UNLOCKING CIRCULAR ECONOMY FOR CAPITAL EQUIPMENT: EXPLORING IMPLEMENTATION OF LIFECYCLE EXTENSION

Jyväskylä University
School of Business and Economics

Master's Thesis

2022

Author: Vilma Jokela
Subject: Corporate Environmental Management
Supervisor: Tiina Onkila

JYVÄSKYLÄN YLIOPISTO
UNIVERSITY OF JYVÄSKYLÄ

ABSTRACT

Author
Vilma Jokela

Title
Unlocking Circular Economy for Capital Equipment: Exploring Implementation of Lifecycle Extension

Subject
Corporate Environmental Management

Type of work
Master's thesis

Date
29.5.2022

Number of pages
67

Abstract
This Master's Thesis study aims to explore the implementation of circular economy driven lifecycle extension (LCE) in the capital equipment industry. Researchers highlight the role of LCE to contribute to a circular economy (CE) in this industry where common product characteristics include inherently long lifetime and high material intensity. Despite the attention capital equipment has received from researchers in the context of LCE, it seems that previous research has somewhat overlooked the role of studying implementation through challenges and opportunities.

Implementation of LCE is researched in this study from a business point of view, through perceived challenges and opportunities as well as expected benefits. Studying benefits is justified, as expected benefits are noticed as the most important driver for companies to implement CE activities. By exploring this topic, the thesis intends to improve the understanding of how LCE can be promoted among capital equipment companies. This thesis has been conducted as a qualitative, intensive case study. The case organization is a manufacturer of material handling equipment. The data has been gathered in interviews with the personnel of the company as well as with representatives of four companies within this industry.

The findings from this study propose service strategy, stakeholder collaboration, and organizational factors as the main factors whose challenges and opportunities influence LCE implementation. Additionally, the results propose various benefits from addressing LCE, from which the most likely seem to be customer value creation, positive environmental impact, and risk reduction. Based on these findings, recommendations for action are given for the case company in the areas of rethinking value and benefits, developing the service concept, collaborating with suppliers and recyclers, and advancing management for CE.

Key words
circular economy, product lifecycle extension, capital equipment

Place of storage
Jyväskylä University Library

TIIVISTELMÄ

Tekijä
Vilma Jokela

Työn nimi
Kiertotalouden mahdollisuudet käyttöön pääomahyödykkeille: Tutkimus elinkaaren pidentämisen käytäntöönpanosta

Oppiaine	Työn laji
Yritysten ympäristöjohtaminen	Pro gradu -tutkielma
Päivämäärä 29.5.2022	Sivumäärä 67

Tiivistelmä
Tämän Pro Gradu työn tavoitteena on tutkia kiertotalouteen perustuvaa tuotteen elinkaaren pidentämistä pääomahyödykkeiden teollisuudenalalla. Tutkijat korostavat tuotteen elinkaaren pidentämisen roolia kiertotalouden edistämisessä etenkin tällä teollisuudenalalla, jossa tuotteille ominaista on pitkä elinkaari ja huomattava materiaalien käyttö. Huolimatta pääomahyödykkeiden jo saadusta huomiosta elinkaaren pidentämisen tutkimusalalla, vaikuttaa siltä, että tutkijat ovat ylenkatsoneet haasteiden ja mahdollisuuksien tunnistamisen roolin osana elinkaaren pidentämisen edistämistä.

Tuotteen elinkaaren pidentämisen käytäntöönpanoa tutkitaan tässä työssä yrityksen liiketoiminnan näkökulmasta keskittyen havaittuihin haasteisiin ja mahdollisuuksiin sekä koettuihin hyötyihin. Tätä aihetta tutkimalla tämä Pro Gradu pyrkii parantamaan käsitystä siitä, miten pääomahyödykkeiden elinkaaren pidentämistä voidaan edistää. Tämä tutkimus on toteutettu laadullisena, intensiivisenä tapaustutkimuksena. Tapaustutkimuksen kohdeyrityksenä on ollut materiaalien käsittelylaitteiden tuottaja. Tutkimusaineisto on kerätty haastatteluissa yrityksen sisällä ja ulkopuolisten asiantuntijoiden kanssa.

Tämän tutkimuksen tulokset viittaavat siihen, että palvelustrategiaan, sidosryhmäyhteistyöhön ja organisatorisiin tekijöihin liittyvät haasteet ja mahdollisuudet vaikuttavat olennaisesti tuotteen elinkaaren pidentämiseen. Lisäksi tulokset osoittavat monia hyötyjä elinkaaren pidentämisestä, joista todennäköisimmät vaikuttavat olevan arvonluonti asiakkaille, positiiviset ympäristövaikutukset ja riskien väheneminen. Näiden tulosten perusteella suosituksia kohdeyritykselle on annettu arvojen ja hyötyjen uudelleenajattelemiseen, sekä palvelukonseptin, sidosryhmäyhteistyön ja kiertotalouden johtamisen kehittämiseen.

Asiasanat
kiertotalous, tuotteen elinkaaren pidentäminen, pääomahyödyke

Säilytyspaikka
Jyväskylän yliopiston kirjasto

CONTENTS

1 INTRODUCTION

The current global economy relies on the draining of resources, which causes growing concerns of resource shortages but also growing emissions and waste generation. The ecological footprint has increased from less than one planet Earth in 1961 to more than 1.4 planet Earths in 2005 and two planet Earths are expected to be required to fulfil human needs in 2030 (Milios, 2018). According to Korhonen et al. (2018), the main challenge for sustainable development is the linear flow of materials and energy. In a linear economy, resources are unsustainably exploited and consumed fast, without giving a thought to their recovery (Milios, 2018). Consequently, the circular economy (CE) is viewed as an important enabler for sustainability because of its capability to reduce pressure on natural resources (European Commission, 2020).

The CE is gaining interest among manufacturing companies (Bjørnbet et al., 2021), and companies are intrigued by the economic potential of this concept (Sarja et al., 2021). Following the increasing interest in the CE concept, also research regarding the implementation of the concept is raising. However, the research on the concept is seen to be unsaturated and diffused (e.g., Fontana et al., 2021; Korhonen et al., 2018; Sarja et al., 2021) which also relates to the challenges in CE implementation in companies (Ingemarsdotter et al., 2021). Consequently, it seems that companies are still struggling with CE implementation.

Companies have various ways for CE implementation, but one with great potential is seen to be circular economy driven lifecycle extension, which can be shortly called lifecycle extension (LCE) of products. This practice of prolonging and extending a product's useful lifetime is seen as one of the most important ways to preserve resources in a CE because these activities enable the minimization of waste (den Hollander et al., 2017). Also, The EU's action plan (European Commission, 2020) toward the CE illustrates the importance of extending the lifecycles of products. As part of the action plan, rules are set up for activities that facilitate implementation of LCE strategies, such as rules on ease of product repair.

LCE of products can be seen as an especially promising way to contribute to a CE in the context of the capital equipment industry. The capital equipment industry consists of a wide range of companies producing capital intensive products which have a relatively long lifetime (Circle Economy, 2019). These products include but are not limited to medical scanners, solar panels, cars, and elevators. CE presents special potential in this industry, because of the related significant materials and emissions. According to Circle Economy (2019), CE has the potential to influence both material consumption (6,5% of global annual material consumption), and released emissions within the industry. For the companies in this industry, LCE presents also a way to respond to the ever changing markets. The capital goods industry is seen to face an increasingly competitive market situation (de la Calle et al., 2021) where providing services is more and more important (Adrodegari et al., 2018). Hence, studying LCE in this industry is not only relevant for facilitating the otherwise challenging CE implementation, but also because of the sustainability potential as well as the business potential.

Previous research in CE implementation through LCE in the context of capital equipment seems to focus on the specific assets within the industry, and researchers have explored the adoption of different LCE strategies in the settings including automotive (Subramoniam et al., 2009), aviation (Ayeni et al., 2011), construction machinery (Tait & Gereffi, 2016) and heavy vehicles (Saidani et al., 2018). Despite this interest, no one to the best of my knowledge has studied CE implementation through LCE in the context of material handling equipment. This particular equipment seems to be overlooked in the research field of LCE implementation, and therefore a material handling equipment manufacturer provides a context for the empirical case study of this thesis.

Additionally, within the capital equipment industry, researchers have only seldom focused on studying the implementation of LCE through challenges, opportunities, and expected benefits. LCE related barriers and drivers have been studied but only in the context of consumer products (Jensen et al., 2021). As researchers (Jensen et al., 2021; Milios et al., 2019) note, implementation of LCE requires barriers identification, looking at how they influence one another, and addressing them in the current business operations. Consequently, one of the objectives of this study is to identify both challenges and opportunities to facilitate LCE implementation in companies. Also studying expected benefits is justified. On one hand, increasing business complexity within this industry stresses the importance for companies to better understand the financial and environmental implications of CE implementation (Rossi et al., 2022). On the other hand, expected benefits drive and push companies to implement CE activities (Sarja et al., 2021; Tura et al., 2019). Therefore, analysing benefits can help companies to understand the implications LCE has to their business as well as it can motivate companies to adopt LCE as part of their business operations. Consequently, the purpose of this research is to explore the implementation of LCE by researching perceived challenges and opportunities as well as expected benefits in the context of the capital equipment industry and material handling

equipment manufacturer. By doing this, this study intends to provide results that contribute to achieving a more holistic understanding of how the LCE of capital equipment can be promoted.

1.1 Research questions and limitations

The main objective of this research is to explore, from a business perspective, how circular economy driven lifecycle extension can be promoted in a company operating in the capital equipment industry. More specifically, this study focuses on examining the actions that can be taken to promote circular economy driven lifecycle extension. This topic is examined through a case study, and contribution is sought both to the research field and to practice. In addition to developing the activities of the case company, this research contributes to the research on LCE implementation in the capital equipment industry. Supporting the aim presented for this study, the main research question of this study is framed as follows:

What actions should be taken to promote circular economy driven lifecycle extension at the case company?

Moreover, subordinate research questions are created to support answering the main research question:

1. *What challenges and opportunities are related to circular economy driven lifecycle extension in the case company?*
2. *What benefits the case company could gain by addressing circular economy driven lifecycle extension?*

This study has been conducted under a set of limitations and assumptions. The scope of this thesis is outlined to cover the actions, that would facilitate the LCE of already existing equipment. The reason to focus on the existing equipment comes down to the long lifetime of the capital equipment as well as the existing studies in the field. Due to the long lifetime, it is important to understand how the LCE of already existing equipment can be facilitated. Additionally, it seems that design for LCE is one of the most studied areas of LCE research. For these reasons, the beginning of life of the equipment including design is excluded from the scope of the thesis. Another outline to the research scope is the emphasis of only environmental sides of CE. According to researchers (Bjørnbet et al., 2021; Kirchherr et al., 2017; Korhonen et al., 2018; Salvador et al., 2020), CE should address also economic sustainability and social prosperity, but these are not considered in this thesis in order to improve the clarity and straightforwardness of this study. Related to the concept of CE, also one grounding assumption has been made. In this study, it is assumed that CE and LCE benefit the environment, even if studies show that positive environmental impact is not a guaranteed

result from LCE implementation. This assumption had to be made, because evaluation of the environmental impacts would require rather extensive calculations such as lifecycle assessments.

1.1 Research structure

This study is structured as it follows. Section 2 presents the theoretical framework of this study. This section discusses the relevant research in the field while aiming to introduce the important related concepts for this study. Section 3 introduces the reader to the empirical study including data collection and methodology, which was conducted as part of this research. Additionally the section introduces the case study in detail. Afterwards, in Section 4 the findings of the empirical research in relation to the subordinate research questions are described. The 5th section then reflects these findings to the theoretical framework of this study while it also gives recommendations for action following the main research question. Finally, Section 6 is the conclusion section which suggests the key takeaways from this study and presents the future research recommendations.

2 THEORETICAL FRAMEWORK

This section will present the theoretical framework of this study. In the first chapter (2.1), the concept of CE will be discussed considering the definition, roots, aim, and implementation of this concept. The second chapter (2.2) will explore circular economy driven lifecycle extension including different product life definitions, conceptualisation, and framework for LCE as well as issues related to the implementation of LCE. The third and last chapter (2.3) of the theoretical framework will examine the benefits of circular economy driven lifecycle extension. The chapter discusses the benefits by describing how they differ in a CE compared to a linear economy and presents the potential benefits of LCE.

2.1 The concept of circular economy

2.1.1 Definition and roots of the concept

A circular economy has been conceptualized in the literature in various ways. According to den Hollander et al. (2017), In a CE

> the economic and environmental value of materials is preserved for as long as possible by keeping them in the economic system, either by lengthening the life of the products formed from them or by looping them back in the system to be reused. It follows that the notion of waste no longer exists in a CE because products and materials are, in principle, reused and cycled indefinitely. (p. 517)

However, many researchers have for long created their own definitions, and it seems that new definitions are made based on the principles that the researchers have seen at that time as the most relevant. Based on the analysis of 114 definitions by Kirchherr et al. (2017), the definitions vary in their level of emphasis on a systems perspective, waste hierarchy, circular principles, and

sustainable development. From previous research, it seems that the researchers have still not found one unifying definition for the concept. Reasons for the challenges in creating a definition are related to the unsaturated research on the concept, which is discussed more in Chapter 2.1.3.

Regardless of the lack of a widely accepted definition, one relatively popular definition is from the Ellen MacArthur Foundation (2012) which defines a CE as

> an industrial system that is restorative or regenerative by intention and design. It replaces the end-of-life concept with restoration, shifts towards renewable energy, elimination of toxic chemicals which impair reuse and return to the biosphere, and aims for the elimination of waste through the superior design of materials, products, systems, and business models. (p.7)

This definition is seen as suitable for this study because it aligns with the purposes of this research. Firstly, the definition considers the system perspective which is required for assessing the total environmental impact of the LCE of products. Moreover, the definition does not only cover reducing, reusing and recycling as part of CE like many definitions do, but it also highlights the role of restoration which is a relevant part of LCE. Last, the definition aligns with this study by acknowledging businesses as an important enabler of CE.

In order to implement CE, it is necessary to be aware of the long background of this concept. Efforts have been made for sustainable manufacturing for a long time. Bjørnbet et al. (2021) describe how people's impact on the environment was gradually noticed starting from Rachel Carson's report (Silent Spring, 1962). Gradually efforts for reducing people's impact on the environment started to come, sustainable production initiatives started in the 1990s, and life-cycle management in the 2000s (Bjørnbet et al., 2021). According to Korhonen et al. (2018), the roots of the CE concept are back in the scientific, older field of ecological economics, which can also help understand and better guide the attempt toward the CE. The authors explain that ecological economics have for long developed macro level concepts that remind of CE. Consequently, Kalmykova et al. (2018) say that the concept of CE has roots in concepts, including spaceman economy (Boulding, 1966), limits to growth (Meadows, Meadows et al., 1972), steady-state economy (Daly, 2005), performance economy (Stahel, 2010), industrial ecology (Frosch and Gallopoulos, 1989) and "cradle-to-cradle" (Stahel and Reday-Mulvey, 1981), among others. Regardless of the multifold background of this concept, CE has only started to gain wider attention in the 2010s (Kalmykova et al., 2018) when the number of published studies has been rising significantly. This diverse background and emerging studies on CE seem to cause the current situation where our understanding of the concept is still under development.

As the grounding reason for implementing CE is to respond to sustainability issues, it needs to be stressed and paid attention to that in the end CE really has an impact on sustainability. Regardless of the fact that CE is

implemented in order to advance sustainability, it cannot be expected that implementation of circular strategies would always lead to resource decoupling (Bjørnbet et al., 2021). Therefore, more research is still needed about the connection between CE and sustainability. This was found out in the systematic literature review by Salvador et al. (2020) who analysed the literature for circular business model implementation. The findings of the study indicate that sometimes circularity can also lead to higher environmental impacts. The authors use the example of activities needed for remanufacturing, where the transportation and material processing might require more material and energy compared to a new product that is manufactured with efficient practices. This explains why the relation between CE and sustainability is not completely clear, and why many researchers (e.g., Bocken et al., 2016; Kirchherr et al., 2017; Salvador et al., 2020) highlight the need for businesses to apply system perspective. When the entire system is considered, the impact of CE activities is evaluated in a company's value chain. This evaluation allows one to identify the possible negative environmental impacts from CE activities.

2.1.2 Circular economy implementation in companies

The functioning of a CE can be evaluated at the level of nations, eco-industrial parks as well as in the level of companies and products. Kühl et al. (2018) name these levels as macro, meso, and micro levels, from which companies and products operate on the micro level. Although the action can be taken on the level of countries or industrial parks, the importance of businesses is highlighted in the transition to the CE. While it is important to examine the actions companies can take, several researchers have expressed the challenge of applying the concept in practice due to the unsaturated research on the concept.

Previous studies indicate that research on CE is underdeveloped for many reasons. Part of the challenge seems to be that the concept is currently developed by practitioners, companies, and policy-makers instead of researchers (Korhonen et al., 2018). There is a multitude of approaches and definitions for the concept (Fontana et al., 2021), which can make it difficult to choose a suitable approach. As Bjørnbet et al. (2021) point out, we still miss a clear way, a "toolbox", on how to implement CE successfully. The authors' literature review reveals that previous research does not give any generalizable conclusions for companies regarding advantageous ways to implement the concept. Consequently, Ingemarsdotter et al. (2021) identify a gap between the current CE research and the struggles companies face when implementing circular economy driven maintenance activities. For CE implementation through LCE, this means that companies can still be hesitant about the direction they should take to move towards circularity.

Regardless of the unorganised research in the field, the CE concept is gaining increasing popularity. As Korhonen et al. (2018) indicate, CE has gained a lot of attention from businesses as a way to take steps towards sustainability. For businesses, it is important to find profitable ways to implement sustainability, and CE might be a low-hanging fruit for companies to do this. Consequently, it is noticed that the main reason for companies to implement CE is the expected

economic benefits (Gusmerotti et al., 2019; Sarja et al., 2021). CE also seems to have the potential to realise economic benefits. Maximising the efficient use of once extracted materials should in principle have the potential of either raising economic gains or at least reducing economic losses (Korhonen et al., 2018). Following this line of thought, the reduction of waste and emissions should also make sense for companies.

Companies have a variety of ways to implement CE in their value chains. Kalmykova et al. (2018) clarify the various approaches by analysing the different ways businesses have for implementing CE. The authors illustrate how companies can manage resource flows through the company's value chain in a CE. First, the company can implement CE in the phases of material sourcing, designing, and manufacturing. After production, the company can influence resource flows in their distribution practices and usage of the product. Last, at the end of the product life, the company can influence how collection and disposal are organised, or how recycling and recovery are enabled.

The discussion about CE implementation in companies seems to be to some extend about if the business model of a company needs to change for progressing toward a CE. In the literature, researchers use the term circular business model when referring to a business model which is specially designed to contribute to the CE. The findings of a literature review by Bjørnbet et al (2021) show that many researchers see circular business models as an enabler of the CE. This is illustrated by a large number of studies that focus on examining these business models. However, not all researchers agree about taking the importance of circular business models for granted. Nußholz (2017) speculates the need for a circular business model. The author proposes that the main difference is in the company's offer because circular business includes circular strategy such as refurbishing or remanufacturing as part of the company's operations.

When thinking about the current level of implementation, analysis by Gusmerotti et al. (2019) shows that CE is currently implemented in manufacturing companies by embedding it into the existing business model. Their results indicate that a lot of advancements need to be made until CE principles will be key aspects of the business operations of the manufacturing firms. This seems to be the case because companies are not aware enough of the business opportunities provided by CE. Gusmerotti et al. (2019) conclude with the suggestion that companies should embed circularity into the whole business because this allows the best chances for economic and market opportunities that are connected to CE. For this reason, it seems more probable to be able to effectively implement CE if the entire business model is designed to support CE.

Even if it is still unclear how much a business model needs to change to implement CE, the previous research at least supports the idea of having various CE initiatives. Bocken et al. (2016) propose that synergies can be gained by combining different strategies, approaches, and methods to accelerate the change to a CE. Matschewsky (2019) comes to the same conclusion and points out the benefit of simultaneously and increasingly having multiple initiatives to be worked on. Consequently, it seems that companies have to find the most suitable way of

implementation for them, a way that fits their market and the positioning of the company. Domestic appliances producer Miele can be seen as a successful example of this (Bocken et al., 2016). The company sells durable washing machines while they also put effort into providing extensive services to the users. The company does not compete with prices but they apply various strategies that allow a long service life for the products (Bocken et al., 2016). Still, starting the journey of applying CE appears challenging, as companies should promote various initiatives simultaneously. As Kabboura et al. (2019) point out, companies are in the need of ways to implement CE without major changes needed in resources or structures of the company.

After this discussion of the grounding issues of CE, the following chapter is dedicated to product lifecycle extension. Extending the life of the products presents one of the many ways for capital equipment companies to take a step towards a CE. From the implementation opportunities presented by Kalmykova et al. (2018), lifecycle extension can take place in consumption and use, collection, recycling, and recovery, as well as in the remanufacturing practices within the value chain.

2.2 Lifecycle extension in a circular economy

2.2.1 Product life and product lifecycles

Various terms can be used to describe product life. Den Hollander et al. (2017, p. 519) define *product lifetime* as "the duration of the period that starts at the moment a product is released for use after manufacture and ends at the moment a product becomes obsolete beyond recovery at product level". In this definition, product life ends when recovery, any operation that is used to avoid obsolescence and maintain usability, is not applicable anymore. Another way to define product lifetime is to see it from the perspective of the user, more specifically to think of the period for which the user finds the product useful (van Nes & Cramer, 2003). Besides product lifetime, researchers refer to the economic, technical, and functional life of a product. *Economic life* illustrates the period which ends when the recovery of a product is more expensive than buying a new one (Heiskanen, 1996; as cited in Ertz et al., 2019). *Technical life* illustrates the time for which a product's physical parts can function (Cooper, 2010; as cited in Ertz et al., 2019). Especially *functional life* is a commonly used term, it illustrates the functioning time of a product without attempts for recovery (Cox et al., 2013). Looking at product lifetime in a CE is crucial because it allows us to examine the ways which can be used to avoid product obsolescence and start a new lifecycle.

Based on the above description, a product can have only one lifetime while this period can be divided into multiple lifecycle stages. Lifecycles can be divided differently based on the perspective and company type. For instance, Bustinza et al. (2021) divide lifecycles based on whether the company is product or service-oriented. One common and simple way is to divide lifecycles into the stages of

beginning, middle, and end of life (Jun et al., 2007). Each of these stages provides possibilities for companies to extend the life of their products. In an optimal situation, lifecycle extension should gain focus already in the beginning of the product life where circular design strategies (e.g., design for long use, a design that enables extended use, and design that enables recovery of the product) are applied (den Hollander et al., 2017). Regardless of the importance of design, in the following subchapters I will focus on discussing the LCE practices in the middle and the end of life of a product as it supports the purposes of this study.

2.2.2 Conceptualisation and framework for lifecycle extension

As mentioned in the previous chapter, a product can have multiple lifecycles, and the amount of these cycles can be increased with LCE activities. This can happen either by prolonging the current lifecycle or by starting a new lifecycle for instance by remanufacturing an item (den Hollander et al., 2017). LCE of products describes activities, that can be used to extend the utilization period of a product (Bocken et al., 2016). According to Salvador et al. (2021) aim of the product lifecycle extension is to increase the time that a product stays in the original function and in this way maximize the resource value before the end of life. However, in this thesis, the scope of LCE is not limited to the original functions of the product. I follow the conceptualisations of researchers such as Linton and Jayaraman (2005) and Fontana et al. (2021), who see also the activities at the end of life as LCE activities even if the product does not stay in the original function. As den Hollander et al. (2017) express, LCE can require modifications that change the physical properties of the product or alterations that even change the original functions.

As research about CE in general, also research on LCE appears to be scattered. It seems that the topic has been studied from various perspectives, without reaching coherence. A literature review by Fontana et al. (2021) reveal that research about lifecycle extension has been strongly increasing in the last five years and that there is a possibility for inconsistencies in the topic. The existing research seems to study LCE from various perspectives, but very popular perspectives seem to be an assessment of environmental impact in general (Cooper & Gutowski, 2015; Gharfalkar et al., 2016) and the impact on CE in the context of product service systems (Chou et al., 2015; Kjaer et al., 2019; Matschewsky, 2019; Yang & Evans, 2019). Furthermore, research has tended to focus on business models (Ertz et al., 2019; Nußholz, 2018; Whalen, 2019), and the adoption of specific LCE strategies in the context of specific types of capital equipment (Ayeni et al., 2011; Khan et al., 2020; Saidani et al., 2018; Subramoniam et al., 2009; Tait & Gereffi, 2016). Considering this current research on the field, it seems that the research has tended to focus on specific ways to adopt LCE and its environmental impacts, and a more general approach to implementation of LCE seems to be missing. Moreover, it appears that researchers have failed to address the case of a material handling equipment manufacturer.

Considering previous research in the field, many researchers have created frameworks for LCE. These frameworks are used to guide LCE implementation

by presenting and defining the available strategies. Here to be mentioned, a generally used framework by Linton and Jayaraman (2005) identify the possible ways to extend product lifecycles. Khan et al. (2018) created a similar framework consisting of all strategies mentioned in the literature whereas Fontana et al. (2021) list and defines LCE strategies among SMEs in the equipment and machinery sector. Differences between these frameworks are minor, as all authors include repair, preventive and predictive maintenance, product reuse, remanufacture, and recycling as LCE strategies. Additionally, recall, midlife upgrade, and part reuse are mentioned both by Linton and Jayaraman (2005) and Khan et al. (2018). In the context of the equipment and machinery sector, Fontana et al. (2021) lists also strategies of cannibalization and reconditioning, which are not mentioned by the other two studies.

Regardless of the existing frameworks, to my knowledge, there is no LCE framework made specifically for capital intensive goods. As Fontana et al. (2021) point out, proper strategy definitions for lifetime extension are lacking and this causes misunderstandings. Therefore a new framework for LCE strategies in the context of the capital goods industry is created for this study. Relevant LCE strategies in the context of capital equipment are shown in Table 1.

Table 1. Lifecycle extension strategies in the context of capital equipment. Classification modified from Linton and Jayaraman (2005) and Fontana et al. (2021).

Strategy	Definition	Lifecycle phase (according to Khan et al. 2018)
Direct product reuse	To use a product for second or further time. Reuse includes leasing of a product and sale of a product to a new owner by the current owner (Linton and Jayaraman, 2005).	Middle of life
Repair	Set of activities performed on a defective product so it can be used with its original function. Repair is also making a broken product operational again through fixing/replacing failed parts. (Fontana et al., 2021).	Middle of life
Preventive maintenance	Inspection and/or servicing tasks that were pre-planned for accomplishment at specific points in time to retain the functional capabilities of operating equipment or systems and to reduce the probability of failure or prevent degradation of the functioning of a product (Fontana et al., 2021).	Middle of life
Predictive maintenance	A condition-driven preventative maintenance program. It uses direct monitoring of the mechanical condition, system efficiency, and other indicators to determine the actual mean time to failure or loss of efficiency (Fontana et al., 2021)	Middle of life

Midlife upgrade	The extension of capital equipment's remaining useful life by means of upgrading components, sub-systems or the like in response to certain triggers from users, environment, or market (Khan et al., 2020). Especially seen useful for complex systems with many sub-components or sub-systems with a shorter lifetime than the system as a whole (Linton & Jayaraman, 2005)	Middle of life
Part reuse	See Direct product reuse. The part reuse focuses on the same use of a part in the same form without remanufacturing (Linton and Jayaraman, 2005).	End of life
Refurbish	Refurbishing is the process of returning an obsolete product to a satisfactory working and/or cosmetic condition, that may be inferior to the original specification, by repairing, replacing or refinishing all major components that are markedly damaged, have failed, or that are on the point of failure, even where the customer has not reported or noticed faults in those components (Den Hollander et al., 2017)	End of life
Remanufacture	Remanufacture is a strategy that implies using parts of discarded products in a new product with the same function. Used products are brought at least to original equipment manufacturer performance specification.. Remanufacture applies where the full structure of a multi-component product is disassembled, checked, cleaned and when necessary replaced or repaired in an industrial process (Fontana et al., 2021).	End of life
Recycle	The processing of materials to obtain the same (high-grade), or lower (low-grade), quality of recycled materials. The purpose of recycling is to reuse materials from used products and components. These materials can be reused in production of original parts if the quality of materials is high, or else in production of other parts (Fontana et al. 2021).	End of life
Cannibalization	Cannibalization is the activity of recovering parts from returned products. Recovered parts are used in repair, refurbishing, reconditioning and remanufacturing of other products. A limited set of reusable parts of the returned products is recovered in cannibalization (Dehghanbaghi et al. 2016).	End of life

2.2.3 Implementation of lifecycle extension

For businesses, there seem to be many issues that should be considered when implementing LCE, and hence this chapter sheds light on these issues. First, prioritization of the LCE strategies will be discussed, followed by a discussion of factors that can have a strong influence when promoting LCE. While this chapter introduces the aspects that appear the most important regarding LCE and this thesis, the list is not exhaustive, and also other issues can be found in the literature.

Prioritization of the lifecycle extension strategies

The concept of CE stresses the utilization of products and materials when the environmental value is the highest and this is something that brings the attention to product lifecycles. As Korhonen et al. (2018) explain, value composition can be analysed by looking at product lifetime and lifecycles which influences also the implementation of LCE strategies. Both Reike et al. (2018) and Fontana et al. (2021) propose a similar "hierarchy" between the strategies in order to show, which strategies are the most favourable from the perspective of the environmental impact of each strategy. As discussed in Chapter 2.1.1., evaluation of the impacts should be done system perspective in mind. Nevertheless, this hierarchy is beneficial because it allows one to quickly get an understanding of which strategies should be applied over the others.

In this so called hierarchy, LCE strategies are divided into short, medium, and long loops strategies based on their level of contribution to a CE (Reike et al., 2018). This distinction between the strategies is illustrated in Figure 1. With the short loop strategies, the products stay close to their prior function (Fontana et al., 2021). As the materials need only minor processing, also the energy usage and waste generation are minimal compared to the other LCE strategies (Korhonen et al., 2018). In practice, short loop strategies include product reuse, repair, and maintenance (Reike et al., 2018). When moving towards the medium loop strategies (upgrade, remanufacture, part reuse, and refurbish), the nature of the product changes which reflects the increased environmental impact. In the long loop strategies, namely recycling and cannibalization, the products are not used for their original purpose but rather as a source of material for other products (Fontana et al., 2021). Especially relevant for businesses seem to be that also the economic value of the materials reduces when it approaches the outer circles (Korhonen et al., 2018). Therefore, based on environmental and economic reasons, companies should be motivated to keep the products in shorter loops for as long as possible.

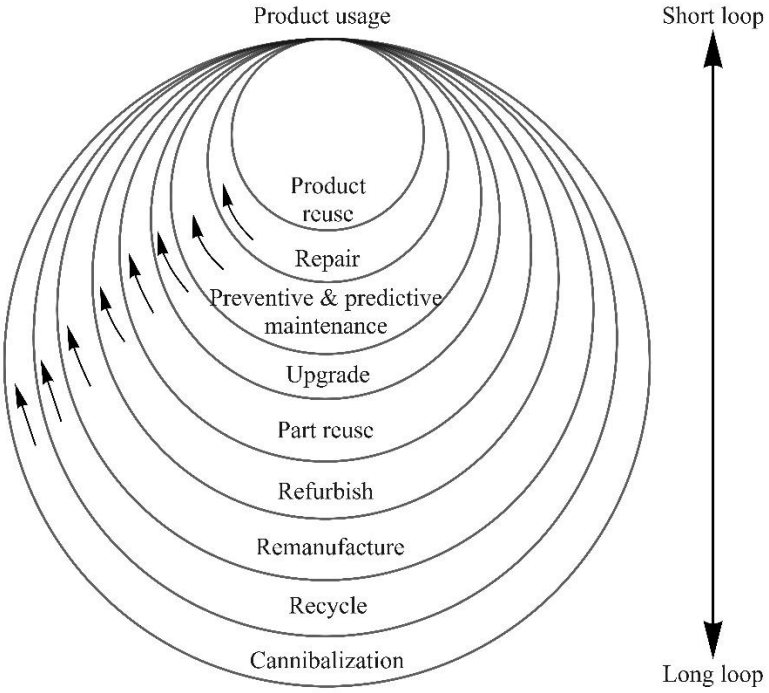

Figure 1. Illustration of the length of the loop among the LCE strategies. Modified from Mihelcic et al. (2003).

In addition to the hierarchy, the nature of the product affects which LCE strategy should be applied from the environmental impact perspective. First, the decision to reuse a product or part and the smartness of this decision depends on the environmental impact of this product. If the impact in the use phase is lower compared to the impact of production, reuse can be a smart choice (Nußholz, 2017). Kabboura et al. (2019) found out with quantitate methods that LCE is a good solution for durable products, which do not need energy for functioning. Considering these products, the environmental impact is high in production and not in consumption. In the case of a product with significant energy consumption in the use phase, the danger is that without an upgrade or replacement, one might use an old model which uses more energy than a newer version of the product. In this way, sustainability is not served. In the capital goods industry, the manufactured equipment can contain both passive durable parts and active energy consuming parts. Above mentioned studies show that in the case of those durable long lasting parts it could be beneficial to extend the lifetime. For the parts that need energy, the decision of extending the life needs to be evaluated in a more thorough way.

Considerations for implementing lifecycle extension

In addition to the hierarchy and the product type, the literature highlights various issues that a company could consider to guarantee effective implementation of LCE. Next, the issue of rebound, hesitations regarding financial implications as well as customer and supplier challenges will be shortly discussed.

As discussed in Chapter 2.1.1, it cannot be taken for granted that CE implementation would always have a positive sustainability impact. This is noticed to be the case also in the specific context of LCE (Chou et al., 2015). When prolonging the product's life, negative environmental impact can be caused for various reasons, from which researchers emphasize especially rebound effect (e.g., Kabboura et al., 2019; Korhonen et al., 2018; Nußholz, 2017; Whalen, 2019). A rebound effect in the context of CE means a situation in which overall production increases regardless of the activities aimed at reducing it (Zink & Greyer, 2017). Various mechanisms can cause a rebound effect but the risk of a rebound effect is seen to exist especially in situations where companies choose to reduce the prices of products because of reduced costs (Kabboura et al., 2019; Whalen et al., 2019). This could happen for instance when suppliers make more sales by selling old models of products and customers can buy more due to the reduced prices (Whalen et al., 2019). However, as Salvador et al. (2021) propose, the rebound effect is mainly an issue in the consumer market. Especially in the context of capital equipment, the purchase of the equipment requires a significant investment from the customer and a reduced price might not lead to buying larger amount of the equipment.

Furthermore, it is good to consider the negative perceptions that companies might have regarding the implications LCE could have for the business. Companies can expect LCE to negatively affect sales, technological development, and time efficiency (Milios et al., 2019). In their multiple case study, Khan et al. (2020) examine opportunities for a midlife upgrade in the context of capital equipment. The authors find out that many manufacturers had the perception that sales would reduce if the equipment is made to last longer, and this understanding was the main reason for the manufacturers not to implement the upgrade. According to the authors, companies might think that LCE would reduce the firm's possibility for new sales as the life of the current product is being extended and the purchase of a completely new product is avoided. This perception can make companies even implement planned obsolesces in order to maximise sales of new products as the old ones are obsolete (Khan et at. 2020).

Perception of reduced sales puts pressure on seeing the business as a whole when implementing LCE. Some researchers encourage companies to consider changing the ownership from customer to supplier as a way to diminish the expected financial risks. This is expressed at least by Khan et al. (2020) and Kabboura et al. (2019) who see that these business models, so called product service systems, maintain the income levels because revenue is not dependent on the sold products. Another way can be to analyse the value proposition of the business together with the competitive situation and in this way guarantee that LCE reflects these areas of the company's business model (Khan et al., 2020). This is in line with Nußholz (2017) who highlight that implementation of circular strategies often require large changes both inside and outside the company. The target of companies is still to maximise sales and stay competitive, and understandably, the decision makers in a company want to implement LCE only if it is a favourable choice from the business perspective.

In addition to the rebound effect and negative perceptions, both customers' and suppliers' expectations are seen as a challenge for implementing LCE. According to Salvador et al. (2020), customers' wishes and expectations are often overlooked. The importance of customers is clear, as there is no viable business without customers. Salvador et al. (2021) indicate that CE strategies generally have an impact on the customer segment of the company. Customer preferences and expectations have also been noticed as a challenge in the context of companies that has LCE at the core of their business. Case companies of the study by Vermunt et al. (2019) have identified resistance from customers for LCE because products whose life have been extended were seen as less valuable. Sometimes customers were also noticed to ask for customized products instead of standardised ones, which caused challenges for some of the companies. Standardisation is a popular option among LCE practitioners, because managing the product becomes more straightforward when there are no various versions of the product.

Moreover to the customer resistance, another major barrier that Vermunt et al. (2019) identified in LCE implementation was challenges in the supply of disregarded products or materials. This was a challenge for companies who instead of using virgin materials, used disregarded materials for producing new products. The case companies faced challenges because of the unpredictable quality of discarded materials and products that are received from the customers or third parties. This was seen to increase the risk of technological and financial difficulties to process the materials and create value from them. Other supply issues were related to the uncertainties of timing and volume of disregarded materials. Companies implementing LCE were often dependent on the supply of others who did not provide a stable supply for their goods.

In this chapter, the LCE of products has been discussed from the perspectives of product lifetime and LCE strategies while also considerations for implementing LCE have been discussed. Following this discussion, the next chapter will focus on describing the benefits that companies gain from extending the life of their products.

2.3 Business benefits from lifecycle extension

2.3.1 Definition of benefits and justification for studying them

Previous studies do not directly examine benefits in the context of circular economy driven lifecycle extension, but related concepts are explored which also illustrate the potential benefits. The main related approach in the literature is circular business models and their areas of value proposition, value creation, and value capture (e.g., Fernandes et al., 2020; Lahti et al., 2018; Ranta et al., 2020). In the business context, values are traditionally seen as related to economic gains and research has overlooked sustainable values including social and environmental values (Patala et al., 2016). However, in the context of circular business it seems that value is increasingly associated with sustainability and approaches

such as sustainable and environmental value propositions (e.g., Kristen & Remmen, 2019; Manninen et al., 2018; Yang & Evans, 2019) are introduced. Additionally, typical for current research is a focus on customers. The vast majority of value related studies appear to explore the topic from the customer perspective instead of purely looking at what benefits the company.

In this thesis, benefits are seen as the positive characteristics that a company receives from extending the lifecycle of its products. Consequently, benefits are the positive outcomes of CE activities. In this way benefits in this study are seen to be related to values, which in the business context means the trade-off between benefits and sacrifices (Flint et al., 1997).

Based on previous studies, identification of the benefits received from CE implementation is important because expected benefits are the main reason for companies to implement CE. Researchers agree that expected economic and other benefits are seen to drive and push companies to implement CE activities (Sarja et al., 2021; Tura et al., 2019). Furthermore, understanding the benefits helps both in internal and external communication and argumentation of the company. As Kotler (2011) expressed, companies operating in the business market might not experience direct pressure from customers as in the consumer market. Therefore it can be that circular solution needs more argumentation even inside the company. Ranta et al. (2020) acknowledge this issue. The authors emphasize the importance of understanding how the CE oriented offer is better than a linear one because this allows the company to communicate and demonstrate these benefits to the stakeholders. Next, the differences between the benefits of linear and circular business will be discussed more closely.

2.3.2 Differences in benefits between a linear and circular economy

Benefits are different in circular business compared to linear one because in circular business benefits are created not only at the moment of sales of the product. Instead, value is recreated during the entire lifetime of the product. In this way, new benefits are enabled, and researchers highlight the need to better understand these benefits (Khan et al., 2020; Nußholz, 2018). Nußholz (2018) argues that circular business models need to be thought of in a new way in which they create and recreate value again and again along the lifecycle of the product. The author develops a framework for mapping all the value that a company delivers to a customer through the first sale, additional sales as well as material collection and recovery. According to her, each of these interventions presents opportunities for a company to map the new value created for the customer. Considering the company's benefits, it seems that each of these interventions is also a possibility for the company to benefit from creating value for the customer.

Different benefits of circular business compared to a linear one can be explained by the different value creation logic. New value opportunities from circular businesses have been studied by Ranta et al. (2020). In this multiple case study, the authors found out that whereas in a linear economy value is created commonly with cost savings or differentiation advantage, CE offers value possibilities by resurrecting, sharing, replacing, and optimizing value. In the study,

resurrect value was noticed to be present mostly in cases in which the company restored used products and returned them to the market. Sharing value is enabled by allowing the product to be used by many users. In the situation of replacing value, companies offer value by replacing the material with a more valuable alternative. Optimizing value was present in cases in which the firms put effort into enhancing and extending the usage of the product which allowed usage of fewer resources or prolonged value creation. Consequently, optimizing value seems like the most relevant way that benefits are gained and value is created in the case of LCE. Moreover, benefits could also be gained through resurrecting value if the company would choose to collect obsolete items and through processing be able to bring them to the market for a second time.

In addition to the new value creation opportunities and mechanisms, circular business allows one to identify and emphasize environmental value. Researchers studying the concept of CE have started to suggest environmental value as an absolute value of its own (Kristensen & Remmen; 2019; Manninen et al., 2018; Patala et al., 2016). I follow this position in this thesis, and any type of environmental benefit is regarded as a benefit to the company. Seeing environmental value as an absolute value is the opposite way of thinking than in a linear economy (Manninen et al., 2018). Consequently, reduced environmental impact can be seen as a benefit in circular business whereas it might not be the case in traditional, linear business.

2.3.3 Benefits indicated by previous studies

Researchers identify various benefits that a company can gain from implementing CE activities. In this chapter, the discussion covers the benefits that appear the most important. I have categorized these benefits from the existing literature, namely: economic, environmental, and social benefits, and risk reduction. Studies specifically about the benefits in the context of LCE are scarce, and for this reason, few studies had to be cited that have studied CE implementation at a general level. A summary of these benefits is presented in Table 2.

Economic benefits are the most significant benefit that companies expect from CE implementation. This was found both by Sarja et al. (2021) and Tura et al. (2019), and research also illustrates the potential of actually gaining these benefits. It appears that a significant part of the potential related to economic benefits is enabled by more efficient use of resources. Korhonen et al. (2018) explain that potential economic benefits can be gained because of reduced material costs as the material is used efficiently and many times. Moreover, optimized material usage diminishes value leaks and reduces costs from waste management. According to Sarja et al. (2021), using waste to manufacture new products can create new potential for revenue but also it can enable savings due to the reduced need for waste management.

These economic benefits could in principle be valid also in the specific context of LCE. Effective implementation of LCE should have the potential for reduced material costs because LCE allows longer utilization of materials and products. Also, waste costs could decrease if the end of life is avoided and

materials get a new use cycle. Some studies indicate the potential for cost reductions in the context of lifecycle extension. In the study of Kabboura et al. (2019), the authors found out quantitatively by the means of life cycle costing that extending the life of passive products led to cost reductions in each of the studied cases. Understandably, the researchers highlight that regardless of the found financial benefits, the costs do not necessarily reflect the total business implications and because of this, uncertainties exist.

Another generally acknowledged economic benefit of CE implementation is the potential to differentiate in the market and in this way gain a competitive advantage. De la Calle et al. (2021) describe the capital goods industry as an industry that is facing new challenges because of the more competitive market situation. More demanding markets push companies to find ways to differentiate and lifecycle extension can be one way to be better than the competitors. The potential of a prolonged lifetime to result in improved competitive advantage was also acknowledged by Nußholz (2018) who says that competitive advantage can be gained for instance by reduced lifecycle costs, increased efficiency, and reduced downtime. CE implementation is also seen to have the potential for improving a company's public image (Korhonen et al., 2018) and work as a way to differentiate and strengthen the company brand (Tura et al., 2019). Also, these aspects could translate into a competitive advantage in the long term.

As discussed earlier (2.1.1), CE activities in general and LCE should lead to reduced environmental impact. Environmental benefits could be gained from the reduced need for materials, reduced waste, and minimized energy consumption (Korhonen et al., 2018). A challenge regarding environmental benefits is, however, that it is often challenging to quantify and demonstrate the delivered environmental benefits (Patala et al., 2016).

On a wide scale, CE implementation should also enable social benefits. These include new employment opportunities, an increased sense of belonging, and sharing with other users (Korhonen et al., 2018). In the business context, a remarkable part of social benefits seems to be related to the customers, and a better relationship with customers is mentioned as the main expected benefit by Ellen MacArthur foundation (n.d.). According to a multiple case study by Tura et al. (2019), companies can experience customer interest and demand for CE. Therefore, CE implementation can help the company answer customer demands and deliver additional value. On the other hand, if the customers do not show interest, like in a part of the cases in Tura et al. (2019), customers might not understand the value that CE brings and consequently social benefits might not be gained. As Sarja et al. (2021) express, customers' attitude to CE initiatives is not certain for many companies, which also results in uncertain benefits in customer relations. This potential but uncertain benefit of improved customer relationship could also be possible in the case of LCE, as customers can appreciate the effort the company makes for extended product life.

Lastly, companies can benefit from reduced risks by applying CE. According to Sarja et al. (2021) and Gusmerotti et al. (2019), a part of companies see a continuation of business as usual and resource scarcity as future risks for their

businesses. Continuing business in a traditional way can create a risk of competitors gaining an advantage from applying CE. Additionally, limited resources are seen as a potential risk in the company's supply chain (Kalaitzi et al., 2018). The global demand for resources is seen to increase due to population growth and wealth which puts more pressure to the already finite resources. Applying CE through reuse, recycling and repairing can be ways to reduce this dependency on natural materials as well as guarantee to not be left behind in the competition. Consequently, also one potential benefit of lifecycle extension could be risk reduction.

Table 2. Summary of potential benefits from LCE with literature references.

Category	Emphasis areas	References
Economic benefits	• Reduced waste management costs • Reduced material costs • Competitive advantage	Korhonen et al., (2018), Nußholz (2018), Sarja et al., (2021), Tura et al., (2019)
Environmental benefits	• Reduced need for materials • Reduced waste • Reduced energy consumption	Korhonen et al., (2018), Matschewsky (2019), Oghazi & Mostaghel, (2018)
Social benefits	• Improved customer relationship	Ellen MacArthur foundation (2013), Sarja et al., (2021), Tura et al., (2019)
Risk reduction	• Risk of business as usual • Reduced dependency on virgin materials	Gusmerotti et al., (2019), Kalaitzi et al., (2018), Sarja et al., (2021)

3 DATA AND METHODOLOGY

In this section, the research methodology of this study is discussed. The first chapter (Chapter 3.1) aims to explain and justify the chosen research method and design. The second chapter (Chapter 3.2) introduces the case that is being studied including description of the case company and the environmental issues of capital equipment. The third chapter (Chapter 3.3) then intends to show the data collection process whereas the last and fourth chapter (Chapter 3.4) of this section describes the analysis process of the empirical data.

3.1 Research method and design

The purpose of this study is to explore circular economy driven lifecycle extension in the context of the capital goods industry. In addition to reviewing the relevant literature, the topic is explored with an empirical case study which also brings special characteristics to the research methodology. This study follows a research approach of an intensive case study which aims to gain an understanding of the unique case and provide an in-depth understanding of it (Harré, 1979; as cited in Eriksson and Kovalainen, 2008). Consequently, an intensive case study does not have targets for the generalization of the results (Eisenhardt, 1989). This differs from the other type of case study, namely an extensive case study, which aims to generalize theoretical constructs and does a comparison between multiple cases (Harré, 1979; as cited in Eriksson and Kovalainen, 2008). The rationale behind choosing an intensive case study approach was a clear choice because of the focus of this research on solving the unique situation of the case company.

The case study approach has received some critique from researchers. One of the topics of critique is the characteristic of intensive case studies not providing scientific generalization (Yin, 1994; as cited in Dubois & Gadde, 2002). However, it can also be argued that there is a rationale behind why an intensive case study does not strictly have to aim for generalizability. As Eriksson and Kovalainen

(2008) describe it, case studies have the ability to research complex issues and to make them accessible and understandable. This aligns also with Dubois and Gadde (2002), who see learning from a specific case as an opportunity to understand also the wider context. As the authors point out, a case study has raised its popularity widely in various disciplines which also can be seen to illustrate the potential of the approach.

Another criticism of case studies is their tendency of having overly shallow approach. Dubois and Gabbe (2002) acknowledge this challenge and refer to a study by Easton (1995) who proposed that case studies tend to rely too much on the reader's role to conclude from the pure descriptions of events made by case study researchers. As a third challenge, some case studies apply an approach that tries to test theories even if this does not work in the complex structures of case studies (Easton, 1995; as cited in Dubois & Gabbe, 2002). Among researchers, Dubois and Gabbe (2002) propose a stronger reliance on theory in case research as a way to address these challenges. By grounding the case study remarkably to the theory, the researcher can somewhat avoid the risk of endless descriptions (Weick, 1979; as cited in Dubois & Gabbe, 2002) while being able to improve the explanatory characteristics of the case results (Dubois & Gabbe, 2002).

All the challenges described can also be seen to highlight the importance of providing the reader with an adequate case description. According to Eisenhardt (1989), the researcher has to offer the reader all relevant information that allows the reader to evaluate the research approach, fit of the theory and the reliability of the results. The information to be provided includes a description of the relevant aspects of the case, data collection procedures, and analysis (Eisenhardt, 1989). This recommendation is followed in this study as the specificities of the case are discussed in Chapter 3.2.

Within the intensive case study approach, the methodological choice of this study was made between qualitative and quantitative research methods. I made the decision based on evaluations of Eriksson and Kovalainen (2008). The authors evaluate that qualitative approaches are commonly used in studies that aim to understand a certain phenomenon whereas quantitative research focuses on testing hypotheses and analysing the topic statistically. Based on these common characteristics, the qualitative method appeared as a better fit for the topic of this study. This study aims to gain a holistic understanding of the research topic while exploring new opportunities, and therefore qualitative approach allows studying the topic without the strict and standardised structure of the quantitative approach.

3.2 Introduction to the case

3.2.1 Introduction to the case company

The case company of this master thesis is a large-sized company that wishes to stay anonymous in this study. The company operates globally and is based in

Europe. The case company produces material handling equipment (illustrated in Figure 2.), which is commonly used in warehousing to allow the movement and storage of materials and products. The company manufactures most of the parts of the equipment, but some of the more specific components of the equipment such as motors are bought from the company's suppliers. Considering the lifetime of this equipment, the customer is generally able to use the equipment from 10 to 20 years depending on the applied maintenance activities.

Figure 2. Example of material handling equipment. Photograph from Intorqusa (n.d.).

Besides selling material handling equipment to new clients, an important part of the company's business is to provide services. Based on a manufacturing companies' service classification made by Mastrogiacomo et al. (2017), the service of the company reminds most closely the service type of *maintenance and support services*. Through this service, the case company aims to optimize and extend the lifecycle of the sold equipment. Consequently, when customers invest in the service projects, they are generally able to use the equipment for multiple years ahead. Enabling a longer lifetime is crucial for the customer because these service projects such as upgrades to the equipment are very expensive.

In addition to the maintenance and support service, the company provides its customers daily maintenance which includes general, everyday maintenance that keeps the equipment in a functioning condition. Compared to everyday maintenance, the maintenance and support service deals with more complex changes to the asset and has a multiyear perspective on the equipment. In practice, this service includes changes to the equipment in two situations: The first situation is that parts or components have come to the end of product life because the supply or support of these parts has ended from the side of a supplier. The second situation is that parts or components have come to the end of their technical lifetime, meaning that these parts cannot perform their original function, and therefore they are changed to bring the entire equipment back to its original condition.

Considering the purpose of this thesis to explore LCE, it is important to look at the maintenance and support service and how the activities within this service

could be improved. Therefore, the maintenance and support service provides the scope of analysis for this thesis in the context of the case company. By now, circularity or sustainability has not received attention in the organization of the service. Undoubtedly, the existence of this service is by principle beneficial for circularity and the environment, as this service results in the extended life of the equipment. However, crucial and relevant for this thesis is to analyse how CE is currently considered within the activities of this service. Moreover important is to examine how consideration of CE could be promoted within the service. When starting this thesis project, the assumption among the personnel was that this service causes waste and new material usage (e.g., in the case of unnecessary replacement of parts), which should be avoided.

3.2.2 Environmental issues of capital equipment

In addition to material handling equipment, the capital equipment industry includes a wide variety of products including industrial printers, solar panels, medical scanners, and cars. Common for these assets is their importance for the functioning of the society and their long lifespan. Previous studies (Haanstra et al., 2021; Milios et al., 2019) and reports (Circle Economy, 2019; Platform for Accelerating the Circular Economy [PACE], 2021) emphasize the high level of material consumption in capital equipment, and therefore virgin material consumption and waste generation seem to be the most important environmental impacts of material handling equipment and many other capital assets. Hence, these characteristics are next discussed more closely.

Capital equipment is commonly large-sized asset with a high material intensity that is caused by the significant consumption of different materials. According to a report from Circle Economy (2019), the yearly material footprint of capital equipment is 3.2 billion tons of emissions (6.5% of the total global footprint). This used material is mainly metals, from which a part is also scarce metal that the companies need for innovative technological applications. Consequently, the capital equipment industry uses half of all metal ores (Circle Economy, 2019). Material consumption is significant also in the specific context of material handling equipment. Apart from plastic conveyors, these often large constructions are mainly built from metals.

The high material intensity and long lifespan of capital equipment stress the importance of the efficient use of these materials. According to PACE (2021), it is especially important for capital equipment to make the lifetime of these assets even longer as well as to slow the degradation of these assets. Haanstra et al. (2021) support this and recommend value adding activities such as upgrading especially in the use phase of the equipment. According to the authors, also the long lifespan of capital equipment increases the importance of these activities. Lifecycle extension and using waste as a resource in the capital equipment industry have great potential to impact material resource savings and waste reduction within this industry (PACE, 2021). In the context of the case company, this stresses the importance of applying the LCE strategies discussed in Chapter 2.2.2. One specific characteristic of material handling equipment is, that the

equipment has a lot of wear and tear parts that need regular replacement and causes challenges to the avoidance of waste generation and material consumption.

3.3 Data collection

Generally, qualitative research evolves through the research process, and this characteristic is highlighted also in the case study research. Eriksson and Kovalainen (2008) explain that during the process new interesting questions might arise that the researcher wants to answer. Based on what the researcher sees as interesting and important, adjustments to the research can be made. This characteristic seems important as changes can allow the research to become more fruitful and innovative. Also, Eisenhardt (1989) emphasizes the possibility of changes during the research process. The author reminds us about the unique characteristics of the case which can cause new issues to arise and by considering these issues also the results can be improved.

In this research, interviews formed the main method for data collection. This is common in case studies, where interviews with open-ended questions are usually the main source of empirical data (Eriksson & Kovalainen, 2008). Various types of interview approaches exist, from which a semi-structured approach was chosen for this study. In addition to a semi-structured approach, I could have chosen a structured interview in which the interviewer has a fully planned script and no flexibility (Eriksson & Kovalainen, 2008). According to Eriksson and Kovalainen (2008) the semi-structured approach differs from a structured one by allowing the interviewer to make additional in-depth questions when needed. Because of these characteristics, I saw semi-structured interviews as the most suitable way to collect empirical data. The purpose of this study is to explore new possibilities, which highlights importance of explorative open ended questions. Semi-structured interviews fit for 'what' and 'how' questions (Eriksson & Kovalainen, 2008) which are suitable questions for this research to explore the experiences and thoughts of the interviewees.

In this study, I followed the recommendation of Eriksson and Kovalainen (2008) and Eisenhardt (1989) to use different data sources in a case study setting. Multiple empirical sources can be used because of stronger and more reliable results (Eisenhardt, 1989) and because of more guaranteed holistic knowledge about the issue (Eriksson & Kovalainen, 2008). Therefore, I decided to aim for interviews both inside and outside the case company. The case company is rather at the beginning of the journey towards circularity, and best practices have already been explored in other settings of the industry. For this reason, I concluded that it would be beneficial to have discussions outside of the company as well.

I started the data collection by interviewing the personnel of the case company. I conducted 10 interviews in February 2022, each interview lasting approximately 45 minutes. Interviewees for this study were chosen based on the

employees' familiarity with the company's lifecycle extension practices. Previous knowledge about sustainability or circular economy was not needed, as these topics were discussed in the interviews together. Furthermore, the selection of people with different roles was highlighted to get answers from different perspectives. Based on these criteria the interviewees consisted of engineers, sales consultants, and managers. All the interviews were arranged virtually via Teams due to COVID-19. In general, interviews are commonly organised face-to-face, but also interviews conducted with the help of computer technologies can be suitable (Eriksson & Kovalainen, 2008). Information about the interviewees is presented in Table 3.

Table 3. Description of the interviewees inside the case company.

No.	Interviewee	Duration of the interview (min)
1	Service sales consultant	41 min
2	Commercial manager	37 min
3	Quality manager	42 min
4	Systems engineer	63 min
5	Sales engineer	24 min
6	Systems engineer	48 min
7	Commercial manager	40 min
8	Innovation engineer	31 min
9	Service manager	46 min
10	Service manager	34 min

In addition to the interviews inside the case company, I managed to organize interviews with four people from different companies within the capital equipment industry. From now on I refer to these interviewees as external interviewees. Because of the inevitably different setting and practices in these companies, I decided that it was best to have a discussion with people who have sustainability matters directly related to their role. In this way, they would probably be able to discuss on a general level the company's approach and experiences on a circular economy driven lifecycle extension. Table 4 presents the description of the external interviewees.

Table 4. Description of the interviewees outside the case company.

No.	Interviewee	Company	Duration of the interview (min)
1	Circular economy consultant	Supplier of energy utilities	35 min
2	Global sustainability manager	Manufacturer of lightning equipment	45 min
3	Sustainability consultant	Manufacturer of electronic equipment	30 min
4	Re-use engineer	Manufacturer of special-purpose machinery	33 min

When forming the interview outline, I adopted the critical incident technique (CIT) in guidance for the questions. With this technique, the researcher studies significant occurrences such as events, incidents, or issues which are identified by the interviewee (Chell, 1998; as cited in Gremler, 2004). In CIT studies, data is typically collected via interviews, in which the interviewer discusses with the interviewee certain significant behaviour relevant to the study (Gremler, 2004). This technique is commonly used in service research, but as Gremler (2004) suggests, it can be useful also in other contexts. According to Chell (1998), the goal of CIT is to better understand the incident as it is perceived by the interviewee (as cited in Gremler, 2004). CIT is seen to have the benefits of reaching the personal experiences of the interviewee without restricting observations to any previously set variables (Walker & Truly, 1992; as cited in Gremler, 2004). The technique is seen as suitable for research that tries to explore a little-known or scarcely researched topic to create a better understanding of it (Gremler, 2004). Based on these characteristics this technique is to some extent applied also in this case study to better understand what type of experiences the interviewees have.

I formed the interview outline separately for the internal (presented in Appendix 1) and external interviews (presented in Appendix 2) because of the slightly different approaches in these interviews. When forming these outlines, I aimed to follow the advices from Eriksson and Kovalainen (2008) and Eisenhardt (1989). Following advice from Eriksson and Kovalainen (2008), I tried to form questions that help in answering the research questions. For this reason, the questions for internal interviewees covered CE implementation in general, LCE strategies as well as resource consumption, and potential benefits from LCE. Another advice I followed was to leave the questions simple and open-ended to make the interviewees feel of having control of the discussion and produce more detailed responses (Eriksson & Kovalainen, 2008).

Following Eisenhardt's advice (1989), I was prepared in making adjustments to the interview outline based on emerging thoughts and opportunities. I also ended up adjusting the interview questions based on the

insights and important points that arose in the so far held interviews. These changes were made only to the outline of the internal interviews within the case company while no changes were made to the interview outline of the external interviewees. The use of different versions of the interview outline is illustrated in Table 5, which shows that I did changes to the interview outline three times: after having the first, second, and seventh interview. The changes I made were usually related to crucial aspects that arose in the discussion about which I wanted to ask the upcoming interviewees more specific questions. An example of this type of change is question 11, which I added after the seventh interview. Based on the previous interviews I had noticed the importance of using the parts from a customer again, and I wanted to explore this possibility with the rest of the interviewees.

Table 5. Illustration of the development of the interview outline in the interviews for the personnel of the case company.

Version of the interview outline	Interviews
1	1st
2	2nd
3	3rd, 4th, 5th, 6th, 7th
4	8th, 9th, 10th

3.4 Data analysis

Qualitative empirical data can be analysed in various ways from which I chose conventional content analysis. In conventional content analysis, the researcher derives codes from the data based on significant aspects of the data, and in the end, these codes are divided into categories (Hsieh & Shannon, 2005). An important characteristic of conventional content analysis is that categories are usually not preconceived from the theory but instead, categories emerge from the data as a result of the researcher's interpretation (Kondracki & Wellman, 2002; as cited in Hsieh & Shannon, 2005). According to Eriksson and Kovalainen (2008), inductive oriented strategy in the analysis is commonly seen as good for case study analysis. The authors point out that even if inductive does not directly categorise the data according to a pre-given theoretical framework like deductive strategy would do, prior theory can also be used in inductive strategy. As Blumer (1969) explains, theoretical concepts can be used as a reference and in this way the data can be sensitized (as cited in Eriksson & Kovalainen, 2008). This characteristic is also highlighted in the context of case studies, as Eisenhardt (1989) says that an important part of the case study analysis is to constantly compare

the arising concepts and hypotheses from the collected data to the existing theory. This includes an analysis of similarities, contradictions, and reasoning behind it.

Additionally, Conventional content analysis is generally used when the research on the phenomenon is still lacking (Hsieh & Shannon, 2005), and both of these characteristics lead me to choose content analysis as my method. Research in LCE implementation is somewhat scarce in the capital goods industry which also makes it useful to be able to create your own categories. Moreover, research applying the CIT technique often applies this technique (Gremler, 2004).

I chose conventional content analysis over thematic analysis which are both common methods in qualitative analysis. These analytic methods are largely similar, but some indications of differences exist (Vaismoradi et al., 2013). Content analysis often focuses more on the micro level than thematic analysis (Wilkinson, 2000; as cited in Braun & Clarke, 2006). The main difference according to Vaismoradi et al. (2013) is that content analysis allows one to quantify the data according to the differences between the emerged categories (Vaismoradi et al., 2013) whereas quantification is generally not done in thematic analysis (Braun & Clarke, 2006). Additionally, the resulting themes of the thematic analysis are often abstract (Braun & Clarke, 2006; as cited in Vaismoradi et al., 2013) whereas content analysis allows one to form categories based on the aspects' frequency (Vaismoradi et al., 2013). This study is practically oriented which justifies the decision to use content analysis.

In the process of conventional content analysis, I followed advices from Tuomi and Sarajärvi (2018) and Hsieh and Shannon (2005). Tuomi and Sarajärvi (2018) divide the analysis process into three stages, namely: reduction, clustering, and abstraction. The analysis process of this study is illustrated in Figure 3, which shows with part of the original data how organizational factors were formed through reduction, clustering and abstraction.

Before actual reduction, important is to choose a unit for the analysis whether it is a word, thought or sentence (Tuomi & Sarajärvi, 2018). In the reduction of the data, irrelevant parts of the material are removed and relevant ones are marked with short codes (Tuomi & Sarajärvi, 2018). As Hsieh and Shannon (2005) express this phase, the researcher notes the arising impressions and thoughts which form the emerging initial codes. The authors describe codes as labels that reflect the key thoughts in the material. Reduction is followed by clustering, in which categories are formed from the codes by comparing the similarities and differences between the codes (Tuomi & Sarajärvi, 2018). Codes can be put into categories based on how they are linked and related to each other (Hsieh & Shannon, 2005).

In the last phase of abstraction, the relevant information for the research is separated from the rest of the material, and this information is then connected to related scientific conclusions and terms (Tuomi & Sarajärvi, 2018). This process of abstraction is continued for as long as different classifications are possible to be combined. Especially in this phase, I followed Eisenhardt's (1989) recommendation of constantly comparing the arising concepts and hypotheses

from the collected data to the theory. This included analysis of existing similarities and contradictions and the possible reasoning behind them. Last, as part of abstraction, I draw conclusions for the empirical study based on the previously organised categories.

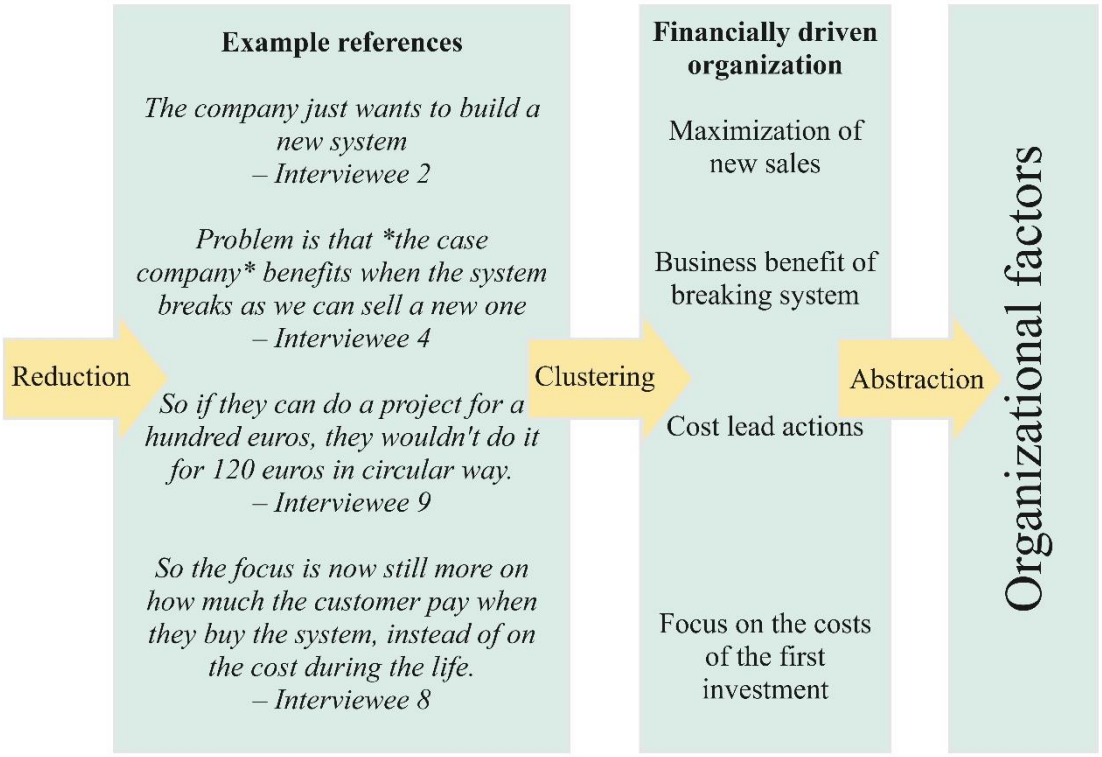

Figure 3. Illustration of the analysis process.

4 EMPIRICAL RESULTS

In this section, I present the findings from the previously described content analysis of the interview data. I start this section by discussing the interventions that the case company could make to promote circular economy driven lifecycle extension (Chapter 4.1). The two following chapters include the results of the first and second subordinate research questions. Consequently, the main factors in circular economy driven lifecycle extension and related challenges and opportunities are discussed (Chapter 4.2). This is followed by a discussion of the findings related to the expected benefits of the circular economy driven lifecycle extension (Chapter 4.3).

4.1 Interventions for lifecycle extension

A lot of the discussion in the interviews was about the different situations in which the case company could increase circularity in their maintenance and support service. Based on the interviews, the discussions about current practices and the improvement areas, these interventions are largely missing: 1) first sale, 2) collection, 3) processing, and 4) repurpose (Figure 4.). Hence, the interviewees highlighted their role in promoting CE. These interventions appeared in the interviews especially when asking the interviewees about the opportunities for LCE within the service. I will shortly describe each intervention and related current practices.

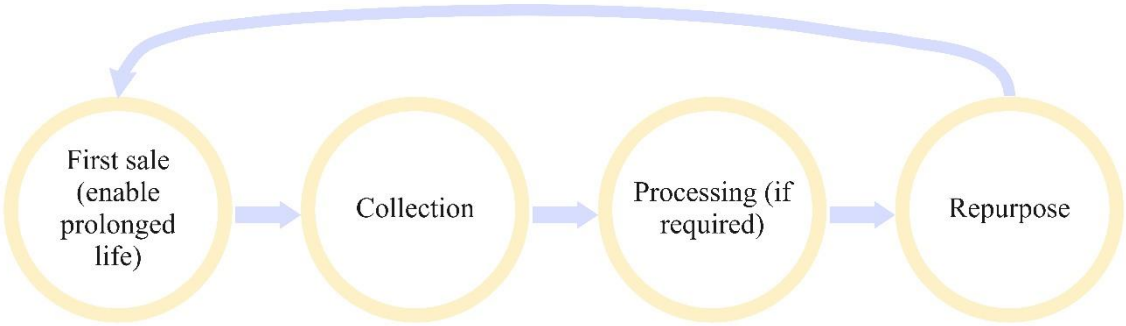

Figure 4. Interventions needed for LCE in the case company

Intervention 1: First sale

First, after selling the material handling equipment to the customer, the case company has the opportunity to enable prolonged life of the equipment through the service. From the four interventions, this is the only one in which the company is somewhat organized. The interviewees described how predictive maintenance is under development and how upgrades are made to the equipment to maintain it in a functioning condition. However, the interviewees seemed to largely agree, that the service activities could still be planned better from the CE point of view and in this way unnecessary replacements to the equipment could be avoided.

Many interviewees pointed out that the service activities include changing or upgrading all the same type of parts of the equipment even if some of them would still be in functioning condition. All parts are changed because the engineer has to be sent to the customer site to make these changes and therefore it is seen easier to do it all at once. Moreover, if all similar parts were not changed, the equipment would have different versions of the part in their equipment which is seen to cause difficulties in the upcoming maintenance activities. In addition, another interviewee told that scheduled changes to the equipment are made without actually evaluating the condition of these items, which is seen to cause changes to items that could still be in a good condition. Consequently, many of the interviewees stated that predictive maintenance should be increasingly implemented as part of the service.

In order to further promote the prolonged life in the first sale phase, the company could put more effort in the product characteristics and service strategy. These are closely discussed in chapters 4.3.1 and 4.3.2.

"I think what we can most easily do [to promote circularity] is instead of advising based on a theory or lifetime expectations, the option is to replace where necessary so that we don't unnecessarily throw parts away."
– *Interviewee 2*

Intervention 2: Collection

The parts of the equipment reach their end of life when these parts are replaced with new ones. This moment of replacement presents another important

opportunity for the company to enable circularity through a collection of the parts. Concerning this opportunity, almost all interviewees described the challenge of customers having ownership of the equipment: this inhibits the case company to have access to the equipment and the replaced items. One interviewee described, that only work equipment needed for the project as well as unnecessary items are returned to the case company. Therefore it is mainly up to the customer to choose what happens to the equipment and its parts when they reach the end of life. Most of the interviewees also highlighted the importance of arranging a return for these items. One interviewee pointed out that the case company never initiates to the customer that the materials could be collected, and another interviewee thought that customers could be interested in giving items back to the company.

*"…a lot [of the replaced items] are thrown away, not everything because some items come back for sure. And they go to the so-called reverse logistics location at *the case company*. This is done only to some customers, it is challenging because each project is different than the past ones. So not all the components are really the same."*
– *Interviewee 8*

The importance of collecting items was also noticed in the companies of the external interviewees. Two of the four interviewees stated, that their companies arrange evaluation of the condition of items at the place where the equipment is installed in order to optimize transportation. If the items are in a bad condition, they can be directly sent to a recycler without first transporting them to the company. Transportation was seen as a challenge by some of the internal interviewees, considering the costs and CO2 emissions.

"So, you need to be able to access a product in the end of life. Somehow in a normal, straightforward transaction, that doesn't happen because someone else owns the product."
– *Manufacturer of complex electronic products*

Intervention 3: Processing

Third, the interviewees describe the opportunity to extend the valuable life of the materials with different LCE strategies. Processing is naturally dependent on the collection practices. Now, if repairs, maintenance, or upgrades are made, the obsolete materials or parts are not processed. For instance, remanufacturing, refurbishing, or recycling are not implemented within the case company. Related to the possible processing, the interviewees bring out both the importance of collaborating with suppliers and recycling agencies. Suppliers produce some of the more complex parts of the equipment and more collaboration with suppliers could be initiated regarding the end of life practices for the items they supply. Few interviewees shared the same example regarding motors, which are bought from a supplier. Recently and because of the request from the motor supplier, the company sent some of the obsolete motors back to the supplier for repair. Again,

no initiative for this type of activity was made from the side of the case company. Furthermore, many interviewees described an opportunity to more extensively partner with a recycling agency and to send items that can not be remanufactured or refurbished to this agency to be processed.

To be considered here is also that not all items would necessarily require processing after they are being collected. Two interviewees saw an opportunity to use the items from scheduled changes as spare parts at the customer site. Even if the item might be outdated based on its operational hours, it could still be used as a spare part if it was inspected and noticed to be in a functioning condition.

"I think it's mainly about recycling of materials and refurbishing exchanged components, I think we can still win a lot there [with regards to circularity]."
– *Interviewee 1*

Intervention 4: Repurpose

Last, after collecting the items and processing the ones that cannot be reused in their current condition, the case company has the opportunity to give a new purpose for these items. At the moment, the company almost always uses virgin materials in their products and in the activities of the service. One interviewee saw an opportunity in reusing materials when making upgrades to the existing equipment whereas other interviewees thought that the case company could refurbish parts and put those into the stock for future replacements.

"It would for example be interesting if you could say [to the customer]: hey, everything we replace at the customer site, we take it home. We might repair it and make it available again for you or for the market with a cheaper price."
– *Interviewee 6*

4.2 Key factors influencing lifecycle extension

In this chapter, I will discuss the findings related to the first subordinate research question. Hence, I will discuss the most important factors, which based on the interviews crucially influence circular economy driven lifecycle extension in the case company. These factors will be discussed in the following order: 1) product characteristics, 2) service strategy, 3) stakeholder collaboration, and 4) organizational factors. For each factor, I will also show the most relevant seeming perceived challenges and opportunities. A summary of these factors, their challenges, and opportunities is presented in Table 6.

Something to note is, that each of these factors is a somewhat external factor that influences the possibilities that the engineers have for taking action within the maintenance and support service. When asking the interviewees about experienced challenges and opportunities in CE implementation within this service, they shortly moved on to describing issues such as management or service

strategy. This indicates that in the current form of the service, these experts see only minor possibilities for contributing to a CE. Therefore it seems, that first, these factors need reorganization before the engineers can make sustainable and circular decisions in their work.

4.2.1 Product characteristics

Even though the focus of this study is on the actions that can be taken considering the already existing equipment, the product characteristics received such unexpected attention in the interviews, that I decided to report related findings. Based on the interviews, the characteristics and features of the product affect largely how other activities for lifecycle extension can be implemented. However, product characteristics are discarded from the detailed discussion in the study as they are not part of the research scope of this thesis.

Interviewees' points aligned as they saw that circular design principles were not properly applied in the designing of the current equipment. Consequently, missing circular design principles together with manual work when reusing parts are the main challenges related to the product characteristics. One interviewee stated that designers should have the entire lifecycle in mind and another interviewee said similarly that CE needs careful consideration in the development of the product. Many of the interviewees identified compatibility, the product's ability to cope with different versions, as a challenge for implementing CE. One interviewee explained how the items of the equipment regularly get new versions and many customers can have different versions of the same item, and for that reason reusing parts in other customer sites becomes challenging. Also design for disassembly, that the equipment would be easily torn apart, was missing according to the interviewees. Moreover, it was seen as a challenge by two interviewees, that using a second-hand part in the existing system requires manual work from the engineers. These interviewees named two reasons for the challenge. Firstly, the systems of the company can only handle new parts and therefore second-hand parts need to be manually added to the system. Second, the company does not have the technology to track the refurbished or remanufactured items in the equipment which they would want to do to be aware of their performance and location. These characteristics together make the implementation of LCE difficult for the existing equipment.

Luckily, one of the interviewees pointed out the goal that the company has in designing the equipment. The company already is working on a more standardized design. Additionally, compatibility is under development, and therefore it should become easier in the coming years to reuse parts in different customer sites. Consequently, compatibility and standardization can be seen as opportunities related to the product characteristics.

"The challenge is that there always comes a new version of everything, even for the adapter. If you plan circularity for the current version, the new version is already on its way. And the challenge is that the current one is probably not designed in a circular way. On the other hand, there are now standardized versions for some parts."

– *Interviewee 2*

4.2.2 Service strategy

In a broader sense, the interviewees described aspects that can be seen to be related to the company's service strategy. These aspects included expectations of financial implications of LCE, but also thoughts about the ownership model, service communication, and service integration. Financial expectations and ownership model are seen to include both challenges and opportunities, whereas service communication and integration of services contain mainly opportunities for the case company.

Firstly, the interviewees agreed, that to promote LCE, the business case and business implications should be well planned. The interviewees saw this as especially important from the perspective of the company, whereas the interviewees themselves were mainly positive about the opportunities that CE offers. Either way, the interviewees generally thought that extra effort on circularity would result at least in a short term in higher costs (e.g., due to the high costs of recycling and purchasing special materials) and if remanufacturing or refurbishing was organized, also the pricing of these items should be thought again. Furthermore, thinking about the business strategy was highlighted by most of the external interviewees. They also highlighted the role of scalability when thinking of potential LCE activities.

The interviewees brought out the issue of ownership of the equipment, which was seen to hinder LCE implementation. As described in 2. Intervention, the customer owns the equipment which makes access to the equipment challenging for the company. The interviewees were consistent about this challenge and they brought out different ideas for how to work on solving it. Opportunities were seen in giving discounts to the customers who give the items back as well as in leasing the equipment to the customer. Both options were brought out both by the internal and external interviewees, and two of the four companies also had leasing as part of their offer. One external interviewee also proposed that implementation of CE and in this way also contribution to sustainability is more probable in a more service oriented business model.

Besides business case and ownership issues, many interviewees highlighted the role of the service communication to tell customers about sustainability. As one interviewee said, "this service is the bridge between *the case company* and the customer to discuss sustainability." Currently, communication of the service does not include sustainability matters, even if the service has a positive overall sustainability impact as the equipment can be in use for more years than without the service. By communicating about sustainability, the financial hesitations might partly be overcome because communication could have a positive impact on the sales. The role of sustainability communication was also highlighted by one external interviewee. She pointed out that her company always communicates to the customer about the processing and repurposing activities that are made to the items that the customer had returned.

Many interviewees brought out the possibility to integrate other activities of the case company into the service and in this way facilitate LCE implementation. The interviewees talked about the potential to integrate with this service daily maintenance activities, spare parts operations, as well as refurbishment and remanufacturing activities. The spare parts operations could be integrated with this service to enable a better optimized level of supply of spare parts. In overall, these integrations were seen to help the company in gaining a better understanding of the equipment and allow the company to give the customer a better overview of the coming maintenance and service costs.

"I think that the value of the service is that it is a place to make the customers think about how we can extend the life cycle of our equipment as much as possible. Also it is a place to make customer think that extending the lifecycle of the whole system with another two or three years is already a sustainability benefit. I think currently it [sustainability] is not at all included at the moment and the conversations that we have with our customers as part of the service."

– *Interviewee 6*

4.2.3 Stakeholder collaboration

In the interviews, the role of supplier and recycler collaboration was highlighted, and the interviewees' perspectives seemed to align in that collaboration with both of them should be improved. Missing collaboration can be seen as a challenge at the moment, whereas initiating collaboration with both suppliers and recyclers is an opportunity. Interestingly, customers as a stakeholder group did not draw a lot of attention from the interviewees, and the interviewees saw that customers are open to the change.

There is already some collaboration with the recycler, but at the moment if materials are recycled, they are just given to the recycler without thinking of the possible return flow or the economic value existing in the materials. After the interviews, I reached out to the department responsible for recycling, and they confirmed the missing common practice for recycling. As some interviewees pointed out, recyclers could work as well as suppliers of the company if recycled materials could be used to produce new items. Recycler agency could also share their knowledge on how to promote easily recyclable materials. The importance of recycler collaboration was also emphasized by the external interviews. Among the companies of external interviewees there appeared differences in the practices for recycler collaboration. One company collaborated with one international recycler agency worldwide, whereas another company had created a network of different recycling agencies to guarantee accessibility to a recycler globally.

Just like recycling, collaboration for processing of the items could be improved for the items that are bought from suppliers. Related to suppliers, the interviewees saw challenges in three areas. First, the company is missing general sustainability requirements for suppliers. Second, there is a practice missing from the suppliers' side to take items back for processing at their end of life. Last and third, challenges exist in the statements that suppliers make regarding the time

for which an item is being supported by a supplier. This statement indicates the length of the product's lifetime. Following this set time, engineers have to plan and implement upgrades to the equipment even though the items might still be in a functioning condition. For this issue, opportunities lie in negotiation and extended supplier support, for which the interviewees mentioned already some initiatives. As one external interviewee stated, collaboration with the suppliers is a necessity to scale the implementation of LCE.

"We buy a lot of equipment from others, for instance from Siemens, and then the situation is that you either have support or no support. We are pushed by statements from Windows which gives their products only a lifecycle of five years. Windows can only support their own operating system so we are really depending on those statements. But luckily we see a lot more extended support agreements."
– *Interviewee 3*

4.2.4 Organizational factors

When asking the interviewees about the changes that are needed to be able to implement CE in the service, many of the interviewees refer also to organizational factors that impact the implementation. These challenges include missing awareness for CE and highly financially driven organization, whereas opportunities were seen in better training and communication among the personnel. From these aspects, the themes that came up clearly the most in the interviews were missing culture for CE and financially driven organization.

Firstly, most of the interviewees expressed in their talk that the company is very financially driven. For instance, many interviewees thought that the current biggest drivers of the service is to make money and to sell with the biggest profits possible. Based on the descriptions of the interviewees, these drivers do not leave space for addressing CE. This conception seemed to be rather discouraging for the interviewees. Some of the interviewees thought, that in the case of CE implementation, the company should be able to look at the bigger picture and not only the financial part. It was seen that certainly LCE would not create profits in the short term, but the organization should assess how CE reflects their values which are also important but not measurable the same way as profits are. This perspective differed in the companies of external interviewees, where two companies had for instance been able to implement recycling even if it was not so far profitable practice. Instead, according to the external interviewees it had the potential to become profitable in the coming years.

Moreover, there seemed to be a consensus among the interviewees, that promoting circular or sustainable behavior among the personnel was insufficient. According to the interviewees, targets and performance measurement should be established according to circularity instead of only focusing on financial performance. Especially the role of financial incentives for sales people was highlighted as the only incentive that the sales personnel has at the moment is to maximize the sales of the service projects.

Considering the organizational culture, the interviewees themselves stated that there is lacking awareness for CE. Also LCE activities such as reusing and remanufacturing were not seen as normal activity. I was curious to ask the external interviewees about the drivers they experience for CE implementation, and one answered that it is strongly embedded to their organizational culture. The interviewee gave examples about sustainability weeks and CEO sustainability talks which make also the personnel engaged in the topic. According to the internal interviewees, this type of culture is still somewhat missing in the case company.

*"Currently *the case company* is very financially driven. So if they can do a project for a hundred euros, they wouldn't do it for 120 euros in circular way. Unless the management said to do so, but that's not the case. It's not that we have goal settings or our targets from the management to do things in a circular way, you know? So that's the biggest problem."*

– *Interviewee 9*

Table 6. Summary of the factors and their challenges and opportunities.

Factor	Challenges	Opportunities
Product characteristics	• Missing design for disassembly, part standardisation and modularity • Manual work when using a processed item again in a system	• Standardization • Compatability under development
Service strategy	• Costs of CE actions • Pricing of processed items • Equipment ownership at the customer	• Sustainability communication as part of the service process • Business case for circularity • Integration of daily maintenance, remanufacturing, refurbishing and spare parts operations into the service
Stakeholder collaboration	• Missing organisation of collaboration with suppliers for long lasting products as well as for processing and repurposing of these product in the end of life • Lacking collaboration with recyclers	• Collaboration with supplier for long lasting products, processing and repurposing • Network with recyclers; recycler as a supplier
Organizational factors	• Missing incentives for CE • Missing awareness for CE • Financially driven organization	• Training for CE • Internal communication about CE • Integration of sustainability into the service targets

4.3 Expected benefits from lifecycle extension

This chapter introduces the research findings related to the second subordinate research question, which was about the expected benefits that the case company could gain by addressing circular economy driven lifecycle extension. In most cases, the interviewees saw it beneficial for the company to put extra effort on LCE, some interviewees were just a bit more hesitant than the others. Circular economy driven lifecycle extension was seen to benefit the company potentially in many ways: 1) value creation for customers, 2) risk reduction, 3) sustainability, 4) green image, 5) competitive advantage, 6) increased sales, 7) reduced costs, and 8) increased profits. Figure 5 illustrates the rough dependencies and the order between the expected benefits.

Firstly, almost everyone mentioned that addressing LCE would create value to the customers. LCE is seen as an opportunity to offer better service and to answer to the customers increasing sustainability demands. This benefit was also acknowledged among the external interviewees, as one external interviewee said that CE and LCE are good ways to stay close to the customer and to understand their needs regarding circularity. Because of the high attention it received, value creation for customers appear as the most important benefit. Another benefit that was seen self-evident among the interviewees was risk reduction considering both the supply chain issues and the risk of being left behind in the global trend towards sustainability. As these interviews were conducted just before the war started in Ukraine, supply chain issues has probably become even bigger risk after the interviews. In addition to the reduction of supply risks, many interviewees saw the chance for customer requirements for sustainability to raise significantly in the coming years. This trend could cause a loss of sales if the case company wouldn't shortly start to take action towards CE and LCE. Additionally, benefits were seen in improved sustainability of the company because of the improved, efficient material usage and waste reduction.

"Basically, if we are not to become circular, then we will lose more projects in the future."

– *Interviewee 1*

Expected benefits in the long term were also seen in gaining of green image and competitive advantage. These benefits seemed more uncertain and partly dependent on the realization of the previously mentioned benefits. Competitive advantage could be gained as LCE works as a way for business development, enables knowledge creation and distinguishing from the competitors. As one interviewee described it, the company needs to find a unique selling point for circularity. Also potential for financial benefits came up in the interviews. Some interviewees identified a possibility for increased sales as a result of improved image. Another financial benefit mentioned among the interviewees was cost reduction. This was mentioned, because of a recent project on remanufacturing, which had shown that remanufacturing is cheaper compared to manufacturing

from virgin materials. Last, if LCE is applied effectively, it could result in bigger profits due to the decreased costs.

"So indirectly, it's [circularity] going to bring us some money."
– *Interviewee 9*

Overall, the interviewees pointed out both the dependency between the benefits as well as the long term perspective that is required when thinking about the realization of the benefits. As it was described in Chapter 4.2.4 regarding organizational factors, the company seems to evaluate CE implementation purely from the financial perspective, whereas the interviewees were able to emphasize and identify also other than direct financial benefits.

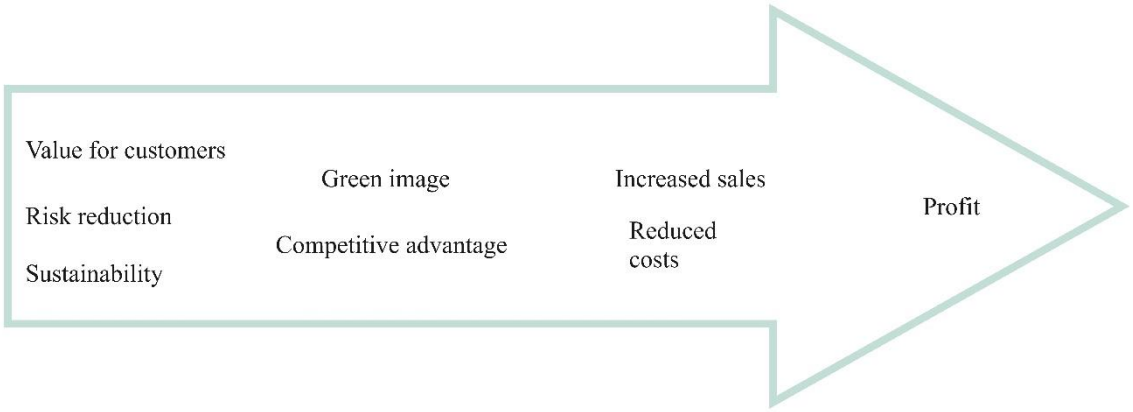

Figure 5. Illustration of the expected benefits from circular economy driven lifecycle extension.

5 DISCUSSION

In this section, the results of this study will be discussed from the perspectives of the theoretical framework and the research questions. Firstly, I will start with general reflection regarding challenges and opportunities for implementing LCE (Chapter 5.1). Afterwards, I will discuss the main factors highlighted in this study in relation to the theory, and based on the reflection, recommendations for actions are given. Consequently, the second chapter (5.2) discusses the findings related to the benefits from addressing LCE, and based on these findings and the literature framework the recommended actions for rethinking value and benefits are described. A similar order continues in the following chapters, where the findings and actions related to the service strategy (Chapter 5.3), stakeholder collaboration (5.4), and organizational factors (Chapter 5.5) are discussed. A summary of the recommended actions is presented in Table 7.

5.1 Challenges and opportunities for lifecycle extension

The findings of this thesis suggest that there are four main interventions to the product lifecycle, through which the case company could promote LCE as part of the maintenance and support service. The interviewees described how the replacements to the equipment could be better optimized, and how waste is created because of the missing collection and processing practices. Moreover, the missed potential of repurposing obsolete items was described by the interviewees. These points highlight the importance of the interventions, namely 1) first sale, 2) collection, 3) processing, and 4) repurposing. These findings align with previous research about CE implementation. Kalmykova et al. (2018) described similar activities of optimizing consumption, collection and disposal as well as recycling and remanufacturing available in companies' value chains. Moreover they support the interventions that Nußholz (2018) described as opportunities for companies to embed circularity in the product lifecycle.

On a high level, the interviews showed, that implementation of these interventions is seen challenging for various reasons within the company. On one hand, the interviewees were hesitant about the environmental benefits of LCE implementation, as transportation and processing could actually worsen the environmental impact. On the other hand, CE implementation was clearly seen as challenging within the current organization of activities within the company. The current way of organizing the operations do not provide effective ways to embed circularity, and the company does not seem willing to change the practices. These perceived challenges support the suggestions of other researchers (Bjørnbet et al., 2021; Fontana et al., 2021; Ingemarsdotter et al., 2021) on that CE implementation is still challenging in companies due to the multitude of approaches and unsaturated research.

It seems that the challenges in implementation can be partly explained by the fact that the case company attempts to implement CE as part of the current business model. Like many other manufacturing companies (Gusmerotti et al., 2019), the case company also tries to find a way to embed circularity into its current business model. This aligns with the observation from Kabboura et al. (2019), who point out that companies are in need of easy ways of implementing CE, without having to make major changes in the company's resources and structures. The challenge seem to lie in the situation that the company wants to change as little as possible whereas researchers (Nußholz, 2017) suggest that implementing CE often requires large changes both in and outside the company. Also the results of this study supports the idea, that rather extensive changes to the operations are needed in order to facilitate LCE.

Many studies seem to focus on the specific LCE strategies and their practical implementation. However, these studies fail to shed light on the issues around these strategies which strongly influence whether these strategies can or will be implemented in businesses. Therefore the main value of this research is to bring attention to the issues that can either challenge or provide opportunities for LCE implementation in capital equipment companies. The findings suggest, that in order to promote LCE, the case company should first look at factors outside of the service. The interviewees were consistent in their description that at the current form of the service, LCE is challenging if not impossible. This is shown by the interviewees aligning descriptions related to product characteristics, service strategy, stakeholder collaboration and organizational factors, which together hinder LCE implementation. These factors with their identified challenges and opportunities serve to answer the first subordinate research question.

From the identified factors in this study, both service strategy and stakeholder collaboration mainly support the previous research findings, whereas organizational factors were not present in the literature. Considering the service strategy, only the opportunities regarding sustainability communication and integration of CE activities were not present in the literature. Looking at the stakeholder collaboration, the importance of collaboration with recycling agencies was not highlighted in the literature. Still, the most interesting findings

are the level of importance that organizational factors including management for CE received in this study. Hence, this study brings new perspective to the already existing research by shedding the light on organizational factors as an important enabler for LCE. More detailed discussion about each factor and their differences to the existing literature is provided in the following chapters.

Besides the emphasis on the organizational factors and recycler collaboration, this study differs from previous research as it does not highlight customers as an important stakeholder group. For implementing CE and LCE, the role of customers is highlighted by many researchers (Kotler et al., 2011; Salvador et al., 2021; Vermunt et al., 2019) whereas the findings of this study does not propose customers as an important factor for LCE implementation. The interviewees barely mentioned customers, which indicates that customers are probably neither pushing nor stopping the change towards LCE. Also, rebound issue was not seen as a challenge the same way as the researchers (e.g., Kabboura et al., 2019; Korhonen et al., 2018; Nußholz, 2017; Whalen, 2019) saw it, instead the company saw the possibility of increased sales as an opportunity. This can very likely be explained by the different aims of researchers and companies. Researchers understandably highlight the environmental impact whereas companies care the most about the financial implications of LCE.

5.2 Rethinking value and benefits

The findings of this research suggest that expected benefits from circular economy driven lifecycle extension include 1) value for customers, 2) risk reduction, 3) sustainability, 4) green image, 5) competitive advantage, 6) increased sales, 7) reduced costs, and 8) increased profits. These benefits serve to answer the second subordinate research question. The findings suggest that part of these benefits, namely customer value creation, risk reduction, and sustainability, might be prerequisites for the realization of a greener image and competitive advantage. If LCE is effectively implemented, also sales and costs could grow which might result in increased profits. However, one has to address that these benefits were seen to develop in the long term, and financial benefits might take many years to be reached.

The expected benefits identified based on the interviews were present also in the literature. Previous research indicates environmental benefits (Matschewsky, 2019; Oghazi & Mostaghel, 2018), customer relation improvement (Ellen MacArthur Foundation, n.d.) as well as risk reduction (Gusmerotti et al., 2019; Kalaitzi et al., 2018; Sarja et al., 2021) as potential benefits from CE implementation. Also, the identified financial benefits are recognized in the literature. Researchers (e.g., Korhonen et al., 2018; Nußholz 2018; Tura et al., 2019) point out the potential for reduced waste management and material costs from applying CE. Also, competitive advantage (Nußholz, 2018) and a greener image (Korhonen et al., 2018; Tura et al., 2019) are proposed in previous studies. Additionally, increased sales are identified in the literature but rather as a

downside due to the increased consumption and negative environmental impact. Due to these similarities with previous research findings on benefits, the findings from this study did not provide unexpected results as such. However, compared to the research in this field, these results shed light on the perceived interdependency between the benefits. Among the interviewees, value creation for the customer was seen as a key enabler to reaching the financial and image related benefits. Based on these findings, it seems that the practice of overly emphasizing financial benefits in companies might reduce the ability to address value creation for customers. Value creation seems crucial for the realization of the other benefits, but if a company looks only at the financial implications, they might not implement LCE in the first place.

Consequently, in order to realise these benefits, it would be important for the case company to understand the value that LCE delivers to the customer. Remarkable financial benefits, which are the most crucial benefits for the case company, might only be created if the company can demonstrate the value to the customer, improve the company image, and advance sales. Together with implementing the interventions, the company could think about how their improved offer creates value for the customer and how it is consequently beneficial also for the company. Previous research highlights the importance of understanding the value creation logic in the middle of life of capital equipment (Khan et al., 2020). Following the proposal by Nußholz (2018), the company could analyse these benefits separately for each intervention. Besides understanding the value creation principles, previous research shows that it is important to analyse how a circular offer is better than a linear offer (Ranta et al., 2020). Compared to a linear offer, a circular offer tends to create new value in the additional use phases of the product (Nußholz, 2018). Moreover, following the researchers' (Kristensen & Remmen, 2019; Manninen et al., 2018; Patala et al., 2016) suggestion, environmental benefits could be seen as a value of their own for customers. This would also change the current perspective of the case company where it seems that the decision to implement CE is made purely from the perspective of how financially feasible it is.

5.3 Promoting service development

The findings of this research indicate that service strategy related issues inhibit LCE implementation in the case company. Based on the findings, it seems that challenges include the interviewees' hesitations about the negative financial impact of CE activities as well as the current ownership model where the customer owns the equipment. Both of these challenges are recognized also in the previous research. Therefore these were expected results. Both Khan et al. (2020) and Kabboura et al. (2019) discussed the issue of financial hesitations and proposed changes to the ownership model as a way to guarantee the money flow. These struggles that the case company and other companies face are very understandable considering the long tradition of selling a product to the

customer. So far companies have benefitted remarkably when their product breaks, and lengthening the product life can be seen as purposively harming one's own business.

Besides these challenges, opportunities related to the service strategy seem to include sustainability communication, finding a business case, and integration of the service with the company's other CE related operations. From these opportunities, the importance of the business case is acknowledged in the literature as it is known that the main reason for companies to implement CE is the expectations of financial benefits (Sarja et al., 2021; Tura et al., 2019). However, integration of LCE activities and sustainability communication were not present in the literature. Therefore, they were not expected findings as such. The findings regarding sustainability communication illustrate the fact that companies might have some sustainable practices which are not even connected to the value creation for customers. As the importance of sustainability is rising in the business market, these companies can find new value in their regular activities. Based on these findings related to the service strategy, actions in the case company could be taken in the areas of service scope, communication, and servitization.

Firstly, LCE could be promoted within the case company by rethinking the scope of the maintenance and support service. As many approaches can allow synergies (Bocken et al., 2016; Matschewsky, 2019) and implementation of CE in the business as a whole (Nußholz, 2017) can help the company, it might be beneficial to embed the company's all LCE related activities within the service. Firstly, the previously discussed interventions could be included in the scope of the service. The interviewees already pointed out the possibility to bring remanufacturing and refurbishing as part of the maintenance and support services. Likewise, the company could consider embedding the daily maintenance and spare parts operations as part of this service. This would not only make implementation of LCE easier, but it would also work as a response to the increasingly competitive market situation in the industry (de la Calle et al., 2021). Within the capital equipment industry manufacturers themselves also highlight the increasing importance of service development (Adrodegari et al., 2018). Integration of CE activities could also help in realizing the potential of LCE to reduce lifecycle costs, increase efficiency and in this way create a competitive advantage. By taking this step forward with the service, the operations for CE activities could become more straightforward which would also help in enabling financial benefits.

Second, the interviewees brought out the issue of lacking sustainability communication as part of the service communication with customers. Broadly speaking, the existence of this service is already beneficial for the environment: focusing on the first sale phase of the interventions extends the life of the existing equipment. This impact on CE could already be communicated to the customer. These communicated benefits could include for instance reduced downtime, increased efficiency, and potentially reduced energy consumption as well as

waste minimization. Communication about sustainability benefits as well as other benefits would be crucial to enhance value creation for the customer.

Third, the company could promote LCE by selling a service instead of selling ownership. These types of product service systems such as leasing would be a way to minimize the risks of financial issues (Khan et al., 2020). Financial risks might reduce in product services systems because money is not lost when revenue is not dependent on the sold products (Kabboura et al., 2019). Leasing could also reduce the risk of being left behind in the global development within the industry. Moreover, the development of the service offer is essential because capital equipment companies are noticed to be behind in the service development compared to other industries (Adrodegari et al., 2018). Researchers seem to increasingly study LCE in the context of product service systems (e.g., Chou et al., 2015; Kjaer et al., 2019; Matschewsky, 2019; Yang & Evans, 2019) and these systems are proposed to be an emerging direction for manufacturing companies (de la Calle et al., 2021). This was confirmed with a questionnaire among European capital goods manufacturers (Adrodegari et al., 2018). The idea of leasing was brought out both in internal interviews within the case company as well as in the interviews with external interviewees. Two of the four companies interviewed externally had already implemented product service systems. Even if the sales volume of these leased products was only a minority of the entire volume, their existence allows the development of leasing in the coming years. De La Calle et al. (2021) highlight that moving toward services requires strong collaboration in the supply chain, and consequently this recommendation is linked to the next action recommendation.

5.4 Initiating supplier and recycler collaboration

The research findings suggest that collaboration with suppliers and recyclers would be relevant but largely missing practices in the case company. Based on the interviews, it is a challenge to set up a collaboration. Opportunities are seen in creating a network with recyclers and collaborating with suppliers.

It is rather surprising how much recycler collaboration received attention in the interviews. The role of recycler collaboration has received only little attention in the literature. Following the categorization of LCE strategies, recycling should be a choice only if the other LCE strategies are not applicable (Linton & Jayaraman, 2005; Fontana et al., 2021). Because of the high emphasis on recycler collaboration both in external and internal interviews, it is still one of the recommended actions of this thesis to explore possibilities to scale collaboration with recycling agencies. Recycling might still be a relevant option in some cases for the case company because the equipment has many wear and tear parts that are not economically valuable but they break relatively often. Recycling activities could include evaluation of the condition of items at the customer site, after which obsolete items would be brought to the recycling partner. The external interviews indicate, that there are a few options for practically organizing

recycling. One company had created a network with many researchers worldwide, whereas the other company collaborates with one agency that operates worldwide. Also, the case company might benefit from thinking about which approach is more suitable considering the current business environment and product characteristics.

Both internal and external interviewees as well as researchers acknowledge that to promote circularity, one needs to have collaboration across the value chain. This is because circularity requires the material flows to move between the actors of the value chain (Sarja et al., 2021). Supply chain challenges were strongly identified as potential issues also in previous studies. Vermunt et al. (2019) identified many issues related to suppliers in the context of circular business. The authors identified issues related to the supply of disregarded materials and the uncertainty of the quality of these materials. Similar issues were not found in the findings of this study, which can be explained by the fact that the material sourcing of disregarded materials is not an activity at the moment in the case company. According to the internal interviewees, collaboration with suppliers for LCE exist currently only in the first sale phase. Therefore the company might especially benefit from thriving towards collaboration in processing and repurposing of parts supplied by suppliers. In practice, this could mean remanufacturing and refurbishing practices. In addition to these activities at the end of life, the case company could promote LCE by negotiating with suppliers for longer support statements as well as creating supplier criteria that would emphasize the role of long lifetime.

5.5 Ensuring management for circular economy

The research findings propose organizational factors within the company as an important factor influencing circular economy driven lifecycle extension. Organizational factors were not present in the literature, and therefore these findings are rather surprising. Based on the interviews, challenges exist in missing awareness for CE implementation among the employees. Also, supportive culture for CE was seen to be missing, as the company seems to be highly profit-driven. The belief among most of the interviewees was that the entire service is organized to guarantee profits instead of prioritizing the activities that maintain the system in a functioning condition. Following these challenges, opportunities are in training the employees for CE, integrating sustainability incentives, and advancing internal communication for CE. These findings raise an interesting point regarding the need to balance prioritization of costs and values in companies. On one hand, it is understandable for a private organization to be driven by profits but at the same time, the company should be able to take action that supports its values. Values in this case drive the company towards CE implementation whereas the focus on profits inhibits CE implementation by influencing the organizational culture and setting incentives.

Based on the findings of this research, the case company might benefit from working on managerial support. Whereas the organizational culture can take years to change, managerial actions could be relatively easily taken and they would probably have a clear impact as well. As Lahti et al. (2018) discuss, managers in linear business are used to planning and predicting coming actions based on historical data, but in circular business, managers might struggle when data is not available. Instead, these managers should think of value creation from a wider perspective and acknowledge issues such as resource scarcity and energy usage. Therefore, the case company could take action in the top management's commitment. In this relation, one practical action to illustrate the commitment would be to add sustainability and circularity to the targets of the sales managers. Interestingly, the interviewees, these sales engineers who together with sales managers sell the services to the customers, seemed well aware of the concept of CE. Additionally, based on their role these engineers are very qualified in understanding the equipment and its functioning. Hence, it seems that the one missing aspect to enable action for CE would be to allow the engineers to take action in their daily work. Getting management commitment relates to the first given recommendation about rethinking value and benefits (Chapter 5.2) because identification of benefits is crucial for making the management motivated for CE.

Table 7. Summary of the recommended actions to promote circular economy driven lifecycle extension within the case company.

Factor	Recommended actions
Value and benefits	• Analysing how circular offer is better than a linear one • Examining the value that is created for the customer separately for each lifecycle, and consider how this value translates to the benefits of the company in the long term • Acknowledging environmental benefits as an absolute value
Service development	• Integration of daily maintenance, remanufacturing, refurbishing and spare parts operations • Including sustainability aspects to the communication within the maintenance and support service • Planning and establishing leasing as an alternative offer along the conventional selling of the equipment
Supplier and recycler collaboration	• Initiating collaboration with suppliers for processing and repurposing of items, but also for sourcing criteria for support times • Establishing collaboration with recycler(s) worldwide
CE management	• Ensuring management commitment for circular economy driven lifecycle extension • Embedding CE aspects into the targets of sales managers.

6 CONCLUSION

The final section of this thesis consists of two chapters in which the current study is being evaluated. In the first chapter, the objectives and the key findings of the study are discussed in relation to the current knowledge in the field. The second chapter then discusses the limitations and proposes future directions for research in this field of study.

6.1 Key takeaways from the thesis

The objective of this study was to explore circular economy driven lifecycle extension in the capital equipment industry. In order to facilitate LCE implementation, the topic was examined through perceived challenges and opportunities. Furthermore, expected benefits from addressing LCE were studied to gain a better understanding of the potential business implications. This topic was approached by both reviewing the relevant literature and by the means of empirical study. The empirical study was conducted with a qualitative case study of the material handling equipment manufacturer. These results contribute to achieving a better understanding of how LCE can be promoted among capital equipment companies. Regardless of the single case study approach, also other companies within this industry might face similar issues and therefore the results can facilitate LCE implementation also in other companies.

The research findings propose that four main factors influence LCE implementation within the case company. Considering the scope of this thesis which excluded product characteristics, the most important factors are service strategy, stakeholder collaboration, and organizational factors. Related to service strategy, challenges appeared in the costs and pricing of CE products, as well as in the ownership model of the equipment. Opportunities for service strategy seemed to lie in finding a business case, improving sustainability communication, and integrating LCE activities. For the factor of stakeholder collaboration, challenges were seen in the missing organization in collaboration both with

recyclers and suppliers. On the other hand, opportunities appeared in creating a network with suppliers and collaborating with suppliers for a longer-lasting product but also processing and repurposing. In organizational factors, the main challenges were suggested to relate to missing incentives, awareness, and culture, whereas the main opportunities were seen in increased training and integration of sustainability into the targets of the service.

Considering these perceived challenges and opportunities, the key findings of this thesis relate to the emphasis on organizational factors in this study. Other studies in the field of LCE implementation seem to disregard the role of management and culture in promoting LCE. Hence, this study brings a new perspective to the already existing research by proposing organizational factors as an important enabler for LCE. Furthermore, another interesting finding of this study is the high attention that collaboration with recycling agencies received compared to the existing studies in this field. Even though recycling is the least favorable LCE strategy, this study proposes that recycling should still be enabled for situations when other strategies are not applicable.

Besides the challenges and opportunities, this study also attempted to examine the benefits, that a company could gain by addressing LCE. The findings of this research support previous research and indicate that the most probable benefits are value creation for customers, risk reduction, and positive sustainable impact. Additionally, in the case company expected benefits also included gaining a green image, competitive advantage as well as financial benefits through increased sales and reduced costs. However, differing from the existing research in this field, the findings of this study highlight the interdependency between the benefits. For instance, increased sales seem probable only if the customers see value in the LCE of the equipment. Similarly, the findings propose that a prerequisite for these benefits is the actions recommended in this study.

Considering the debate on whether CE implementation requires large organizational changes, the findings of this study align with the proposal that company-wide changes are needed to implement CE. Based on the empirical study and the existing literature, it can be recommended for the case company to take action to rethink value and benefits, promote service development, initiate supplier and recycler collaboration as well as ensure management commitment. The research findings suggest that taking action in these areas would help in promoting LCE. Moreover, the findings acknowledge the pressure of industry transformation and mega-trend toward service oriented business models. The case company together with other capital equipment companies are in the need of rethinking revenue streams and value creation when the industry moves towards circularity and service oriented business. Following these trends, the most significant actions for the companies to promote LCE within this industry are perhaps rethinking value and developing the service concept.

6.2 Limitations and future research

Although this study proposes ways how circular economy driven lifecycle extension can be promoted, the findings also contain limitations. Because of the single case study approach, the findings are not fully generalizable to other contexts. The findings can indicate the conditions also in other companies within the capital equipment industry, but still differences among these companies are probable. Another relevant limitation is the inability of this study to draw causal conclusions. This is caused because of the qualitative method, which is not capable of showing the relations between the studied variables. Moreover, the scope of this thesis causes limitations. Design for LCE was not included in this study, even if designing undeniably plays a vital role in the extension of product lifetimes. A large part of the studies on LCE considers already designing which led me to solely focus on other issues. Additionally, I focused purely on the environmental part of CE, even if researchers seem to increasingly point out the importance of including also social equity and economic prosperity in the research scope. I chose to narrow down the thesis scope in this way to promote the clarity and straightforwardness of this study.

Considering future research, studying circular economy driven lifecycle extension in the capital equipment industry still presents various promising research topics. Following the limitation of generalizability of the study's findings, one would suggest having a similar study with a richer sample. Studying circular economy driven lifecycle extension with a multiple case study approach would help in better understanding the challenges and opportunities the companies experience within this industry. Fruitful companies to study could include traditional companies in the starting point of LCE and circularity transition. These companies are especially in the need of straightforward ways to promote CE implementation.

Moreover, one promising direction could be to further explore implementation of service oriented business models such as product service systems, and their barriers and drivers in the capital equipment industry. Following the megatrends of servitization and sustainability, product service systems present an opportunity for capital equipment companies to promote LCE while guaranteeing the money flow to the company. Capital equipment companies lack behind in service development, and meanwhile, hesitations about reduced sales can weaken the companies' interest to implement LCE. For this reason, studying the barriers and drivers within this industry would help businesses to overcome challenges and take the step towards these business models.

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APPENDICES

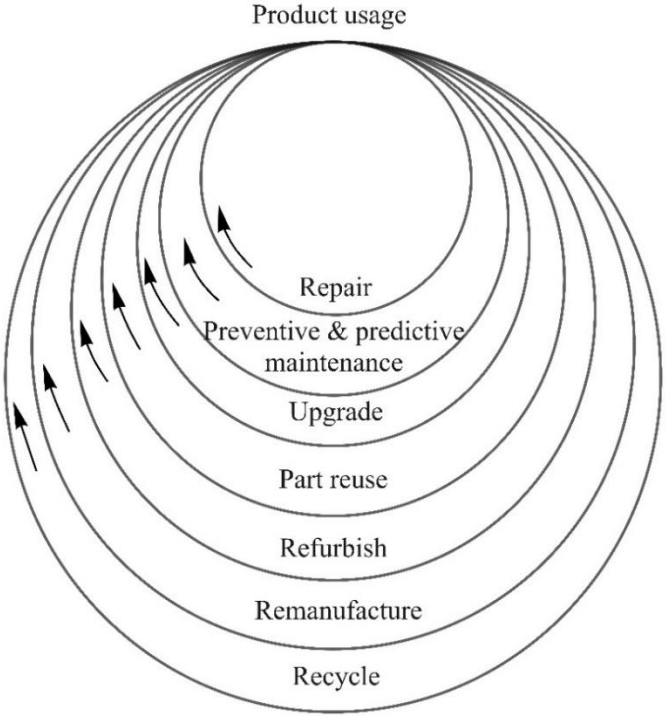
APPENDIX 1: INTERVIEW FRAME FOR THE PERSONNEL OF THE CASE COMPANY

Introduction and circular economy in general

1. Could you briefly explain your role at *the case company*?
2. What does circular economy mean to you?
3. How do you see that circular economy is related to *the maintenance and support service*?
4. How do you see that circular economy is currently considered in the activities within *the maintenance and support service*?
5. What kind of challenges or problems do you see or have you experienced when applying circular economy in the activities within *the maintenance and support service*?

Lifecycle extension strategies

(First short explanation provided for the interviewee about the image below)



6. What is the role of these different strategies currently in *the maintenance and support service*?
7. How could *the case company* improve implementation of these strategies?
8. What do you think is needed to enable further implementation of the strategies on the inner loops?

Resource consumption in *the maintenance and support service* activities

9. How would you describe the material flows of the current service practices? In other words, how do you see that *the maintenance and support service* has an impact on material consumption or waste generation?
10. What actions are needed to reduce material consumption and waste generation in the activities of *the maintenance and support service*?
11. What type of possibilities do you seen in processing (e.g. remanufacturing or repairing) the replaced parts of the system and utilizing them again in *the case company's* projects?
12. How would you describe the impact that the activities of *the maintenance and support service* has on energy consumption?
13. What type of possibilities do you see in *the maintenance and support service* to reduce energy consumption?

Benefits from considering circular economy in lifecycle extension

14. Do you think it would be beneficial to pay more attention to circular economy in *the maintenance and support service*, namely to pay attention on the discussed strategies and impact on resources?
    - If yes, why?
    - If not, why not?
15. What type of impact could the increased attention on circular economy in *the maintenance and support service* have, when considering it from the company's point of view?

APPENDIX 2 INTERVIEW FRAME FOR THE EXTERNAL INTERVIEWEES

Background information

1. Could you briefly explain your role at the company?

Lifecycle extension practices

2. How would you describe the most important ways in which *the company* extends the life the products you manufacture?
3. How do you see that circular economy is considered in the activities for extending the life of your company's products?
4. How do you consider waste generation and material usage when extending the life of your company's products?
5. How do you see the role of providing services instead of selling ownership when moving towards CE?
6. How do you manage the end of life of your products or their parts?
7. Do you have practices for collecting used or obsolete parts back from customer and using them again?
   - If yes, what are these practices?
   - If not, why not?
8. What things have been helpful for your company when minimizing waste or new material usage in the lifecycle extension activities?
9. What has been challenging when minimizing waste or new material usage in the lifecycle extension activities?
10. What did you learn from these challenges?
11. How do you see the importance of collaboration with actors outside the company when working towards minimized waste?

Benefits from considering circular economy in lifecycle extension

12. What has motivated your company to work towards circular economy driven lifecycle extension?
13. What has been the business case of working towards circular economy driven lifecycle extension?
14. How do you think working towards circular economy driven lifecycle extension has benefitted your company?