sub-themes mentioned by respondents that will be presented in this section.

4.2.2.1. Customer Feedback

A recurring pattern in the interviews was the mention of the lack of customer feedback on the LCC process in the case company (A1, A2, A3, A5, B1, B2, B3, B4, B5). While the LCC model is often discussed in the sales process of the product, feedback regarding the accuracy of this model is often lacking. Several interviewees mentioned that the case company does not have direct tracking of life cycle costs in the operational phase as the customer is responsible for the operation of the system (A1, A2, B3, B4, B5). This requires that the customer provides the necessary data to measure the actual costs related to the whole life of the product.

"In the current system we rely on the operators of our products to deliver data on the life cycle cost in the operating stage. This is making it rather difficult to get reliable data about our products once the operator is in charge." – B5

It was cited by several respondents that product operators rarely report the actual life cycle costs of the system to suppliers (A1, A2, A5, B5). Communication of actual costs incurred during operation is omitted in most cases, and only when expected costs are drastically exceeded is there feedback (A1, A2, A3, A4, B3, B5). It was argued that operators often only report on life cycle costs when unexpectedly high costs are incurred in the operational phase. Some respondents mentioned that in some cases operators have requested some kind of compensation for exceeding the estimated life cycle costs (A2, B4, B5). At the same time, in the cases where the life cycle costs during the operational phase are lower than estimated, there is almost no customer feedback. This makes an assessment of the actual costs during the operational phase rather complicated, as there is little direct feedback from the operators of the system (A2, A5, B1, B3, B4, B5).

"In most cases we are not getting detailed data about the cost of operating our products. Only if the actual costs of operation are significantly higher than expected we might get some feedback from the customer or operator." – B4

Some respondents indicated that the company actively requests operators to provide detailed feedback on the life cycle costs of the system. In many cases, it is even contractually agreed with the customer to provide data, but according to the interviewees, this is rarely implemented in operations (B4, B5). It was mentioned that the operators of the systems usually do not see any value in providing operational data, so the process is simply omitted (B5). Even if the case company could improve the development of new products LCC model, the operators of the current systems do not necessarily benefit from this process (A2, A4, B3, B5).

"The operators have the knowledge about the operational cost of our products, as they are paying them for years. Unfortunately, most of them do not see any value in sharing this data with us." – A2

Several respondents stated that getting more operational data about the life cycle cost would be the most effective and cost efficient way of improving the LCC measurement process (A2, B3, B5).

4.2.2.2. Field Data Collection

Another commonly cited issue for measuring LCC is the collection of field data by the company itself. While the collection of data by operators is preferred, the collection of field data can also be done by the company itself (A2, A4, B2, B3, B4, B5). Several respondents indicated that the actual collection of life cycle costs of the product through field data is a complicated process (A1, A2, A3, A4, A5, B3). It was argued that measurement by sensors on the products can be beneficial to gain an understanding of the actual wear and fatigue of the product compared to the estimated characteristics (A2, B3, B4). At the same time, this application of technology is often unreliable and costly to implement and operate (A2, A4, B2, B3, B4, B5).

"To get a better understanding of how our products behave in operation we can use sensor technology on the product. Unfortunately, this solution is rather expensive and complex." – B3

In many cases, the sensors used could reduce the overall reliability of the system if they are integrated into the functionality (A2, A4, B3). Additionally, several respondents mentioned that it is not clear which variables should be monitored by sensors to gain a better understanding of the product (A1, A2, A3, B1, B4, B5). While it is relatively clear that some factors have an impact on the life cycle cost of the system, the combination of multiple factors and the relationship between them is unclear (A2, A4). Some respondents believe that the measurement of field data is mainly focused on product parts, while labor hours are neglected in the measurement (B5).

> *"Even if we are measuring the cost of the parts that need replacement, we are missing a large part of the picture. One cost driver in maintenance are the working hours of technicians. These cannot be measured with our sensors." – B5*

It was argued that even if the cost of spare parts could be measured with sensors, the total cost in the operational phase would still be unknown (A2, B3, B5). Furthermore, measuring field data would require a new data infrastructure to actually store the data in a structured way over the lifetime of the products (B3). It was mentioned that the company is implementing a structured field data collection process for its products (A2, A4). As products are returned to the company for overhaul, data on actual fatigue and wear can be measured directly on the products. It was argued that while this is a good starting point for measuring actual LCC costs, there is still room for improvement (A2, A3, A4, B5). In this context, one respondent mentioned that even if measurements can be made on the product during overhaul, the operational context needs to be linked to these measurements (A2).

> *"It is a good start to measure the products during the overhaul. Unfortunately, we do not know much about the actual utilization util the first overhaul. Having the measurements without use characteristics makes it hard to infer the actual life cycle cost of the product." – A2*

4.2.3. Learning from LCC data

Another theme of challenges in the LCC process relates to the learning phase. In this phase, LCC measurements can help derive insights about the product LCC model. Several respondents mentioned that there are challenges associated with this process.

4.2.3.1. Long Feedback Cycle

In the learning phase of the LCC process, the overall long product life is perceived as a challenge (A1, A2, A5, B3). It was cited that the planned life cycle of products is often more than 30 years, which makes a dynamic feedback process quite complicated (A2, A3, A5).

The greatest learning value could be derived when the planned life cycle is over and estimates could be compared with actual costs throughout the life cycle (A2, B3, B5). Some interviewees argued that because products are often used for decades, there is rarely feedback over the whole life cycle of the products. In many cases, the responsible personnel change several times during the life cycle, both on the manufacturer and on the operator side (A1, A2, A5, B5).

> *"To get a good learning process it would be ideal to compare the estimate over the entire life cycle of the products with the actual cost. Unfortunately, this is a really challenging process as the records are often incomplete or responsible individuals have left the company." – A2*

Several interviewees pointed out that this issue often leads to a relatively low feedback of experience into current LCC processes (A2, A5, B5). It was argued that even the average time to first overhaul is around 8 to 10 years, making rapid iterative learning difficult (B3). In many cases, the underlying technological changes are so drastic that the value of data analysis is relatively small. It has been argued that the products used are constantly changing and that the utility of evaluating 20-year-old LCC estimates for new developments is not very high (A2, A5, B5).

> *"It is interesting to understand the mistakes we have made in the LCC process in the past. At the same time, to get direct improvements from this data seems often unlikely. Our product portfolio is constantly changing with often entirely new technological possibilities." – B3*

Overall, while there is potential in learning from data about the internal LCC process, this is not currently utilized (A2, B3). It was mentioned that a continuous data analysis process would increase likelihood of contributing to current LCC processes (B3).

4.2.3.2. Data Analysis

Another challenge in the learning process in LCC is related to the complexity of processing large amounts of quantitative data. Some respondents mentioned that LCC data often consist of large amounts of quantitative data that need to be structured and processed before they are useful (A2, B2, B3). It was argued that while the data has a lot of value, the current data infrastructure slows down the process (A2). There is a lot of data about the LCC of different products in the company, but the database is not standardized and centralized (A2, B3).

"We have a lot of data about our products in our databases. The problem is that it is very time consuming to find all relevant data in all the different places. And then the data needs to be manually processed which takes even more time." – A2

Some respondents mentioned that the process of data analysis is complex, as patterns in the data are often difficult to find (A2, B3). At the same time, linking patterns in quantitative data with qualitative factors is another complicated step in data analysis. In many cases, it is complicated to judge which factors are relevant to the LCC process and which are irrelevant (B3). Since the process of data collection is not standardized and widely implemented, it is almost impossible to draw conclusions from a limited amount of data (A2, B3, B5). One respondent argued that without a standardized data collection process, the process of data analysis is more guesswork than actual analysis (A2). Additionally, the data needs to be visually presented to aid in decision making. It was noted that the value of quantitative data is limited unless it is well prepared (B3).

"If we want to get real insights from our LCC data, we need to develop a structured and standardized LCC process. Otherwise, the data is just piling up at different places and no one will ever use it." – B3

It was also noted that with the current business model, there is relatively little interest in the data analytics part of LCC. Even if there are patterns in the data, without a clear LCC modelling process in mind, these patterns are never identified (A2, B3, B5). It was argued that the quality of data analysis depends on the quality and quantity of relevant data, so improvements should be made in these areas rather than the analysis itself (A2, B3, B5).

5. Discussion

In this part of the paper, the empirical results of this study are critically discussed in the context of the research objective. The discussion relates the extracted patterns of the interviews to the relevant academic literature. The aim of this section is to provide a logically coherent overview of the findings of this research in order to contribute to answering the research questions and fulfilling the research objective. First, the findings related to the general benefits of LCC in a servitization context are discussed. Then, the results related to the challenges of LCC in a servitization context are presented. Finally, additional findings that emerged in the process of data collection and analysis are briefly presented in a broader LCC context.

5.1. Utility of LCC in Servitization

The entire research process of the benefits of LCC in servitization was complicated by the fact that the case company does not currently have a servitized value proposition. Nevertheless, many respondents discussed the perceived benefits of LCC in terms of solving assumed problems in moving to a servitised business model. This is consistent with the relevant literature as the majority of manufacturing companies have a product-dominated value proposition and little experience with servitization (Baines et al., 2009; Brax, 2005).

The findings of the primary research process suggest that there are a variety of potential utilities of LCC in the servitization process. One factor that mainly defines the usefulness is the actual LCC approach adopted. As described in the literature, there is no clear consensus on the choice of LCC and the components of the process (Westkämpfer & Osten-Sacken, 1998; Zhang et al., 2018). From the data, it is clear that the concept of LCC is an integral part of managing a servitized value proposition for manufacturing companies. These findings clearly reflect the perspective of academic literature on LCC as a tool to change the value proposition in manufacturing firms (Aurich et al., 2006; Adrodegari et al., 2016). The broader benefits of LCC are often difficult to specify by respondents who hold a specialized position in the case company, while generalists in the field provided more valuable contributions. Moreover, the perceived benefits often refer to complex processes that are multidisciplinary. This is consistent with the described complexity of the servitization process in companies that use an organizational structure based on a predominantly product-based value proposition (Brax, 2005; Vandermerwe & Rada, 1988).

5.1.1. Identify Servitization Potential

The results of primary and secondary data collection in this research suggest that life cycle costing can help manufacturing companies identify and understand servitization potential. In most cases, the move to a servitized value proposition for manufacturing firms is motivated by an expected increase in profitability and an assumed competitive advantage for the firm. At the same time, servitization for manufacturing companies often expands the responsibility for covering lifecycle costs that were previously covered by the plant operator. Therefore, to understand the potential of servitization, it is essential to gain a deep understanding of the costs associated with the life cycle of the product. Life cycle costing can assist the manufacturing company in gaining an understanding of the life cycle costs of the product and provide the basis for further servitization development. Without knowledge of life cycle costs, the clear development of a servitization proposition is made much more difficult.

These findings support the idea that life cycle costing can be helpful in identifying servitization potential in manufacturing companies. When discussing the servitization process in the case company, several respondents mentioned that there is a high level of uncertainty regarding the servitization potential of the company. While the majority of respondents agreed that combining a product offering with a service component would be beneficial, the form and scope of the service in the offering was unclear. As noted in the literature, the process of servitization is shifting towards an integration of product and service on a continuum (McManus et al., 2019). This allows the manufacturing firm to place the value proposition at a desired location on this continuum and choose the constellation of product and service in the value proposition (Adrodegari et al., 2016). While this offers great flexibility in shaping the value proposition, there is little practical guidance in the servitization process of manufacturing companies. The proposed model Product-Service System provides a more granular perspective on the servitization process of companies by integrating equipment responsibility and complexity variables (Tukker, 2004; Meier et al., 2010). While interviewees mentioned that the PSS model could provide a brief overview of possible servitization stages, this does not provide direct guidance for practical application in the case company. It was mentioned by several interviewees in the case company that the servitization efforts of the company should be focused on developing a competitive advantage and increasing the profitability of the company. This is consistent with the academic literature that the servitization process should be guided by increasing the competitiveness of the firm (Baines et al., 2009). In order to effectively understand the potential of servitization in increasing the profitability of the firm, the potential revenues, and associated costs of servitization offerings must be understood. As mentioned in the academic literature, life cycle costing can assist the firm in determining the cost of the product in relation to the various life cycle stages (Kambanou, 2020). This can be essential in determining which life cycle phases the company should incorporate into the servitization offering based on the current costs

associated with each life cycle phase. While lifecycle costing cannot determine the associated value and customer willingness to pay, the bottom line costs can be used in determining the starting point for developing a servitization value proposition.

These findings are of great importance in understanding the role of life cycle costing in manufacturing companies. In more traditional product-dominated value propositions, life cycle costing is mostly used as a reactive cost reporting tool (Reim et al., 2017; Kiruma et al., 2007). In this case, the benefits of life cycle costing are mostly associated with the identification of cost drivers and the active management of the company's performance. The results of this research suggest that the role of life cycle costing in a servitization context should be a more active integrated tool in defining and shaping the company's value proposition. In particular, for value propositions where products have a long life span, the process of life cycle costing can help the case company to identify potentials for servitization by increasing the ownership and responsibility for the products provided. This implies that manufacturing companies seeking to servitize their value proposition should implement life cycle costing processes to increase the chances of successful value proposition transformation. At the same time, the results of this case study should be interpreted with caution, as both servitization and life cycle costing are highly context-dependent concepts (Aurich et al., 2006; Benedettini et al., 2015). Further research is needed to establish the role of life cycle costing in the servitization process of manufacturing companies.

5.1.2. Aligning Internal Incentives

The results of this research suggest that life cycle costing can have a valuable impact on aligning the incentives of stakeholders in the servitization process. In manufacturing companies that provide a predominantly product-based offering, the organizational structure is usually designed to meet the requirements of the current structure. Introducing servitization in such an organization can lead to challenges because the incentives of the different parts of the organization may not be aligned. For example, an increase in reliability may be perceived as beneficial in the sales department because it provides value to the customer. At the same time, increased reliability will lead to a decrease in MRO-related revenue for the company, which is perceived as bad by the after-sales department. Life cycle costing can provide quantitative evidence of the overall impact of change and align the organization's focus on a holistic profitability management process. With this approach, the servitization process in manufacturing companies can benefit from clear data-driven decision making. At the same time, the life cycle costing process requires collaboration among the different parts of the organization. This process can potentially foster understanding of the challenges and perspectives in the different parts of the organization and enable a collective approach in designing and shaping a servitized value proposition.

These findings support the viewpoint that life cycle costing is an active tool in shaping the servitization offering and not just a reactive reporting of life cycle costs (Kambanou, 2020). While life cycle costing is mainly a cost reporting tool in the product-dominated manufacturing business, the introduction of a servitized offering creates new challenges that change the requirements for understanding life cycle costs (Benedettini et al., 2015). When the firm assumes responsibility for a greater proportion of the total product life cycle, it internalizes additional life cycle costs and risks associated with the life cycle stages. The results suggest that this increase in internalized risk requires a different competency in terms of estimation accuracy and speed. In order to effectively utilize internal competence within the organization, collaboration is a key factor for success. It was mentioned by the interviewees in the primary research process that collaboration is difficult as communication channels are not well established and there are different views on the most desirable approach to servitization. A collective life cycle costing process is therefore a potential application that can promote collaboration and understanding between different departments (McManus et al., 2019). While the academic literature suggests that there could be a potential benefit in life cycle costing in the servitization process, the alignment of internal stakeholders is not often mentioned (Kambanou, 2020). A possible reason for this could be that the majority of research focuses on either servitization or life cycle costing, but rarely both. This would explain the lack of understanding of the contrasting perspectives and incentives of experts in the two fields. At the same time, there is no clear definition of life cycle costing as an interactive and collaborative process. If it is used in a top-down approach with little collaboration, the benefits of aligning incentives and promoting understanding could be reduced to complete irrelevance. Therefore, a clear definition of life cycle costing in the context of servitization would be beneficial to increase the quality of insights into the potential benefits of life cycle costing.

5.1.3. Aligning External Incentives

While the research findings suggest a link between life cycle costing and internal incentives, this also seems to be the case when working with external stakeholders. In many cases, the manufacturing company itself is part of a value chain dominated by product-based offerings. This can lead to conflicting incentives and perspectives on the importance of life cycle costing. In order to effectively provide a service-oriented offering to the customer, the value chain must align with a similar approach to life cycle cost allocation strategy. In predominantly product-based value chains, which are often geographically dispersed, the focus is not on reducing the total lifecycle cost of products. In a service-based value chain, incentives need to be changed to enable effective use of an integrated value proposition. Life cycle costing as a process can serve as a collaborative process of multiple stakeholders along the value chain focused on reducing the total cost of a product life cycle. This process has the potential to align the incentives of the manufacturing company's external network and help in the process of servitization.

A recurring theme in the primary research was the mention of interaction with external shareholders. Interaction with suppliers was described as the main challenge in actually developing a servitization offering due to low flexibility and a cost structure with suppliers based on a product-based offering. These findings are consistent with the overall described complexity of sourcing products in a product-service system context (Matschewsky et al., 2018). As many manufacturing companies have complex international value chains, changing suppliers' perspectives on life cycle costs is perceived as a major challenge. While suppliers' life cycle costing and reliability management approach might be adaptable to servitization, the cost structure is still mainly based on a product-dominated approach. This reduces the freedom to design product life cycle costs at later stages of the value chain, which was cited as a problem by many respondents. The process of life cycle costing was mentioned as a possible solution to this challenge, at least as part of a broader set of measures. These findings are consistent with the idea that life cycle costing is a collaborative process that can promote understanding (Brax, 2005; Kiruma et al., 2007). Life cycle costing can provide a quantitative measurement that effectively implements control of actual life cycle costs incurred. In many cases, the actual life cycle costs of products are not treated transparently in the interaction further down the value chain. It has been mentioned that this information may be intentionally withheld if it is suboptimal for the sales process, or simply treated as irrelevant. This finding is consistent with the general benefits of implementing a product-service system in that costs are tracked more efficiently (Aurich et al., 2006). It is argued that this is the case as servitization providers internalize life cycle costs to a greater extent, which encourages them to reduce them as much as possible (Adrodegari et al., 2016). On the other side of the value chain, customer interaction was also mentioned as a potential area where life cycle costing could be beneficial. Customers of manufactured products do not necessarily have an incentive to reduce life cycle costs over the life of the product. It was discussed that life cycle costs are of secondary interest to the customer if they are not the operator of the system or only own the product for a small portion of its life. This finding further supports the idea of misalignment in the life cycle cost allocation of manufactured products. In particular, for products with lifecycles of several decades, where operators change regularly, there is no real alignment of incentives (Keine & Steven, 2012; Meier et al., 2010). In these cases, it was mentioned that tracking actual life-cycle costs is nearly impossible and that life-cycle cost estimates are often not tracked by customers. In interactions with customers who are the operator or with whom there is a close working relationship, the life cycle cost process can be of greater benefit. With a collaborative life cycle cost process and a deliberate decision on how to allocate life cycle costs, servitization can be a mutually beneficial approach. This result is consistent with the general argument that servitization requires close cooperation and a common interest in allocating resources to minimize life cycle costs over a larger period of time (Aurich et al., 2006).

5.2. Challenges of LCC in Servitization

The results of the research process to identify potential life cycle cost challenges in servitization provided several different perspectives on actual and anticipated challenges. In discussing the process of life cycle costing with experts from different parts of the organization, it was found that the actual process is not always interpreted in the same way. This is in line with the relevant literature describing the lack of a general understanding and definition of life cycle costing. However, all interviewees acknowledged that it is important to understand the life cycle costs of products. Especially when considering servitization, it became clear that the role of life cycle costing could be even more significant than it is today. At the same time, most respondents mentioned that the growing importance would also require changes in the life cycle costing process. This is in line with the findings of previous studies that life cycle costing needs to be adapted to the organization's business model to be effective (Kambanou, 2020; Reim et al., 2017). The actual and expected challenges of life cycle costing depend on the form and scope of the life cycle costing process to be used in a servitized business model. These challenges represent the primary research process to provide a complete picture of life cycle costing challenges. However, the results reflect a wide range of different challenges that may be encountered in life cycle costing, they do not necessarily occur in all forms of life cycle costing in a servitization context.

5.2.1. LCC Perspective

The results of this research suggest that a major cause of challenges in life cycle costing is the change in perspective of the life cycle costing process. In product-based value creation, the organization usually focuses on the life cycle costs incurred until the product is sold. The primary research suggests that this is also the case with the case company, which has effective mechanisms to design and measure life cycle costs that are directly internalized. This is consistent with the literature which suggests that direct internalized costs are the most substantial focus of life cycle cost activities in manufacturing firms (Farr & Faber, 2018; Brax, 2005). While life cycle costs associated with the operations phase are estimated and tracked to some degree, the focus in the manufacturing sector is not on these life cycle costs. With the shift to a service-oriented business model, life-cycle costing requires a change in perspective to focus on life-cycle costs from a product perspective. Research suggests that this shift from the producer perspective to the product in life cycle costing is a cause of several challenges in the manufacturing company's life cycle costing process. This is coherent with academic literature indicating the drastic implications for life cycle costing that a change in perspective has on the overall process (Baines et al., 2009; Erkoyuncu et al., 2013). Research suggests that this shift to a product perspective in life cycle costing is necessary to understand life cycle costs across the product life value chain. It was mentioned that the manufacturer perspective of understanding total costs associated with product life may be inadequate to provide a holistic understanding of cost drivers and total life cycle costs. As these factors are essential to enable the design of a

service-based value proposition, the findings suggest that a manufacturing company needs to change its approach to lifecycle costing to effectively be able to determine an appropriate value proposition. The shift towards product-based life cycle costing has significant implications for the design of appropriate life cycle costing, which currently uses a manufacturer perspective (Farr & Faber, 2018; Kambanou, 2020; Keine & Steven, 2012). In the following sections, the main challenges that have emerged in this research are discussed in detail.

5.2.2. Life Cycle Cost Design

The findings of this study suggest that there are challenges associated with the design phase of the life cycle cost process in a servitization context. It was discussed by the respondents that designing an appropriate life cycle cost model for their products is a main challenge in life cycle costing itself in a product-based offering. The main challenge described is that the design of a life cycle cost model for a product is mainly influenced by customer requirements in terms of target selling price and operating cost structure, which are rarely shared in the development process. This supports the academic literature that describes life cycle costing as a highly interconnected process (Peruzzini et al., 2014). It is therefore necessary to work with the client to define an appropriate life cycle costing model that is consistent with the overall system. A challenge for the case company is that the desired life cycle costs of their products need to be modified according to the broader requirements of the operator's overall system. Because the case company's product is not perceived as a cost driver of the system, active collaboration with the system operator is often limited. This supports the perceived challenge of coordinating life cycle costing decisions for complex manufacturing products (Aurich et al., 2006; Annarelli et al., 2016). In the context of servitisation, interviewees mentioned that a servitised business model design is unlikely to be successful without collaboration with the operators of the system. If the case company designs a theoretically ideal life cycle cost distribution with maintenance and overhaul intervals already defined, the operators' requirements may not be met in actual projects. Therefore, in order to effectively design the life cycle cost of the product portfolio, the case company needs to increase active collaboration with operators.

It was discussed that since the main life cycle cost decisions are made at the component level, operator input needs to be implemented early in the component development process. Since many components used by the case company are sourced from external suppliers, procurement needs to consider operator input in the early stages to enable a successful life cycle cost design phase. These findings imply that the case company needs to increase collaboration with the operators of its systems as well as with the suppliers of the components of its products. This is a challenge in the life cycle costing process as collaboration and communication channels need to be established that are only partially in place in the current state. While this challenge is already observed in life cycle costing with product-dominated value creation, the extent of collaboration will most likely

increase (Kambanou, 2020; Reim et al., 2017; Tukker, 2004). The findings of this research also suggest that in addition to external collaboration, internal collaboration in life cycle cost planning may also be challenging. Respondents to the primary research process discussed that internal collaboration in product life cycle costing is already an existing challenge in the current business model. This is because the incentives of the different parts of the organization are not aligned, as discussed in the previous sections of this discussion. In the current product-based value proposition, the design of life cycle costs is mainly influenced by achieving internal target costs to achieve a competitive selling price with sufficient margin. While life cycle costs are part of the business process in the operations phase, they are rarely the central point of discussion in life cycle cost design. This is coherent with the literature that focuses on selling price rather than a holistic life cycle cost perspective (Aurich et al., 2006; Brax, 2005). It was mentioned by several interviewees that in the current business model, customer negotiations in the sales phase are dominated by achieving the target sales price rather than a discussion of the whole life cycle cost of the product. Life cycle cost is mostly seen as a theoretical construct that can be managed by adjusting service intervals and overhaul periods.

With the shift to a service-based value proposition, this dynamic in the lifecycle cost design process is likely to change towards a focus on low lifecycle cost rather than low selling price. It was mentioned by several interviewees that this will be a challenge as the customer perspective is often still focused on selling price rather than total lifecycle cost. It is expected that there will be a misalignment in the customer negotiation if the perspectives are not aligned. For the case company, it is expected that the dynamics of internal collaboration will change, and new internal communication channels will need to be established. While lifecycle costs in the operations phase are currently related to company revenue and are deliberately not minimized, the trade-off in servitization is likely to change towards a more holistic lifecycle cost minimization instead of a focus on costs until the product is sold. This confirms the idea of a necessary internal restructuring in the life cycle costing process that will require new forms of collaboration (Matschewsky et al., 2018; Wallin et al., 2013). Therefore, it is likely that manufacturing companies that design their business model to be service-oriented will face increasing demands for collaboration in the design phase of the life cycle costing process. To ensure a life cycle cost design that meets operator requirements while focusing on minimizing total life cycle costs, manufacturing companies need to understand the current life cycle cost design and the required changes to their product portfolio. As described in the literature, the lifecycle cost design of traditional product-based offerings is likely not an optimal starting point for servitization efforts (Benedettini et al., 2015). Despite the assumed relevance of these findings, it is not clear how this collaborative process should be designed and implemented in the manufacturing organization. Further research should be conducted into what form of collaboration effectively enables organizations to work together in life cycle costing. It is still not apparent how the challenges in life cycle costing depend on the

level of servitization. While it is expected that complexity increases with servitization, the impact on collaboration is not clearly clarified by this research (Matschewsky et al., 2018).

Another finding of the research process is the relevance of portfolio standardization to the life cycle costing process in the context of servitisation. It was mentioned by several interviewees that since life cycle cost allocation is mainly driven by the available choice of parts and components, it is essential to have an appropriate level of choice in the portfolio. This confirms the importance of product portfolio management in the servitization process as indicated in several academic sources (Benedettini et al., 2015; Aurich et al., 2006; Ambad & Kulkarni, 2013). While the portfolio is already a relevant driver of competitive advantage, interviewees highlighted a change in the requirements of the portfolio management process triggered by servitization. As previously argued, operational costs associated with products are an integral part of the internalized risk in the servitization offering. The case company needs to establish a benchmark for assessing the quality of lifecycle costs in the operational phase to incorporate the risk of higher actual lifecycle costs than estimated in the risk analysis. To validate its own estimates, measuring actual life cycle costs is key. If the case company has a customized product portfolio with low standardization and modularisation, the measurements of one product constellation may not help to get a broader understanding of other products offered. It was argued that for more efficient life cycle cost validation, the parts and components used need to be standardized, which would allow a significant increase in data that can be used to validate similar products. This would reduce risk in the life cycle cost design process and allow for greater confidence in the design of new product life cycle cost models. In the process of risk analysis, confidence in one's ability to accurately estimate life cycle costs is a critical factor (Herzog et al., 2014; Benedettini et al., 2015). These research findings imply that in order to effectively design product life cycle costs, the product portfolio should be critically evaluated and designed to allow significant transfer of measurement knowledge between different product constellations. This will reduce the cost of measuring life cycle costs in the operational phase and increase the accuracy of estimating life cycle costs. It was mentioned by some respondents that this standardization process is crucial, but that portfolio design should also take into account the desired benefits of customers. This confirms the perceived challenges in portfolio management, where a trade-off between standardization and customisation needs to be achieved in order to provide the desired benefits while being cost-effective (Aurich et al., 2006; Neto et al., 2015).

5.2.3. Life Cycle Cost Measurement

The results of this research suggest that there are significant challenges in the life cycle cost measurement process in the operational phase. While effective measurement of life cycle cost in the operations phase is already a part of the firm's life cycle cost process, the scope and accuracy of measurement is likely to be increased in a servitization context. In a product-based value proposition, the measurement of life cycle costs in the operations

phase is mostly the concern of the operator, as it effectively internalizes these costs (Ambad & Kulkarni, 2013). It was discussed in the interviews that operators rarely share these measurements with the case company. Only in cases where life cycle costs are exceptionally high during the operational phase do operators discuss the actual costs incurred during the operational phase relative to the estimates previously made. This is consistent with academic literature highlighting the challenges of effective life cycle cost feedback, where mostly negative feedback is provided, while lower life cycle costs than estimated are mostly not communicated (Azarenko et al., 2009; Castaneda et al., 2019). This lack of effective feedback on actual life cycle costs in the operational phase reduces the learning process in the manufacturing company providing the product. While this is already a challenge in a traditional product-based value proposition, it has much greater implications for the product provider in a servitization context. Interviewees discussed that the shift to a servitized business model will increase the responsibility of the company for its products in the operations phase. This is also cited in academic literature as one of the most important changes in a servitization offering compared to a product offering (Annarelli et al., 2016; Tukker, 2004). This increase in responsibility is effectively linked to the internalization of a greater proportion of the operating costs of the products offered. In moving towards a service-oriented business model, the case company needs to take into account the increasing responsibility for operating costs and develop a more detailed understanding of the actual life cycle costs. It was argued by interviewees that in order to design a servitised business model, the company needs to understand the costs associated with the entire lifecycle, with the post-sales stages in particular being mostly based on theoretical estimates with several critical assumptions. This dynamic underscore the importance of establishing effective lifecycle cost measurements even before a servitization proposal is designed. This reinforces the importance of the role of life cycle costing in the process of designing a servitization offering that is competitive and increases profitability (Kambanou, 2020; Benedettini et al., 2015).

It was mentioned by several interviewees that the process of comparing actual life cycle costs and estimated life cycle costs helps to create an understanding of the quality of the life cycle costing process. While the quality of the process does not necessarily have to provide a completely accurate process, a clear benchmark should be established. This benchmark of the lifecycle cost process can then provide an understanding of the underlying risk that the case company is exposing itself to by offering servitization. If the life cycle cost process is very accurate, the risk of high variances is low, while an inaccurate life cycle cost process introduces a greater risk in overruns of actual costs. It was discussed that this risk factor can help to create a servitization proposal that considers the commercial and technical risk in the pricing process. These findings are in line with the academic literature that highlights the importance of life cycle costing in the effective risk management process of the firm (Reim & Sjödin, 2016). While the whole process of life cycle costing has an impact on the accuracy of risk assessment, the

measurement process is a crucial part. Several interviewees argued that implementing effective measurements of actual life cycle costs is the biggest challenge in assessing the risk exposure associated with increasing product responsibility in the operational phase. In order to adapt the life cycle cost measurement process to the changing demands that servitization brings, the product provider and the system operator must work together. In current product-based offerings, the costs associated with operation are internalized by the operator, which provides an incentive for the operator to measure and minimize the costs associated with the operational phase. In a servitization offering, this incentive to measure and minimize is likely to diminish for the system operator (Baines et al., 2009). To ensure that the operator and vendor implement effective measurement processes, the responsibility and benefits of low total life cycle costs must be clearly communicated. It was discussed by several interviewees that collaboration in the measurement process is necessary as the operator is closer to the product in the operational phase and measurement without collaboration would likely result in increasing costs for the provider of the serviced value proposition. Therefore, it was considered critical to collaborate with the operator of the system throughout the lifecycle of the system to implement effective measurement and gain insights on how to effectively manage operational costs. These findings are in line with the academic literature that emphasizes the increasing need for collaborative efforts in life cycle costing in the context of servitization (Matschewsky et al., 2018; Zhang et al., 2018). It has been suggested to increase the sharing of operational data even before the implementation of a servitization business model, as this would help the company to understand the current situation in life cycle costing. Based on this initial assessment, the company could then define a desired measurement process and design appropriate changes to align the actual and desired life cycle cost measurement process in the operations phase. This approach would enable effective and data-driven change management that replaces assumptions with data. This approach is likely to increase the chances of successful implementation of an appropriate life cycle costing process (Farr & Faber, 2018; Ambad & Kulkarni, 2013; Benedettini et al., 2015).

6. Conclusion

This chapter of the thesis briefly summarizes the findings of the primary and secondary research process in relation to answering the research questions. The overall contribution to the fulfillment of the research objective in the academic context is then discussed. Then, the findings are briefly discussed in the context of the practical contribution to the case company and the implications for further research. In the end, the results of this research process are discussed by establishing the limitations of the findings.

6.1. Utility of Life Cycle Costing

In this research process, two main research questions were formulated to gain a better understanding of the role of life cycle costing in the servitization process of manufacturing companies. The first research question posed in this research is as follows:

RQ1: What utility can Life Cycle Costing provide in the servitization process?

The research process for this research question was challenging due to the lack of a consistent definition for the term life cycle costing. Furthermore, the literature did not provide conclusive findings on the benefits of life cycle costing, as the servitization process of manufacturing companies is a very diverse context that lacks clearly defined general concepts (Annarelli et al., 2016). In the primary research process, it has been found that the perceived benefits of life cycle costing in the servitization process are mainly related to solving obvious challenges in the transition from a product-based to an integrated value proposition. The main benefit discussed in the servitization process was that life cycle costing can help the manufacturing company gain an understanding of the servitization potential within the company. With a clear understanding of the current life cycle cost distribution, the company can establish a starting point for evaluating servitization potential. Additionally, the lifecycle cost process allows the company to understand what level and form of servitization might be appropriate. While existing theoretical frameworks often outline existing forms of servitization, the life cycle costing process provides practical guidance in establishing an integrated value proposition. Another benefit of life cycle costing in the servitization process is its positive impact on aligning internal incentives within the manufacturing enterprise. Discussions about servitization in manufacturing companies are challenged by a lack of quantitative data on the actual life cycle costs of products. This can lead to a rejection of servitization because the context is vaguely defined, and practical guidance is often lacking. The research suggests that by providing a clear quantitative measure of life cycle costs, life cycle costing can be a balancing factor between different departments that have their own objectives. By adopting whole life cycle costing as a goal for all departments, the incentives of internal stakeholders can be aligned with a more holistic life cycle costing approach that lays the foundation for practical servitization (Benedettini et al., 2015). Similarly, the life cycle

cost process can be used to align the incentives and perspective of external stakeholders in the wider value chain of the organization. Since most manufacturing companies are still involved in a value chain with a traditional product-based business model, the role of life cycle cost is usually secondary. By establishing effective life cycle cost processes internally and then with external entities, the incentives and perspective can be aligned with a total life cycle cost approach. This allows for more effective discussion and negotiation when sourcing appropriate products for a servitization offering, while communicating the benefits of a servitized value proposition to potential customers.

6.2. Challenges of Life Cycle Costing

The research implies that the process of life cycle costing provides a benefit in the manufacturing service process that goes beyond the mere reactive tracking and comparison of costs. The second research question then focuses on the challenges of actually performing life cycle costing in a servitization context:

> **RQ2:** What are the challenges associated with Life Cycle Costing in the servitization process?

Answering this research question is complicated by the vague definition of what life cycle costing actually entails and how it is structured. In the context of this research, the findings reflect broader challenges that may be encountered in the life cycle costing process of manufacturing companies moving towards a service offering. The main source of the challenges is that the perspective of life cycle costing is changing significantly. While manufacturing companies focus their life cycle costing process on the costs of the life cycle phases until the sale is completed, the costs of the operational phase are usually of secondary interest (Kambanou, 2020; Ulaga & Reinartz, 2011). In the context of servitization, the perspective of life cycle costing is shifting to a product perspective that considers and measures costs over the entire life cycle of the product. This shift in perspective of life cycle costing is necessary to effectively manage costs for the servitization provider and to realize the potential of an integrated value proposition. It has proven to be one of the biggest challenges in life cycle costing for manufacturing companies to develop an appropriate life cycle cost model for their products. This is partly because manufacturing is part of a broader value chain dominated by product-based value propositions. On the one hand, the company must work with suppliers to ensure that the parts and components used in their products are consistent with the desired life cycle cost distribution. Beginning to develop a desired life cycle cost model cannot be achieved without considering the practical availability of appropriate supply chains. On the other hand, the organization must work with its customers and the operators of its system to identify the desired life cycle cost distribution. In this collaboration, it is important to start working together in the early stages of development, as it is in these stages that the most

important life cycle cost allocation decisions are made (Helo et al., 2017). This need for collaboration challenges the design phase of the life cycle costing process and requires the establishment of new communication channels with suppliers and customers. Another aspect that challenges the organization in the life cycle costing process is the measurement of actual life cycle costs. In the context of servitization, understanding the actual costs incurred during the operational phase of the product is an integral part of the risk management process (Herzog et al., 2014). Without understanding the actual life cycle costs, the life cycle costing process lacks an effective feedback loop that increases the understanding of one's product portfolio. Especially since the operational phase of the product is several decades long, the uncertainty associated with operational costs should be reduced by implementing effective measurement processes. This increasing importance of measuring the cost of ownership of their products presents challenges to vendors, as this task has not been a focus of their life-cycle costing processes. Establishing a concerted effort in tracking the actual life cycle costs incurred during the operational phase seems to be one of the biggest challenges to be solved in order to implement an effective life cycle costing process.

6.3. Contribution

The objective of this research was to gain valuable insights into the role of life cycle costing in the servitization process of manufacturing companies. This case study provides a relatively narrow perspective on the entire field of servitization in manufacturing organizations. As previously discussed, the findings of this research process should not be generalized without considering the scope and context of this study. Nonetheless, this study generated valuable insights that can assist manufacturing organizations in implementing an integrated value proposition. The benefit that the organization derives from life cycle costing in this process is highly dependent on the context of application. At a minimum, the results of this study suggest that life cycle costing should be evaluated as an alternative to address the obvious challenges in creating an integrated value proposition. Similarly, the challenges that the organization will face in the life cycle costing process will depend to a large extent on the context and form of the life cycle costing process to be used. The results of this study can provide insight into the challenges that the manufacturing organization should expect to face when deciding to use some form of life cycle costing as part of the transition to a service-oriented business model.

6.4. Implications for Future Research

As discussed, the ongoing shift toward servitization in the manufacturing sector will likely require more research on the challenges and potential benefits of using life cycle costing. It is evident that there is a gap in academic research that should be addressed through further primary research. As a result of this research proposal, there are some suggestions on topics that should be further researched to provide practical guidance to companies in the servitization process.

First, further research should be conducted to determine whether life cycle costing can assist manufacturing companies in identifying servitization potential. Since the results of this research indicate a potential to assist manufacturing companies in the servitization process, it would be of interest to test this hypothesis in different contexts. This would enable a practical tool for manufacturing companies to establish a starting point for the transition to an integrated value proposition.

Second, there is a need to further explore different process structures of life cycle costing in the context of servitization. As there are currently very few general frameworks for the application of life cycle costing, this could support the process of conceptualizing the life cycle costing process. This would further enable various life cycle costing process structures to be evaluated in utility in servitization. Manufacturing companies could then directly benefit from the academic research findings in designing their life cycle costing process to consciously contribute to a successful servitization process.

Finally, it would be of value to further explore the collaboration between different stakeholders in the life cycle cost process. This research suggests the need for collaboration between suppliers, the manufacturing company, and the system operator. Investigating whether this actually contributes to a successful life cycle cost process would help the various stakeholders in the value chain understand their role in servitization. And if there is a potential benefit in collaboration, it would be of interest to conceptualize the forms and structures of collaboration that are most beneficial to a successful life cycle cost process in the context of servitization.

References

Adrodegari, F., Saccani, N., & Kowalkowski, C. (2016). A framework for PSS business models: formalization and application. *Conference: 8th CIRP IPSS CONFERENCE - Product-Service Systems across Life Cycle.* Bergamo: Elsevier. doi:10.1016/j.procir.2016.03.073

Ambad, P. M., & Kulkarni, M. S. (2013). A method for deisgn for warranty with focus on reliability and warranty policies. *Journal of Advances in Management Research, Vol. 10*(1), pp. 139-155. doi:10.1108/09727981311327811

Annarelli, A., Battistella, C., & Nonino, F. (2016). Product service system: A conceptual framework from a systematic review. *Journal of Cleaner Production, Vol. 139*(1), pp. 1011-1032. doi:10.1016/j.jclepro.2016.08.061

Aurich, J. C., Fuchs, C., & Wagenknecht, C. (2006). Life cycle oriented design of technical Product-Service Systems. *Journal of Cleaner Production, Vol. 14*(17), pp. 1480-1494. doi:10.1016/j.jclepro.2006.01.019

Azarenko, A., Roy, R., Shehab, E., & Tiwari, A. (2009). Technical product-service systems: Some implications for the machine tool industry. *Journal of Manufacturing Technology Management*, pp. 700-722. doi:10.1108/17410380910961064

Baines, T. S., Lightfoot, H., Benedettini, O., & Kay, J. M. (2009). The servitization of manufacturing: A review of literature and reflection on future challenges. *Journal of Manufacturing Technology Management, Vol. 20*(5), pp. 547-567. doi:10.1108/17410380910960984

Benedettini, O., Neely, A., & Swink, M. (2015). Why do servitized firms fail? A risk-based explanation. *International Journal of Operaions & Production Management, Vol. 35*(6), pp. 946-979.

Betz, F. (2011). *Managing Science: Methodology and Organization of Research.* New York: Springer.

Blank, S. (2013). *The Four Steps to the Epiphany.* K&S Ranch.

Braun, V., & Clarke, V. (2006). Using Thematic Analysis in Psychology. *Qualitative Research in Psychology, Vol. 3*(2), pp. 77-101. doi:10.1191/1478088706qp063oa

Brax, S. (2005). A manufacturer becoming service provider – challenges and a paradox. *Managing Service Quality: An International Journal, Vol. 15*(2), pp. 142-155. doi:10.1108/09604520510585334

Bryman, A., & Bell, E. (2011). *Business Research Methods.* New York: Oxford University Press.

Castaneda, R. A., Majic, T., Ostrosi, E., & Stjepandic, J. (2019). Modular Approach to Technical Risk Management in Product Lifecycle Management. *Conference: 26th ISTE International Conference on Transdisciplinary Engineering.* Tokyo. doi:10.3233/ATDE190144

Dimache, A., & Roche, T. (2015). Implications of the Transition to a Product-Service System on the Business Model. *School of Engineering GMIT*.

Erkoyuncu, J. A., Durugbo, C., & Roy, R. (2013). Identifying Uncertainties for Industrial Service Delivery: a Systems Approach. *International Journal of Production Research, 21*, pp. 6295-6315. doi:10.1080/00207543.2013.794316

Farr. (2011). *Systems Life Cycle Costing - Economic Analysis, Estimation, and Management.* Boca Ranton: Taylor & Francis Group.

Farr, J. V., & Faber, I. (2018). *Engineering Economics of Life Cycle Cost Analysis.* London: CRC Press / Taylor & Francis Group.

Foussier, P. M. (2006). *From Product Description to Cost: A Practical Approach.* London: Springer-Verlag.

Galar, D., Sandborn, P., & Kumar, U. (2020). *Maintenance Cost and Life Cycle Cost Analysis.* CRC Press.

Helo, P., Gunasekaran, A., & Rymaszewska, A. (2017). *Designing and Managing Industrial Product-Service Systems.* Springer International.

Herzog, M., Meuris, D., Bender, B., & Sadek, T. (2014). The Nature of Risk Management in the Early Phase of IPS2 Design. *Procedia CIRP, Vol. 16*(1), pp. 223-228. doi:10.1016/j.procir.2014.02.010

Kambanou, M. L. (2020). Additional uses for life cycle costing in life cycle management. *Procedia CIRP 90*, pp. 718-723. doi:10.1016/j.procir.2020.01.128

Keine, J., & Steven, M. (2012). Risk Management of Industrial Product-Service Systems (IPS2) - How to Consider Risk and Uncertainty over the IPS2 Lifecycle? *19th International Conference on Life Cycle Engineering.* Berkeley.

Kiruma, F., Matoba, Y., & Mitsui. (2007). Designing Product Reliability based on Total Product Lifecycle Modelling. *CIRP Annals, Vol. 56*(1), pp. 163-166. doi:10.1016/j.cirp.2007.05.039

Lancaster, G. (2012). *Research Methods in Management.* Hoboken: Taylor & Francis.

Leung, L. (2015). Validity, Reliability, and Generalizability in Qualitative Research. *J Family Med Prim Care, Vol. 4*(3), pp. 324-327. doi:10.4103/2249-4863.161306

Matschewsky, J., Kambanou, M. L., & 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, 6*, pp. 2150-2168. doi:10.1080/00207543.2017.1332792

McManus, J., Winroth, M., & Angelis, J. (2019). *Service Operations Management.* London: Red Globe.

Meier, H., Völker, O., & Funke, B. (2010). Industrial Product-Service Systems (IPS2). *The International Journal of Advanced Manufacturing Technology*, pp. 1175-1191. doi:10.1007/s00170-010-2764-6

Mont, O. (2002). Clarifying the concept of product–service system. *Journal of Cleaner Production, Vol. 10*(3), pp. 237-245. doi:10.1016/S0959-6526(01)00039-7

Muro, M., Liu, S., Whiton, J., & Kulkarni, S. (2017). *Digitalization and the American Workforce.* Brookings India. Retrieved from http://hdl.handle.net/11540/7892

Mydin, M. (2017). Significant of Building Maintenance Management on Life-Span Of Buildings. *Robotica & Management, Vol. 22*(1).

Neto, G. Z., Pereira, G. M., & Borchardt, M. (2015). What problems manufacturing companies can face when providing services around the world? *Journal of Business & Industrial Marketing, 5*, pp. 461-471. doi:10.1108/JBIM-05-2012-0090

Ng, I. C., Maull, R., & Yip, N. (2009). Outcome-based Contracts as a Driver for Systems Thinking and Service-Dominant Logic in Service Science: Evidence from the Defence Industry. *European Management Journal, Vol. 27*(6), pp. 377-387. doi:10.1016/j.emj.2009.05.002

Olivera, M. G., Mendes, G. H., Albuquerque, A. A., & Rozenfeld, H. (2018). Lessons learned from a successful industrial product service system business model: emphasis on financial aspects. *Journal of Business & Industrial Marketing, 3*, pp. 365-376. doi:10.1108/JBIM-07-2016-0147

Olivia, R., & Kallenberg, R. (2003). Managing the Transition from Products to Services. *International Journal of Service Industry Management, Vol. 14*(2), pp. 162-172. doi:10.1108/09564230310474138

Osterwalder, A., & Pigneur, Y. (2010). *Business Model Generation.* New Jersey: John Wiley & Sons.

Peruzzini, M., Germani, M., & Marilungo, E. (2014). Product-Service Lifecycle Management in Manufacturing: An Industrial Case Study. *International Conference on Product Lifecycle Management (PLM)* (pp. 445-454). Yokohama: HAL. doi:ff10.1007/978-3-662-45937-9_44

Reim, W., & Sjödin, D. (2016). Risk management for product-service system operation. *International Journal of Operations & Production Management, Vol. 36*(6), pp. 665-686. doi:10.1108/IJOPM-10-2014-0498

Reim, W., Lenka, S., Frishammar, J., & Parida, V. (2017). Implementing sustainable product–service systems utilizing business model. *The 9th CIRP IPSS Conference: Circular Perspectives on Product/Service-Systems*, (pp. 61-66). doi:10.1016/j.procir.2017.03.130

Ries, E. (2011). *The Lean Startup: How Today's Entrepreneurs Use Continous Innovation to Create Radically Succesful Businesses.* Currency.

Schick, T., & Vaughn, L. (2013). *How to Think about Weird Things.* McGraw-Hill.

Smith, D. J. (2013). Power-by-the-hour: The role of technology in reshaping business strategy at Rolls-Royce. *Technology Analysis and Strategic Management, Vol. 25*(8), pp. 987-1007. doi:10.1080/09537325.2013.823147

Spring, M., & Araujo, L. (2009). Service, Services and Products: Rethinking Operations Strategy. *International Journal of Operations & Production Manegement, Vol. 29*(5), pp. 444-467. doi:10.1108/01443570910953586

Stark, J. (2015). *Product Lifecycle Management (Volume 1).* Zürich: Springer.

Tracy, S. J. (2020). *Qualitative Research Methods: Collectinf Evidence, Crafting Analysis, Communicating Impact.* Hoboken: John Wiley & Sons Inc.

Tukker, A. (2004). Eight types of product–service system: eight ways to sustainability? Experiences from SusProNet. *Business Strategy and the Environment, Vol. 13*(4), pp. 246-260. doi:10.1002/bse.414

Ulaga, W., & Reinartz, W. J. (2011). Hybrid Offerings: How Manufacturing Firms Combine Goods and Services Successfully. *Journal of Marketing, Vol. 75*(6), pp. 5-23. doi:10.1509/jm.09.0395

Vandermerwe, S., & Rada, J. (1988). Servitization of business: Adding value by adding services. *European Management Journal, Vol. 6*(4), pp. 314-324. doi:10.1016/0263-2373(88)90033-3

Wallin, J., Chirumalla, K., & Thompson, A. (2013). Developing PSS Concepts from Traditional Product Sales Situation: The Use of Business Model Canvas. *Conference: 5th CIRP International Conference on Industrial Product-Service Systems (IPS2).* doi:10.1007/978-3-642-30820-8_23

Westkämpfer, E., & Osten-Sacken, D. v. (1998). Product Life Cycle Costing Applied to Manufacturing Systems. *CIRP Annals, Vol. 47*(1), pp. 353-356. doi:10.1016/S0007-8506(07)62849-2

Whiting, L. S. (2008). Semi-structured Interviews: Guidance for novice researchers. *Nursing Standard: Official Newspaper of the Royal College of Nursing, Vol. 22*(23), pp. 35-40. doi:10.7748/ns2008.02.22.23.35.c6420

Wise, R., & Baumgartner, P. (2000). Go downstream: The new profit imperative in manufacturing. *Harvard Business Review, Vol. 28*(1), pp. 89-96.

Witt, U., & Gross, C. (2020). The rise of the "service economy" in the second half of the twentieth century and its energetic contingencies. *Journal of Evolutionary Economics, Vol. 30*(1), 231-246. doi:10.1007/s00191-019-00649-4

Zhang, W., Guo, J., Gu, F., & Gu, X. (2018). Coupling life cycle assessment and life cycle costing as an evaluation tool for developing product service system of high energy-consuming equipment. *Journal of Cleaner Production, Vol. 183*(1), pp. 1043-1053. doi:10.1016/j.jclepro.2018.02.146

Appendix A

Interview Guide – Pilot

Introduction

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

Build - Life Cycle Cost design

- Is the company actively designing the LCC over the entire life time of the product?
- Which processes are there to design the LCC?
- Are there challenges in designing the LCC of the products?

Measure - Life Cycle Cost measurement

- Is the company actively measuring/analyzing the LCC over the entire life time of the product?
- Which processes are there to measure/analyze the LCC?
- Are there challenges in measuring the LCC of the products?

Learn – Life Cycle Cost / Business Model

- Which role does LCC have in the business model design?
- Which role could LCC have in the business model design?
- Is the collected data used in the design process?

Product Reliability

- How would you judge the overall product reliability at [*Case company name*]?
- What are the main cost drivers in maintenance?
- What are the main cost drivers of failure cost?
- Is there potential for "Design out" at [*Case company name*]?
- Where do you see potential for improvements regarding product reliability?

Servitization Opportunities

Do you see potential opportunities associated with following servitization approaches:

- Condition Based Maintenance
- Extended Warranty
- Power-by-the-hour

Challenges

Do you see any potential challenges associated with:

- Servitization
- Build - Life Cycle Cost Design
- Measure - Life Cycle Cost Measurement
- Learn - Business Model Change

Appendix B

Interview Guide – Final

Introduction

- What is your position at the company?
- How long have you been working at the company?
- Have you been working with LCC previously?
- Have you been working with servitization previously

Establish Context

- Introduce the relevant concepts of this research
- Explain the aim of this research
- Explain the research questions

Part I – Life Cycle Costing

Build - Life Cycle Cost design

- Is the company actively designing the LCC over the entire life time of the product?
- Which processes are there to design the LCC?
- Are there challenges in designing the LCC of the products?

Measure - Life Cycle Cost measurement

- Is the company actively measuring/analyzing the LCC over the entire life time of the product?
- Which processes are there to measure/analyze the LCC?
- Are there challenges in measuring the LCC of the products?

Learn – Life Cycle Cost / Business Model

- Which role does LCC have in the business model design?
- Which role could LCC have in the business model design?
- Is the collected data used in the design process?

Part II - Servitization

Servitization Application

- Have you been involved in Servitization projects at this company?
- Do you see any potential for Servitization at this company?
- Do you think the company should be focusing more on servitization?

Servitization Challenges

- Have you experienced any challenges in the servitization projects at the company?
- How are servitization projects different to usual projects in terms of challenges?

LCC in Servitization

- Is the company actively using LCC processes in the servitization projects?
- Do you see a potential use of LCC in the servitization process?
- Are the current LCC process suitable for servitization projects?
- What changes would you recommend making LCC more suitable to servitization projects?