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Remanufacturing Furniture: Mapping the Process Flow and Assessing Environmental Impact.

Master's thesis in Quality and Operations Management.

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This thesis is conducted at the TME department at Chalmers University of Technology. The authors are responsible for the opinions, conclusions, and results presented in this research.

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SUMMARY

Purpose
This research has three main purposes. Firstly, to identify the key steps and critical activities of the process of remanufacturing furniture. Secondly, to assess the environmental impact of the process. Lastly, to provide targeted recommendations to improve the process of remanufacturing furniture.

Methodology
The methodology used in this thesis is based on a multiple case study design. The data was collected through document studies, one Gemba walk, and semi-structured interviews with six different Swedish furniture SMEs. Thematic analysis was used to extract key findings and support process mapping techniques, which were applied to visualise remanufacturing flows. Moreover, a partial Life Cycle Assessment was conducted to assess the environmental impacts specifically related to the remanufacturing stages.

Findings
The critical activities of remanufacturing are cost and workload appraisal, transportation, and manual labour. As for the environmental impact, it is clear that remanufacturing a piece of furniture for 15 years still has less impact on the environment than producing new furniture that lasts for 15 years. As for the targeted recommendations, they include digital tools, modularity, related technology, improve logistics, inter-company partnerships, and PaaS model.

Implications
This thesis proposes a practical framework combining process mapping and environmental assessment tailored for SMEs to visualise, evaluate, and improve their remanufacturing processes. The findings provide actionable insights for companies aiming to align operational practices with circular economy goals.

Delimitations
The case companies operate in Sweden and are categorised as furniture SMEs. The assessment is limited to the remanufacturing process and the environmental impact. Further research may be needed to improve the generalisability of all the findings discussed in this research.

Key words
Circular economy, remanufacturing, Process mapping, Flowchart, LCA, Furniture industry, Sustainability, SMEs.

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List of Abbreviations

BOM Bills of Materials

C2C Cradle-to-Cradle

C2G Cradle-to-Grave

CE Circular Economy

CNC Computer numerical control

DPP Digital Product Passport

EPR Extended Producer Responsibility

EPD Environmental Product Declaration

EU European Union

GHG Greenhouse Gas

GWP Global Warming Potential

GSCM Green Supply Chain Management

LCA Life Cycle Assessment

MFA Material Flow Analysis

PaaS Product-as-a-Service

PM Particulate matter

QR code Quick-Response code

RFID Radio-frequency identification

RQ Research Question

SMEs Small and Medium Enterprises

TBL Triple Bottom Line

TPS Toyota Production System

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1 Introduction

This chapter outlines the foundation of this research and includes the background necessary to introduce the topic to the reader. In particular, it highlights the purpose of this research, the research questions, the delimitations that specify the scope, and the outline of the thesis.

1.1 Background

In 2020, the government of Sweden proclaimed a vision of a society in which materials are used in a toxic-free and circular flow to aid in the creation of a circular economy (CE) (Regeringskansliet, 2023).

The transition from a linear economy to a CE is increasingly recognised as a necessary shift to achieve sustainability in various industries, including furniture manufacturing. The CE model emphasises value retention by extending product lifespans, reducing waste, and integrating high-value recovery strategies such as remanufacturing (Circular Sweden, 2025). Looking at statistics provided by the circularity gap report, 96% of Sweden's materials used for production come from virgin sources, and of these, 3.4% are cycled back into the economy after use (Circle Economy, 2024). This can be compared to the average in the European Union (EU), which was 11.5% in 2022 and, according to their goal for 2030, should be 23.2% (ReBuilt, 2024). Gathering from this, it is clear that Sweden is below the European average and is currently not expected to meet the established goals. Given the scenario in which the government imposes more legislation in accordance with the extended producer responsibility (EPR) policy, more pressure is placed on corporations to take action for their products at the post-consumption stage (The European Organisation For Packaging And The Environmnet, 2025). Thus, businesses can gain an advantage in being prepared for this scenario by working on how their products can be incorporated into circular flows.

Building on this, a sector that can contribute towards a CE is the furniture industry since it is highly dependent on wood. Today, a large volume of furniture becomes waste, making it a pressing issue on the EU's environmental agenda (Lee, 2019). Furthermore, furniture waste generated in the EU consists of complex combinations of materials, such as wood chipboards, fibreboards, metals, plastics, textiles, and even electronic components. Although some materials are recycled, the fate of most used furniture remains unclear, with evidence showing that 10 million tonnes of furniture end up in landfills or are burnt, reflecting both a missed opportunity for material recovery and a challenge for the CE transition (Forrest et al., 2017). Creating circular flows can help save wood in a world where there is a global shortage (Danske Bank, 2024). Initiatives for this development have already been launched with research projects such as Cirkuträ and ReFurn, which aim to increase knowledge about remanufacturing (Chalmers Research, 2023), of which this research is part of. It is worth mentioning that SMEs in the EU have limited resources to develop new business models (Kans & Löfving, 2024). And according to European Investment Fund (2025), SMEs represent around 99% of all businesses in Sweden, and it is the same percentage for the furniture industry, according to (Trä- och Möbelföretagen, 2024) and (Brege et al., 2005). Therefore, it is worth focusing this research on Swedish furniture SMEs.

Barriers to remanufacturing are highlighted by Kans and Löfving (2024), who point to a general lack of awareness, knowledge, incentives, feedback channels, and supporting organisational structures. Therefore, the lack of knowledge when it comes to the details of the steps of remanufacturing is a problem. To investigate furniture remanufacturing, it is important to visualise the processes and steps involved. This means process mapping is important to visualise the steps involved in remanufacturing, so it is clear which steps have an environmental impact that need to be quantified. Moreover, it provides a structured approach to analysing production and refurbishment activities, helping businesses make informed decisions regarding resource allocation and process modifications (Damelio, 2011).

Furthermore, Calzolari et al. (2022) point out that an absence of explicit metrics quantifying the 'circularity' of the process on a supply chain level. Additionally, transparency through the supply chain has gained importance in recent years since companies are aiming to increase the transparency and sustainability of their supply chains. Kleindorfer et al. (2005) states that sustainability movements attracted more attention to the fact that production processes are not environmentally friendly enough. This was a growing concern for a long time, and companies are under pressure to measure and report their impact and footprint. for Standardization (2006) suggest that it is helpful to visualise the process using a flow diagram. This suggests that there is a need for a standardised tool to visualise and quantify the

impact of remanufacturing. Tools such as Life Cycle Assessment (LCA) provide a structured method for quantifying environmental impact and supporting decision-making regarding material use and waste reduction (Sonnemann et al., 2018). LCA enables the identification of the most critical impact areas and helps companies choose the best approach that minimises environmental footprints (Niero & Kalbar, 2019). Moreover, LCA has developed throughout the years and nowadays includes steps, such as recovery, reuse, and recycling, which are outside of the regular steps, such as production, usage, and end of life. This helped LCA to transition more towards the circular economy from being purely linear (Abagnato et al., 2024). However, the gap remains clear regarding the ambiguity of mapping and assessing the impact of the remanufacturing process by itself. This suggests the need for research that focuses on the remanufacturing and circularity of furniture.

1.2 Purpose and Objectives

The focus of this research is directed towards helping furniture Small and Medium Enterprises (SMEs)in Sweden refine their remanufacturing processes by highlighting the key steps and critical activities in the process, with targeted recommendations on how to improve the remanufacturing process potential. Since this area is under-researched, SMEs may lack the necessary resources to develop/improve this business model on their own, according to Kans and Löfving (2024). It aims to explain the process of furniture remanufacturing and the way it can be improved to support the goals of CE. This is done by mapping the remanufacturing process flow and assessing its environmental impact.

Given this focus, the primary objectives of this research are to identify the key steps and critical activities involved in remanufacturing furniture, assess the environmental impacts of these processes, and offer targeted recommendations for improvement. This research provides a clearer picture of environmental impact, allowing businesses to make more informed decisions regarding the use of resources and waste reduction. By addressing these objectives, this thesis contributes to the broader perspective on circular economy implementation and offers insights into optimising furniture remanufacturing for long-term sustainability.

The ultimate goal of this study is to give targeted recommendations that help companies become more circular and sustainable by enhancing their remanufacturing processes, thus increasing their efficiency and lowering their environmental impact/carbon footprint. By offering insights into reducing waste, streamlining processes, and measuring environmental impact, this research aims to provide practical guidance to furniture companies to become more efficient and sustainable.

1.3 Research questions

Based on the challenges outlined in the Background, certain topics require further investigation. The large amounts of furniture waste in Sweden and the EU continue to end up in landfills or burnt (Forrest et al., 2017), showing missed opportunities for material recovery and a transition toward CE. However, despite Sweden's reputation as a sustainability frontrunner, it lags in the effective reuse and remanufacturing of materials, creating a dependency on virgin materials instead. This emphasises the urgency to pinpoint strategic improvements. Building upon everything previously mentioned, the absence of a clear and standardised remanufacturing process with explicit metrics to quantify environmental gains represents another problem. These identified issues guide the formulation of the following research questions:

1. What are the key steps and critical activities involved in the furniture remanufacturing process?
2. How can the environmental impact of the remanufacturing process be assessed?
3. How can furniture companies improve the remanufacturing process?

It can be said that research questions are logically structured and focused on the remanufacturing process. The first question is exploratory and important to describe the process itself, which offers valuable insights into the key steps and critical activities. This question is foundational and needed for quantifying the impact, as in RQ2, and identifying areas of improvement, as in RQ3.

The second question is mostly analytical. It is expected to add a piece of quantitative evidence to support the argument that remanufacturing is better for the environment than manufacturing new furniture.

The third question is prescriptive and progressive. The main outcome of this question is to suggest recommendations tied to improving the remanufacturing process. It builds on the understanding from RQ1 and the support from RQ2 to propose potential improvements that can help SMEs involved in the remanufacturing of furniture.

1.4 Delimitations

This thesis is limited to focusing on remanufacturing, including refurbishment and reusing, in different furniture SMEs in Sweden. Having multiple case studies means that the in-depth research will not be as comprehensive as in a single case study. The companies are categorised as SMEs, which means that this study excludes large manufacturers. The focus will be on creating a new framework using well-established theories such as process mapping and LCA. Moreover, only a partial LCA will be conducted because the focus will be on the end-of-life stage in the partial LCA, which is relevant to remanufacturing in the furniture industry. This means that the partial LCA will be conducted for the remanufacturing processes only and not for the full life cycle assessment of the product or the production process. Lastly, only the environmental aspect of sustainability will be examined, excluding social and economic.

1.5 Outline of Thesis

This thesis begins with a theoretical background, providing relevant information in the form of an overview of circular economy principles, practices supporting circularity, organisation design strategies, and then visualising remanufacturing. The methodology chapter follows, detailing the research design, case study approach, and data collection methods, including interviews, observations, and document review. The findings chapter presents the results of the study, including a summary of the data collected and process maps for each company with remanufacturing practices. The analysis chapter presents the thematic analysis and the remanufacturing impact analysis. The discussion explores the broader implications of the research, reflecting on methodological strengths and limitations while considering practical applications for SMEs, and answers the research questions. The recommendations chapter suggests strategies for improving remanufacturing efficiency and sustainability. Finally, the conclusion summarises key findings, discusses contributions to circular economy research, and outlines potential directions for future studies.

2 Theoretical Background

In the theoretical background, theories, tools and concepts are presented that contribute to the framework and analysis.

2.1 Circular Economy

In this chapter, definitions of circular economy (CE) are presented together with ways it can impact businesses and how it is related to sustainability.

2.1.1 Definitions of circular economy

CE as defined by the EU Parliament (2023) is a model of consumption and production involving different steps, such as sharing, leasing, reusing, repairing, refurbishing and recycling materials/products for as long as possible to extend the life of a product. Figure 1[1] represents the circular economy model as defined by the EU Parliament (2023), with the waste management step aiming to inject the material back into the system. Moreover, waste reduction is highlighted as a key principle, and further value is created through keeping used materials in the economy, wherever possible, through recycling. On the other hand, in Sweden, according to the definition provided by Circular Sweden (2025), a CE is an industrial system designed to preserve value. It substitutes linear flows with a prolonged life span and preservation of the product and material value. It means a shift to renewable energy and the elimination of waste through the high-quality design of materials, products, systems, and business models. It is clear that the definitions of CE can vary, but in this research, the definition provided by Circular Sweden (2025) will be used.

Figure 1: The circular economy model

2.1.2 Extended producer responsibility

Extended producer responsibility (EPR) is a form of legislation that obliges producers to take more responsibility for their product throughout its life cycle, including beyond the consumer stage, to meet environmental goals regarding recycling or recovery targets (The European Organisation For Packaging

[1] This figure is inspired by the EU Parliament (2023)

And The Environmnet, 2025). It is clear that this type of legislation is closely related to CE and promotes this type of practice. Concrete examples of this according to Naturvårdsverket (2023) include the obligation of the producer to assume responsibility for the design and label of their products, collecting it when it becomes waste, taking care of or recycling the product once it becomes waste, and registering and reporting information to the Swedish Environmental Protection Agency. Although not all industries have been impacted by this yet, it is clear that these sorts of policies will be in effect in the near future for all industries. Therefore, companies can gain a competitive advantage by working on incorporating their product into circular flows after overcoming the barriers mentioned by Bhatia and Srivastava (2018). These barriers such as uncertainty in the quantity and timing of returned products, a lack of consumer awareness and incentives, and lastly, the absence of organised collection channels. These barriers complicate planning, discourage product returns, and further hinder the remanufacturing process.

Moreover, Gupt and Sahay (2015) also concludes that EPR is pushing more businesses to adopt sustainable strategies and that remanufacturing is one of the strategies businesses can apply to shift towards a CE instead of the linear economy. And for the sake of this research, remanufacturing is defined as Sundin (2004) chose to define industrial remanufacturing based on previous definitions for remanufacturing inspired by the works of Seaver (1994); Amezquita and Bras (1996); Bras and Hammond (1996); Lund (1996); and APICS (1998). Sundin's definition of remanufacturing is that it represents an industrial process that restores end-of-life products, known as cores, to a functional state. This involves a series of structured steps, including inspection, disassembly, cleaning, part replacement or refurbishment, reassembly, and testing to ensure the final product meets specified performance and quality standards. Therefore, furniture manufacturers can redesign their items to make them simpler to recycle, disassemble and repair, which helps them to meet the EPR requirements. Moreover, this will make the manufacturers more sustainable as well.

Furthermore, Geissdoerfer et al. (2017) argues that the concepts of CE and sustainability are often tangled together and that the lines between their similarities and differences are often blurred. Therefore, it is important to understand that it is not the same thing. Rather, sustainability is defined, according to Geissdoerfer et al. (2017), as *the balanced integration of economic performance, social inclusiveness, and environmental resilience, to the benefit of current and future generations*, and CE is a prerequisite for this vision.

2.1.3 Life Cycle Assessment (LCA)

The core principle of a CE is to reuse raw materials and thus be more efficient with the use of resources while at the same time eliminating waste from the material flows (Parliament, 2023). However, measuring environmental impact is crucial and can be done via LCA, which is a well-established tool for quantifying the environmental footprint of materials used in various manufacturing processes. Furthermore, it can be used to enhance circular flows, as it helps in decision-making, as it accounts for environmental impact (Sonnemann et al., 2018), thus allowing policymakers to base their decisions on facts.

LCA has traditionally been used to analyse and compare individual products from an environmental point of view. LCA is increasingly used in CE frameworks, where it is often combined with material circularity indicators to quantify circular product strategies (Niero & Kalbar, 2019). LCA provides a quantitative assessment of the environmental performance of a product throughout its entire life cycle, via a formalised four-step process (International Organization for Standardization, 1997):

1. Define scope
2. Performing a life cycle inventory analysis
3. Performing an impact assessment
4. Interpreting results

Standards for conducting an LCA is carried out exist, and they are called ISO14040 and ISO14044, and belong to the 14000 family standard. In addition, furniture-specific frameworks on how to quantify the environmental impact of office furniture, such as the model proposed by Røyne (2019), exist. Furthermore, various environmental impact assessments have been conducted and presented in the form of an

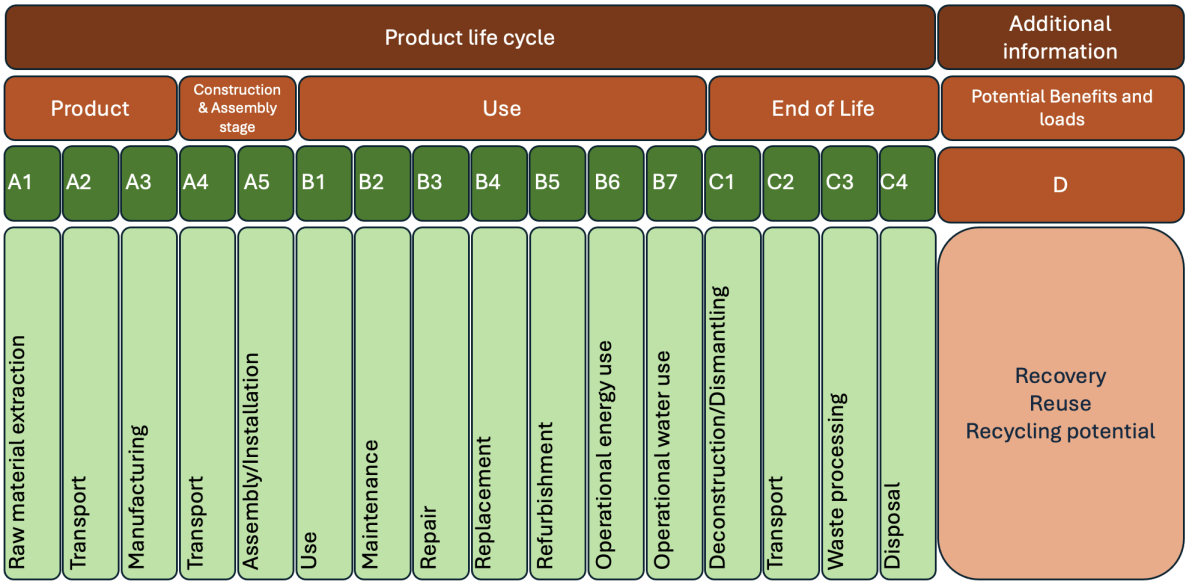

Figure 2: Life cycle stages

environmental product declaration (EPD) with furniture as the subject (Del Borghi, 2013).

As laid out by Rebitzer et al. (2004), LCA is a tool used to quantify the environmental impact for a product from cradle-to-grave (C2G) or cradle-to-cradle (C2C), meaning it is traditionally applied on linear flows with the optional of including other scenarios. Furthermore, depending on the question the LCA intends to answer, only the relevant life cycle phases should be included in the analysis (Røyne, 2019). Therefore, when it comes to circular systems, LCA has its limitations, as traditional LCA techniques frequently give recycling impacts precedence over high-value retention tactics such as remanufacturing, making it difficult to capture the concepts of the circular economy, as discussed by Bjørn and Hauschild (2018).

In Figure 2[2], the "card" for the LCA stages is presented, inspired by the EN 15804 and ISO 21930 standard for buildings. This framework was originally created for buildings as implemented by (Antunes et al., 2021), but it is clear that it is used in several LCAs/EPDs for furniture, such as the one used by The Norwegian EPD Foundation (2023) to show which phases of the product life cycle are considered in the LCA. Therefore, it is justified that this framework is used to perform LCA on furniture.

According to Böckin and Johansson (2024), the stages labelled with "A" include considerations such as the environmental impact generated from the extraction of all materials, their transportation, the manufacturing of the product, transportation to the customer and installation. Furthermore, the stages labelled with "B" include the impact generated during the use phase of the product, including use, maintenance, repair, replacement, refurbishment, operational energy use, and operational water use. As for the "C" module, it includes the processes related to the end-of-life phase. This includes dismantling, transportation, energy and materials used for preparation for waste treatment, and final waste treatment. Lastly, the "D" stage describes the materials and energy outside the system. It describes the injections back into the system instead of using raw materials. Therefore, when using recycled materials, the recycled share is deducted to avoid counting it twice.
As for C2C, according to Lin et al. (2020), means that waste from certain products would serve as raw materials for newly produced items, and this phase of the manufacturing process needs to be aligned with the environmental regulations to be more effective with resources, reduce emissions, and therefore increase sustainability. Depending on how well different products do this, different C2C certifications can be rewarded as evidence of being environmentally and sustainably (Bjørn & Hauschild, 2018).

Bjørn and Hauschild (2018) point out that there are key points that need to be considered when looking

[2]This figure is based on the work of Antunes et al. (2021)

at the full picture of assessing and designing a product from an environmental point of view. They highlight the fact that a product that receives C2C certification without any changes to the elementary flows in its life cycle will have the same LCA score as before certification. Furthermore, the authors identify the fact that C2C operates with *a positive environmental impact* and that LCA operates with a *negative environmental impact*. What they mean by this is that LCA aims to remove emissions and waste from the systems, and that C2C aims to create new systems where the environment can benefit from the addition of nutrients.

From an LCA perspective, reducing waste directly contributes to minimising environmental impact by decreasing resource consumption, emissions, and overall material usage. Studies by Ruben et al. (2018) and Mostafa and Dumrak (2017) highlight that the implementation of lean waste elimination techniques in sustainable manufacturing systems improves resource efficiency and reduces the environmental footprint of production processes. Thus, integrating lean manufacturing with sustainability strategies not only supports the LCA goals but also reinforces the broader objectives of the circular economy.

In summary, understanding both the C2C philosophy and the usage of LCA is important when understanding the life cycle and environmental impacts of a product in any material flow and provides a theory to discuss, analyse, and answer the research questions.

2.2 Practices Supporting Circularity

This subchapter focuses on presenting and elaborating on practices that support circular flows to support a framework for what a company can do to improve circularity.

2.2.1 Lean methodology

The research by Salibi et al. (2022) indicates that applying lean methods can help achieve CE goals by minimising waste and improving process efficiency. By aligning lean principles with CE objectives, organisations can improve their operational efficiency while promoting environmental sustainability. This integration not only streamlines processes, but also encourages innovation in product lifecycle management, contributing to a more sustainable industrial ecosystem.

Lean manufacturing is fundamentally centred on waste elimination, as highlighted by Womack et al. (2007), who define any activity that does not add value to the customer as waste. This principle is closely aligned with sustainability frameworks, particularly the Triple Bottom Line (TBL) approach introduced by Elkington (1997), which emphasises the need to balance economic, environmental, and social dimensions in business operations.

Beyond environmental benefits, the social and economic aspects of TBL also intersect with lean manufacturing. From a social perspective, lean practices contribute to better ergonomics in the workplace, better labour conditions, and increased job satisfaction by eliminating inefficiencies that cause stress and overwork (Shah & Ward, 2007). Economically, lean operations drive cost savings through lower material expenses, improved energy efficiency, and streamlined production flows, thereby enhancing long-term profitability. Furthermore, Cherrafi et al. (2018) demonstrate that the integration of lean and green practices fosters innovation in manufacturing processes, leading to improved supply chain performance and competitive advantages. Their findings suggest that companies implementing lean sustainability initiatives experience improved product quality, reduced lead times, and greater customer satisfaction, reinforcing the economic pillar of the TBL framework.

2.2.2 Green supply chain management

According to Alvarenga et al. (2015), green supply chain management (GSCM) is the integration of environmental thinking in supply chain management, such as product design, material and supply selection, manufacturing processes, final product delivery, and end-of-life management. Moreover, Singh (2024) stresses the importance of implementing this to achieve circular flows of materials and to establish closed-loop systems where resources are regenerated and reused. One of these GSCM practices that has gained recognition in recent years is reverse logistics, which enables remanufacturing, thus contributing to a circular economy where dependence on virgin materials is reduced while prolonging the lifetime of the materials, while reducing environmental impact (Tveit et al., 2021).

A reverse logistics framework for circular supply chains is presented by Tveit et al. (2021), which can be adapted by the furniture manufacturers. This study highlights that cost is highlighted as one of the largest challenges for furniture companies, especially the cost of transportation and retrieving the products. They also found that another large cost arises when examining the products to decide if they are suitable for remanufacturing and comparing them to cheap raw materials in Sweden. This means that manufacturing new products can be cheaper for many SMEs. Furthermore, many businesses do not have standardised processes for remanufacturing. This makes material recovery a costly process with an uneven flow. However, despite all the problems stated, manufacturers are encouraged to establish take-back programs to comply with the EPR regulations.

In addition, Alvarenga et al. (2015) and Xing et al. (2016) state that process mapping and LCA are tools and practices to help guide green supply chain management and therefore establish circular flows. In this context, it is possible to see that green supply chain management practices are key to understanding circular flows and to providing insights on this topic.

2.2.3 Product-as-a-service

According to Garrone (2024), the Product-as-a-Service (PaaS) model is useful to keep old materials in use for as long as possible by increasing the possibility of remanufacturing. Businesses can use it strategically to shift the emphasis from product ownership to service supply. In the furniture industry, this can be done by leasing or renting the products instead of selling furniture. Therefore, manufacturers can design their products with the purpose of longevity, modularity, and ease of disassembly when they maintain ownership of their products, which aligns with the principles of circular economy, according to Circular Sweden (2025). Therefore, this promotes remanufacturing and having furniture as a service to lessen the reliance on the extraction of raw materials.

Tveit et al. (2021) highlight how the provisions of services for the collection of old furniture when delivering new products can be incorporated into circular business models through the use of remanufacturing and reverse logistics. Therefore, by adapting the PaaS model, manufacturers can monitor product usage, forecast maintenance requirements, and streamline refurbishment cycles with lease agreements. Moreover, this guarantees that furniture will continue to be useful and valuable over time, which can help the furniture industry reduce waste and increase resource efficiency.

2.2.4 Digital product passports

As to improve transparency, digital product passports (DPP) can be implemented. In 2024, it was legalised that almost all products sold in the EU must feature a DPP (European Union, 2024b). The objective is to improve transparency throughout the value chain of a product by providing information about the origin, materials, environmental impact, and disposal recommendations of each product (European Union, 2024b). It is a law that is enforced in line with the ambition of creating a circular economy in the EU (European Union, 2024a), and it further shows the pressure on companies to adapt to these practices.

According to Jensen et al. (2023), DPP allows more transparency and more access to high-quality data, which is beneficial and valuable for decision making during the life cycle of a product. Furthermore, seven points are mentioned that need to be included in the DPP that allow for decision-making:

1. Usage and maintenance
2. Product identification
3. Product and materials
4. Guidelines and manuals
5. Supply chain and reverse logistics
6. Environmental data
7. Compliance

2.2.5 Modularity and product design

Modular design, according to Erixon (1996), is an excellent practice for continuing product renewal and restoration, as well as a means to reduce manufacturing throughput time, and by extension, remanufacturing throughput time.

Tseng and Wang (2014) define a modular system as a system that subdivides smaller parts, which they refer to as modules, that can be independently created and used in different systems for different functions. They elaborate and highlight some key benefits associated with this practice. Such as cost-effectiveness, providing a higher degree of design flexibility, and systems can be upgraded by easily adding or changing an old module for a new one. The main purpose is that removing one part or module will not influence a change in another part.

2.3 Organisation design strategies

Lindlöf (2014), explains Galbrait's model from 1977 in ways in which information processing capabilities can be increased in an organisation. As task complexity increases, the organisation must utilise design strategies to adapt. This boils down to two lines of action. The first one is reducing the amount of complexity or information that needs to be processed, or increasing its capability to process uncertainty and information. To reduce the amount of information that needs to be processed, an organisation can engage in environmental management, create slack resources, or create self-contained tasks. To increase its capability to handle uncertainty or information, an organisation can either invest in vertical information systems or create lateral relations (Lindlöf, 2014). What Galbraith means by environmental management is that the organisation "takes control" over their own resources by modifying the environment in which it operates. Having more slack resources means that the company has more free resources in case they are needed urgently. As for creating self-contained tasks, it means that the organisation has teams that work more in autonomy, so that the need for information processing is reduced. The investment of a vertical investment system means that it should be easy to reach the right person to ask for help or direction. Lastly, the creation of lateral resources means that the organisation divides itself into self-organising functions.

2.4 Visualising remanufacturing

According to Kumar and Phrommathed (2006), in the context of remanufacturing, process mapping can be used to increase the sustainability of production. Producers can find methods to cut waste, reuse materials, and improve energy efficiency by visually monitoring the flow of materials through a system.

Gilbreth and Gilbreth (1921) developed a device that helps visualise processes in order to improve them. This device was called the "process chart", which created the foundation for flowcharts. According to Gilbreth and Gilbreth (1921), it is suggested to include as many details as possible about the process because that means more suggestions can be proposed for improvement.

Process mapping is a tool used to visualise processes. Through visualisation of a process, expenses, cycle time, and inefficiencies can be eliminated, while increasing job satisfaction and streamlining the flow (Kalman, 2002; Kumar & Phrommathed, 2006). This supports concepts like the circular economy, Material Flow Analysis (MFA) for processes, and LCA for products, by enabling them to link environmental benefits with real-world operational improvements. For these reasons, this method is used in the project to provide a visual overview of the process of remanufacturing, and allow for potential improvement measures to the processes.

According to Damelio (2011), there are three different categories of process maps:

1. Relationship maps
2. Cross-functional maps
3. Flowcharts

The relationship map is described as a map that visually lays out the different parts of the organisation and the internal and external supplier-customer relationships between these parts. It does not include

work activities, but shows the input and output connections among selected parts of the organisation.

Secondly, the cross-functional map illustrates the workflow in the organisation, which, according to the definition provided by Damelio (2011), is a set of interrelated work activities and resources that follows a distinct path as work input that is converted to output.

The flowchart is a graphic representation of the sequence of work activities used to create, produce, or provide a single and unique output, such as the one illustrated in Figure 3[3]. It is also suitable for identifying value-adding and non-value-adding activities. It is also known to be the type of chart that gives the most detailed view of a process.

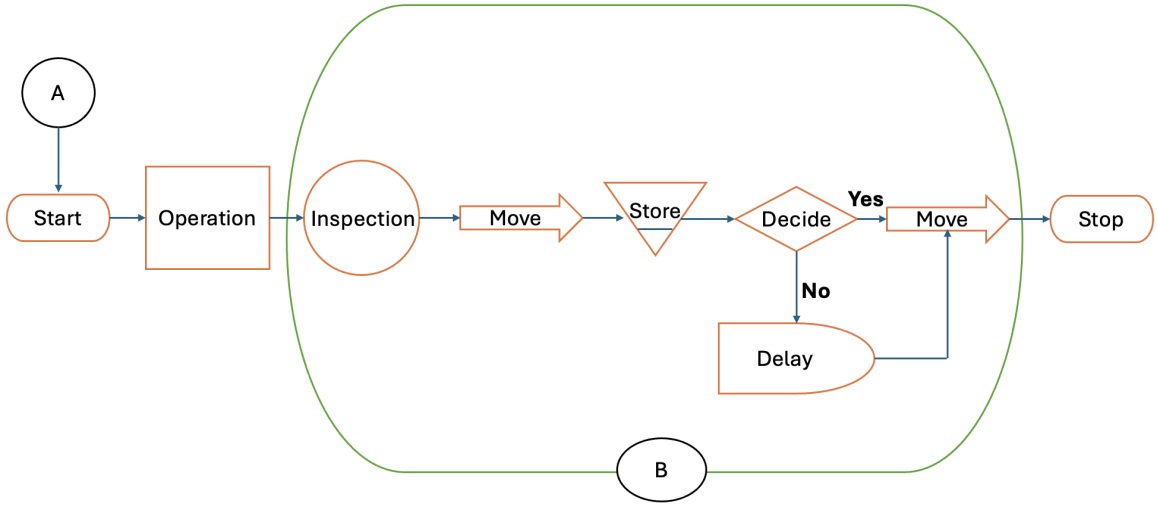

Figure 3: Flowchart with symbols and their meaning

Figure 3 represents a generic and simplified example of a flowchart and the components that it usually includes.

According to ReBuilt (2024), mapping material flows helps companies identify inefficiencies, resource loss, and areas for intervention to close material loops. Therefore, quantifying material inputs and outputs can be used to evaluate resource efficiency and circularity levels in a specific system. This is called Material Flow Analysis and can be used in wood-based value chains, according to Khan et al. (2024). Khan et al. (2024) claim that wood products frequently have linear material flows, which results in significant waste production and virgin resource consumption. Therefore, furniture manufacturers can find material inefficiencies and adapt strategies to reduce waste, boost material recovery, and enhance remanufacturing procedures by putting MFA, LCA, and flowcharts into practice.

[3]This flowchart and the symbols are inspired by the work of Damelio (2011).

3 Methodology

This chapter offers a detailed overview of the research process to guide the reader in understanding the study findings. It describes research design, data collection methods, and data analysis techniques. In addition, it explains the rationale behind the methodologies chosen to ensure data reliability. This chapter includes a discussion of the validity and reliability of the study and a subchapter discussing ethical considerations.

3.1 Research Design

The research design of multiple case studies is chosen as the most suitable approach to this research to attempt to answer the research questions. This is motivated because it is difficult to generalise what the process of remanufacturing looks like. This means identifying the key steps and critical activities in the process based on one example only, so multiple processes need to be analysed in order to map the process accurately. The case studies are conducted in parallel, according to Thomas (2022), which means that the data from the different companies are used simultaneously to add value. Figure 4 illustrates how the research questions can be answered in this research design using which data sources. This approach justifies the use of this method in this case.

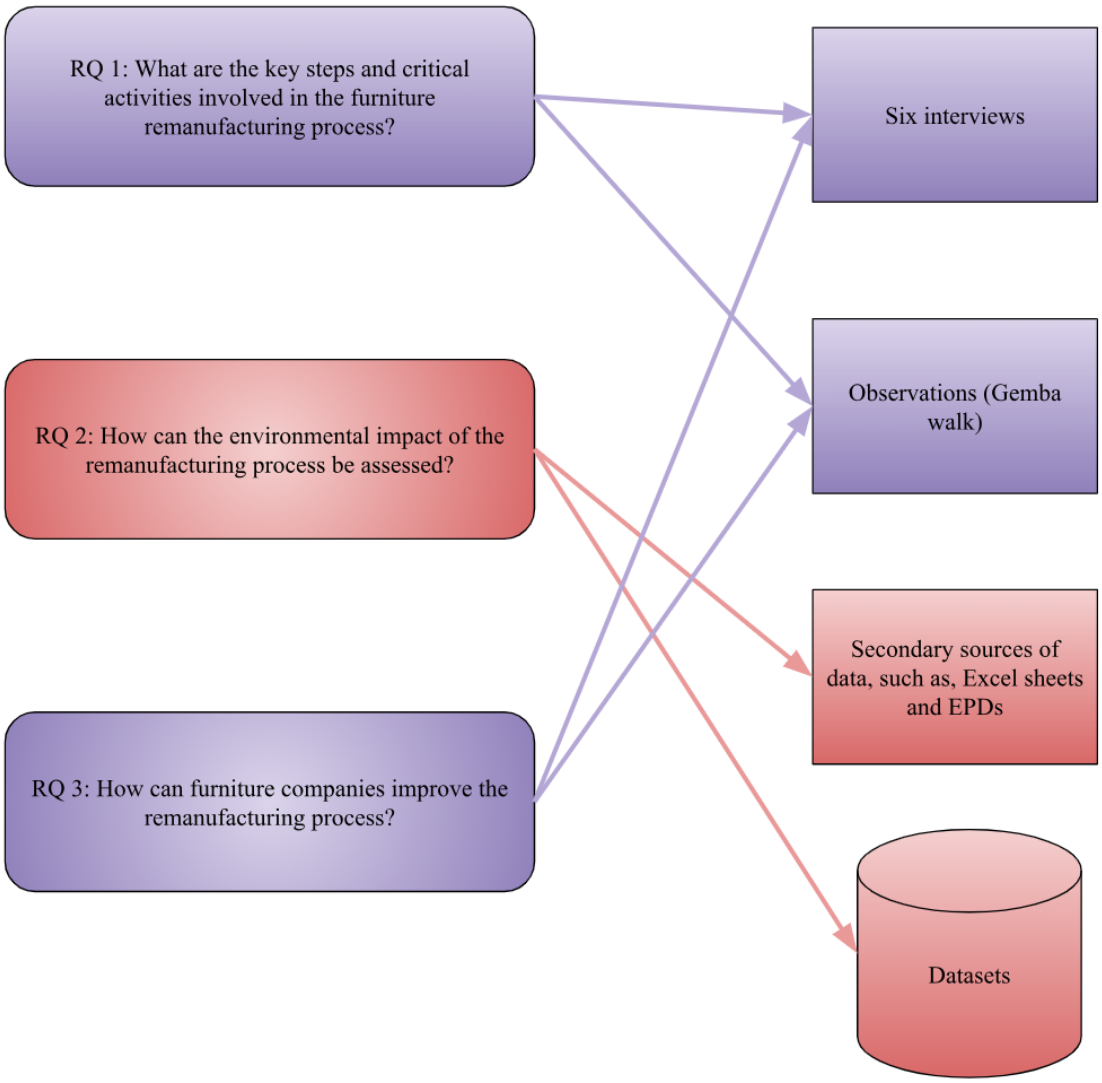

Figure 4: The research design

According to Yin (2017), through structured data collection and analysis, the explanatory approach is used to verify and validate theories and hypotheses by explaining the relationship between different

variables. Therefore, this research is considered explanatory with mixed methods, as this research aims to explain how process mapping and LCA can be used to optimise sustainability in furniture remanufacturing.

The choice of having multiple case studies may leverage the advantages of the explanatory research approach by employing a mixed-method design. This method can facilitate a more thorough investigation of the issue and help ensure the reliability and validity of the results, according to Yin (2017).

According to Morse and Niehaus (2009), a primarily quantitative case study is unable to fully describe the complex phenomena that occur, which is a limitation. Because of this, the quantitative results can be supported by qualitative data, which increases the reliability of the data extracted from the case companies.

According to Yin (2017), case studies provide rich and empirical accounts of a single occurrence of a phenomenon. Although they are narratives, they also function as experiments. Each case is a free-standing unit of analysis and constitutes a discrete experiment. If there are multiple cases to examine, then they are distinct experiments in which replication, contrast, and extension are feasible. Various data sources, including interviews, archival records, surveys, ethnography, and observation, can be applied in case studies. Researchers use a deductive approach, using cases to illustrate pre-established theories (Yin, 2017). Yang (2014) states that the choice of research questions dictates the choice of methodologies and data collection methods. Therefore, the research questions inspired the choice to have case studies with mixed methods. According to Thomas (2022), this means that the study employs a deductive approach, in which the theory is derived in advance and is based on established theories. The thesis design seeks the most objective perspective by first reviewing quantitative data, followed by the collection of qualitative data through interviews to provide additional insight and an explanation of the quantitative data.

Regarding process mapping, an assessment can be made by interviewing key people according to Voehl et al. (2014). Therefore, interviews are conducted with key people who have the most knowledge of the process, together with a Gemba walk to find key steps and critical activities in the process.

Furthermore, Damelio (2011) highlights three reasons for using the flowchart, and in summary, it is recommended when *"getting to the ground truth of what actually happened in a process, distinguishing between value-creating and non-value-adding activities",* and *"make types of waste in non-value-adding activities visible"*. For these reasons, the flowchart is selected for this research, as it aligns with the goal of the research instead of MFA. Although MFA is more related to LCA than flowcharts, MFA is not used since a full LCA will not be conducted and due to a lack of data.

LCA as a method is used to perform a "partial LCA" focusing on stages C2 to D, as seen in Figure 5. The reason behind this is not only the lack of necessary data in SMEs to perform a full LCA, but also because there is no need to perform a full scope LCA since this research is only limited to the remanufacturing process, which is defined by the stages C2 to D in Figure 5.

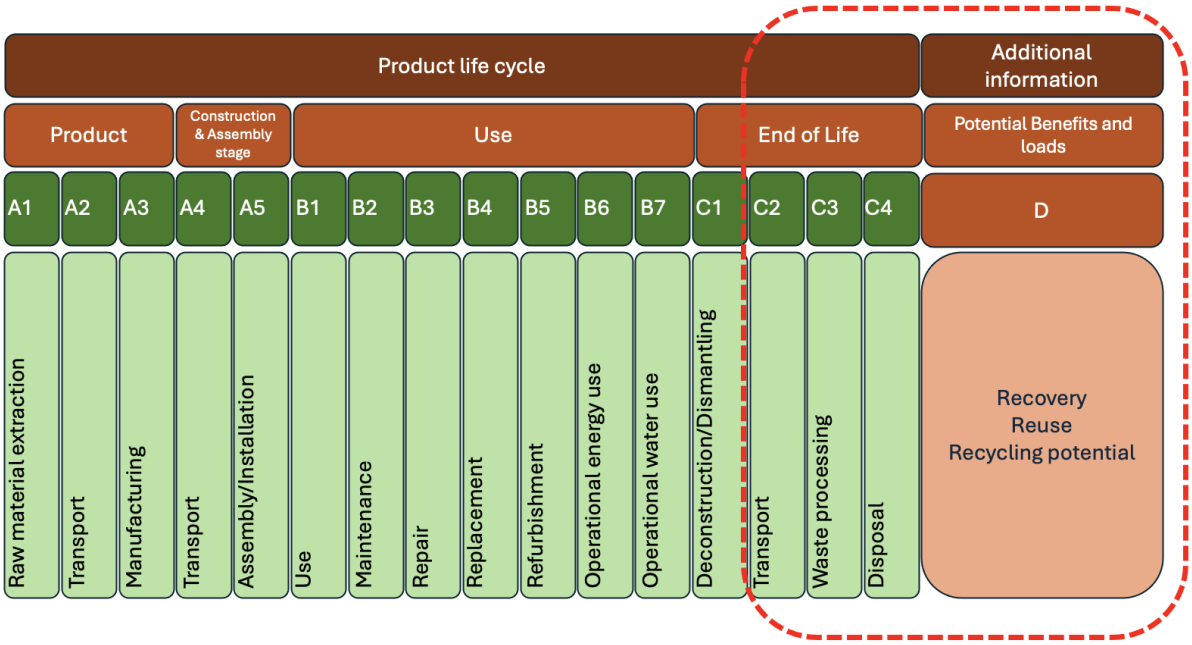

Figure 5: Generic LCA card and the remanufacturing process circled in red

However, the card in Figure 5 is a generic and standardised approach to LCA on linear life cycles. Thus, it is not applicable for a purely circular process. Although it includes the D stage, it looks like an optional step that companies may or may not choose, such as the C2C or C2G approaches. Therefore, a new approach for a circular LCA is needed for a more fitting analysis to answer research question three, which is developed in this research.

Starting with the research questions, theoretical background, and using the steps in Figure 5, Codes were predefined in order to be used in the thematic analysis. From the research questions, the focus was on codes similar to remanufacturing (refurbishment), critical activities (challenges), environment, and impact. As per the literature in the theoretical background, the focus was on codes related to circularity, logistics (reverse logistics), EPR (legislation), material flow, modularity (design and disassembly), price (cost), quality, DPP, chemicals, and technology. As per the steps in Figure 5, the focus was on the codes related to raw materials, transport, manufacturing, assembly, usage, maintenance, repair, replacement, refurbishment, energy, and waste.

In addition, the findings of RQ1 and RQ2 are integrated to create a framework that helps SMEs to visualise the remanufacturing process and quantify the environmental impact. This, with the thematic analysis of the interviews, helps generate the recommendations offered in RQ3. By reviewing key activities, key steps, and environmental footprint points, the research aims to propose targeted improvements that harmonise operational efficiency with sustainability objectives. The final goal is to develop a framework for enhancing remanufacturing processes with targeted recommendations so that companies can enhance sustainability while remaining economically viable and operationally efficient.

3.2 Case Companies Descriptions

This subchapter introduces each case company and presents information about the companies involved in this research. Moreover, this subchapter explains what type of data is collected from each case company and how.

3.2.1 Company 1

The first case company is a Swedish furniture manufacturer, called Ekdahls Möbler, specialising in the production of furniture for public spaces. The company is located in Skillingaryd in Småland and has a long history dating back to the 1940s. Over time, it has transitioned from the production of home

furniture to focusing on furniture for offices, institutions, and other public environments.

The company operates a small-scale production facility where most of the furniture is manufactured in-house. However, certain semi-finished components, such as untreated wooden chair frames, are sourced from other suppliers. The company also acts as a subcontractor, providing furniture parts and components to other manufacturers in Sweden.

In recent years, the company has explored remanufacturing and refurbishment as part of its sustainability efforts. Although the demand for remanufacturing services remains relatively low, the company has noticed an increase in requests for furniture refurbishment, particularly replacing seat cushions. The remanufacturing process primarily involves receiving used furniture, inspecting its condition, performing necessary repairs, refinishing surfaces, and replacing upholstery before returning the product to the customer.

The data collected from this company is primary data, mostly qualitative, through an interview with one of the co-owners.

3.2.2 Company 2

The second company included in the study is called Gärsnäs AB. Like Ekdahls, they also specialise in producing furniture for public spaces. They are located in Scania and are named after the village of the same name just outside of Simrishamn.

The company has around 40 employees and is considered a medium-sized company. All of their production is made in-house in Gärsnäs, but for certain parts of their furniture, they order them from suppliers.

Sustainability is a central concept at Gärsnäs, and they have been developing systems both for remanufacturing and refurbishment of furniture. They exclusively perform refurbishment and remanufacturing on their own products, and services included are using old parts to create new furniture, changing damaged parts, giving the product a new finish in terms of repainting, changing textiles, and putting on new upholstery, as well as general repairs.

Data collected from this company is primary data, and the majority is qualitative. The data collected is through a field visit and an interview with the company's CEO. In addition, secondary quantitative data are also collected from Gärsnäs in Excel sheets and EPDs.

3.2.3 Company 3

The third case company is a Swedish furniture manufacturer called Gemla Möbler, focusing on high-quality furniture for private and public spaces. The company is located in Diö in Småland and has a long history dating back to the 1860s. Over time, it has developed a long-standing tradition of refurbishment through its service brand called Gemla Original Restoration, which has been part of the business since the 1990s.

The company operates a small-scale production facility where most of the furniture is manufactured and restored in-house. The company employs around 16 people.

In recent years, refurbishment has become increasingly relevant as part of the company's sustainability efforts. The refurbishment process typically includes dismantling the furniture, inspecting its condition, reinforcing the structure, sanding, replacing the upholstery, and applying surface finishes. All restoration work is integrated into the company's regular production flow, and the company provides services such as temporary chair replacements, flexible scheduling, and storage during customer renovations.

The data collected from this company is primary data, mostly qualitative, through an interview and emails with the range manager.

3.2.4 Company 4

The fourth case company is called Balzar Beskow. They manufacture high-quality furniture for public spaces, and have a rigorous approach to sustainability and are proud of their focus in this area. It is a family-run business that started furniture manufacturing in Mönsterås, in Småland, in 1957.

Balzar's vision is to keep on spreading Swedish design and to keep developing sustainability. They offer remanufacturing of both their own and other companies' furniture, and this process usually involves dismantling the furniture, assessing its condition, reinforcing the structure, sanding, reupholstering, and applying surface finishes. All remanufacturing work is done at their production site in Mönsterås and is integrated into the regular production workflow.

The data collected from this interview is primary data via an interview with the co-owner, who is also the sustainability developer at the company.

3.2.5 Company 5

The fifth case company is called Götessons Interior AB. They are located in Ulricehamn and highlight quality and sustainability as key to their business, and were founded in 1986.

Götessons specialise in office furniture and have a take-back system called LOOP that allows them to reuse parts from old furniture in the manufacturing of new furniture.

Primary data is collected through an interview with the sustainability developer at the company, and secondary data is also collected in the form of EPDs.

3.2.6 Company 6

The sixth case company is called Maze Interior, which is a company from Stockholm, founded in 2003. They produce furniture for private spaces and emphasise the necessity of sustainability.

Most of their furniture is produced in Sweden, and they highlight the use of recycled materials in their production, and their ambition is to minimise their environmental impact as much as possible.

Data is collected in the form of primary data from an interview with the purchasing manager.

3.3 Data Collection Methods

This subchapter explains the methods used for data collection. This section includes a document study (to collect secondary data from the companies), observations, and interviews. A visual summary of the data collection from each company is presented in Table 1:

Table 1: *Case companies, interviewees, and data collection methods*

Company	**Interviewee**	**Data collection method**
Ekdahls AB	Co-owner	Semi-structured interview
Gärsnäs AB	CEO	Semi-structured interview, Gemba walk, Quantitative data: Excel sheets with production information, BOM, EPD
Gemla AB	Range manager	Semi-structured interview
Balzar Beskow	Co-owner	Semi-structured interview
Götessons AB	Sustainability developer	Semi-structured interview
Maze Interior	Product & Purchase manager	Semi-structured interview

3.3.1 Interviews

The interviews are part of the qualitative research methodology in this study, providing detailed information on the remanufacturing process, operational problems, and steps toward sustainability. Interviews are conducted with key people who possess full details on the processes of the company and are involved in remanufacturing operations. The interviews provide a more intensive investigation of decision-making processes, material flows, and constraints on both process efficiency and environmental performance.

The semi-structured interview method was employed to be flexible with a structured approach to gather appropriate data. The method enables researchers to investigate important topics that emerge during the course of discussion while still covering predetermined issues concerning process mapping and LCA. As observed by earlier research, semi-structured interviews are particularly useful in case studies since they provide contextual depth and allow for the determination of factors that will not be obvious from observation (Yin, 2017).

Interviews are also required to cross-verify and complement information obtained through observations and document examination. By cross-referencing interview responses with field observation and secondary information, this research enhances the dependability of outcomes and offers comprehensive knowledge of the remanufacturing process. Interviews also offer a means to obtain organisational and social elements of remanufacturing, such as the existence of workforce abilities, decision-making on process adaptation, and the company's response to environmental policy.

To increase the reliability and validity of the interview data, the two researchers interviewed in pairs so that multiple perspectives were captured in analysing the data. With this methodological approach, combining LCA and process mapping is more strongly validated, enabling more precise advice on how remanufacturing performance for sustainability and efficiency can be improved. Through careful analysis of the interview results, this study provides an improved circular production systems understanding and evidence-based information for remanufacturing optimisation in the furniture industry.

3.3.2 Observations

Observations play an important role in this research, which supports the goals of LCA and process mapping by offering first-hand knowledge of the remanufacturing process and its effects on the environment. The Toyota Production System (TPS) concept of the Gemba walk, which emphasises direct observation at the location where value is created, is an observation technique employed in this study (Imai, 2007). To learn how material flows, process inefficiencies, and non-value-adding activities affect environmental performance, facilities should conduct Gemba walks (Soliman, 2020). Observing how furniture components are disassembled, refurbished, and reassembled, this study aims to identify critical activities, waste generation points, and opportunities for process optimisation that could enhance circularity (Kalman, 2002).

Unstructured field observations give the data collected for process mapping and LCA an extra level of contextual understanding. As Fetters and Rubinstein (2019) point out, such observations ensure a more thorough evaluation of environmental and operational performance by placing other research findings in context. Important insights into the real-life challenges of circular production models can be gained by observing how employees participate in remanufacturing procedures, how materials are managed, and how choices are made about product recovery and disposal (Yin, 2017). Furthermore, Thomas (2022) highlights that field observations provide a deeper understanding of organisational and social factors, such as operator engagement, process standardisation, and environmental compliance, that affect the success of remanufacturing.

Both researchers make observations concurrently to reduce bias and improve reliability, making sure that different viewpoints are taken into account as recommended by Yin (2017). This strategy will increase the validity of the results and ensure that the integration of process mapping and LCA are based on practical operational insights. This study supports more efficient environmental assessments in remanufacturing processes and helps improve circular production systems in the furniture industry by methodically examining these observations. This technique was conducted during the field trip to Gärsnäs's production facility on 12/2 2025, which provided valuable insights regarding the remanufacturing process. The field trip to Gärsnäs was the only on-site data collection conducted because the other companies did not have the opportunity to organise this type of activity.

3.3.3 Document Study

The quantitative information gathered in this study is utilised for partial LCA as well as process mapping. This means that the data is related to the C and D stages in an LCA, as highlighted in Figure 5. Information is basically gathered in the form of Excel sheets and EPDs, which are requested after on-site observation during a site visit or after interviewing influential actors who have significant information regarding the remanufacturing process. This approach ensures that the information gathered is applicable to the purpose of the study and leads to a general analysis of the remanufacturing system. By linking data collection with first-hand data from industry experts and on-the-spot observation of the process, the reliability and applicability of the results are increased.

In addition to primary data gathered through interviews and direct observation, secondary sources of data provide valuable information about the materials and chemicals used in the remanufacturing process. This includes reading reports such as Bills of Materials (BOMs) and EPDs, which detail the materials used in manufacturing and remanufacturing. Information about the types of wood used, whether sustainably sourced or not, is also taken into account. Secondly, the research considers data on adhesives and coatings such as traditional wood glue, two-part adhesives, and polyurethane-based lacquers, because these items affect the product's lifespan and environmental impact. The chemicals used to clean and finish the surface of the furniture are also included in the provision of complete information on the materials involved in the process. Some data is difficult to obtain, so it is justified that it is easier to use data from datasets used by Bianco et al. (2021), who created an LCA calculator using Excel.

3.4 Reliability and Validity

Transparency in the methodology chapter makes it possible to build on the findings or replicate the study, increasing the validity and reliability of the research (Kallet, 2004).

The study employs a triangulation technique to improve validity and reliability by combining multiple methods and data sources. According to Noble and Heale (2019), the approach identifies a common goal that the data from different sources points to. This means that the information is verified from different perspectives or different sources. However, the fact that part of the data is obtained from a secondary source and that the initial methodology may not have been trustworthy or reliable presents an additional risk to reliability. However, since the data is used for improvement and not auditing or external reporting, it can be considered transparent, reliable, and useful for the objectives of this research.

Thematic analysis is used, and the reliability of this study is increased by the use of themes, which will offer a more objective opinion and less subjectivity in the findings, as pointed out by Nowell et al. (2017). Some of the quotes which the codes are based on are also included in the appendix so that the reader has the information they need to assess how objectively the themes in the analyses chapter are developed.

For a more detailed description of the thematic analysis, first, coding is done, and this is the phase where the data is made familiar, meaning it is revisited repeatedly to generate the initial code themes. Coding allows for simplification and focus on specific data aspects, allowing for a transition from unstructured data to more structured ideas. During the process, critical sections (quotes) of the text taken from the transcript of the interviews are labelled as they relate to a trend or issue mentioned repeatedly in the interviews. This process is done independently between the two researchers and then compared to achieve the best result as suggested by Nowell et al. (2017). The next phase is to search for themes amongst the codes, and these themes are reviewed and given a representative name. The last step is to search for aggregate dimensions based on the themes generated. Of course, the aggregate dimensions are also reviewed and given names (Wæraas, 2022). Figure 6 summarises the steps of the thematic analysis and how the aggregate dimensions were conceptualised.

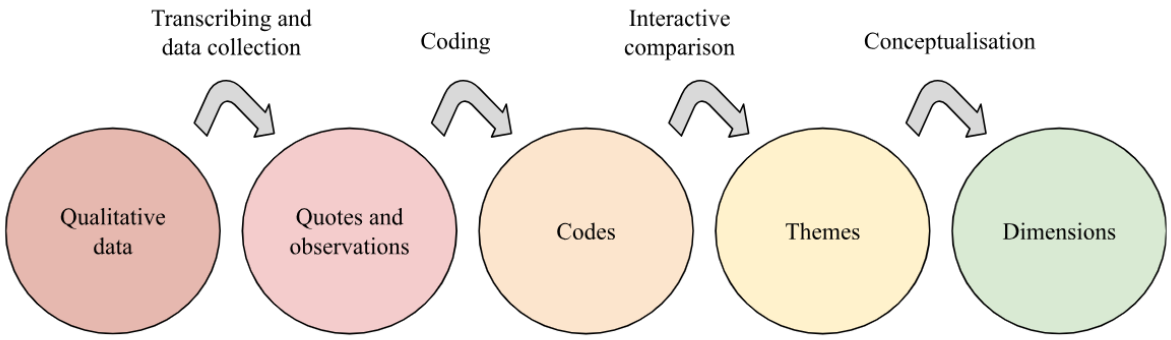

Figure 6: The steps involved in the thematic analysis

3.5 Ethical Considerations

In order to maintain the integrity and credibility of this research, ethical considerations are essential. Informed consent, voluntary participation, confidentiality, and anonymity are the four main ethical principles that have been carefully followed in this study.

Informed consent is an important ethical factor. All participants in the study were fully informed about the goals, purpose, and nature of their involvement in the research, as advised by Akaranga and Makau (2016) and Arifin (2018). Every participant received information about the study's completely voluntary nature and the fact that they could leave at any time without facing any consequences. This study respects ethical responsibility, fairness, and individual respect by obtaining informed consent.

Voluntary participation is the second factor. In accordance with Arifin's (2018) ethical guidelines, no participant was forced to participate in the study, and they were all granted the freedom to withdraw at any time. Interviews were prearranged through Teams to minimise any interference with the participants' work duties, enabling them to decline or reschedule as necessary. In order to respect their time constraints and guarantee minimal disruption to daily operations, interviews were also limited to 60 minutes.

Confidentiality is the third ethical principle that has been identified. Any information deemed confidential will not be included in this study due to the sensitivity of some of the case companies' data. Additionally, in compliance with the suggestions of Arifin (2018) and Akaranga and Makau (2016), participants' private information will not be shared. This ensures that all parties involved maintain a commitment to ethically handling data and respect the privacy of the organisations/individuals participating in the study.

Finally, all participants are offered anonymity, and this is a measure to enable interviewees to answer honestly and unbiased without having to worry about how their statements may affect their positions within their organisation.

This research upholds a high standard of integrity by following these ethical guidelines, guaranteeing that all participants and case companies receive respectful treatment and that their data and rights are not compromised during the study.

4 Findings

This chapter presents the findings of the research. The findings based on the interviews and the observation are presented together to aid in mapping the processes for each company.

4.1 Description of the Remanufacturing Process

The main focus of the interviews is the remanufacturing process. Qualitative data is collected by conducting interviews with key employees and an observation in one of the case companies. The interviews provide insights that can be analysed to help answer the research questions. It is worth noting that the full interview descriptions are available in the appendix, and they are verified by the interviewees.

4.1.1 Interview with Ekdahls

Based on the interview with the co-owner of Ekdahls, one of the key challenges in remanufacturing is logistics. Transporting used furniture for refurbishment is costly and inefficient, particularly when individual chairs or small batches are sent back. In addition, the company faces critical activities in the remanufacturing process due to the manual nature of refinishing and lacquering, as well as the limited availability of skilled labour in specialised areas such as upholstery and lacquering.

Despite the challenges, the company continues to evaluate opportunities to expand its remanufacturing capabilities and improve the sustainability of its operations. The chair remanufacturing processes at the company are illustrated in the flowchart in Figure 7. From studying Ekdahls' remanufacturing process, the initial event that happens is that the items are transported to Ekdahls' facility in Skillingaryd. Upon arrival, there is a decision point to determine whether the refurbishment work can begin immediately or if the furniture needs to be stored due to existing production commitments.

Once the process is started, the first step is to receive and check the furniture. This includes an initial condition assessment to determine what needs to be restored or replaced. The furniture then goes through a cleaning stage, where dirt and surface contaminants such as oils and old finishes are removed. After cleaning, a structured inspection is performed to evaluate the integrity of the joints, frames, and materials to identify areas that need repair.

Next, any necessary repairs are performed to restore structural strength. This is followed by a surface treatment, typically involving sanding to prepare the wood for a new finish. After being sanded, the furniture is painted according to the customer's specifications. After that, if upholstery is required, the process includes a decision point: whether to replace the fabric. If so, the old fabric is removed and new fabric is applied. This step often depends on the customer's preferences regarding fabric type and style.

Following aesthetic and structural restoration, the furniture is subjected to a quality check to ensure that it meets the standards of Ekdahls. Once approved, the item is packaged and returned to the customer via transport.

This remanufacturing process allows Ekdahls to extend the lifecycle of their products, offering a sustainable alternative to new furniture production while maintaining their commitment to craftsmanship and quality.

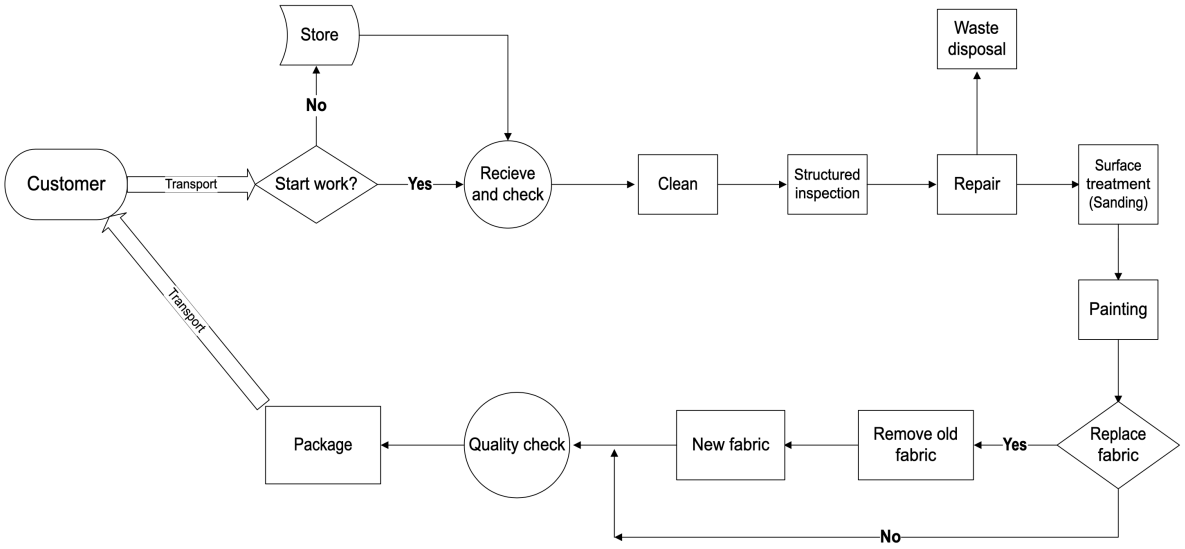

Figure 7: Flowchart of Ekdahls' remanufacturing process of a chair

4.1.2 Interview and observation at Gärsnäs

Based on the interview with the CEO of Gärsnäs and the observation data collected during the Gemba walk at the factory, it was noticed that the company demonstrates a proactive approach to refurbishment, considering it as a core part of their sustainability strategy. It was also noticed that Gärsnäs focuses exclusively on remanufacturing and refurbishing their own products, which allows for better process control and standardisation as claimed.

The process begins with requesting pictures of the furniture for an initial inspection. After that, the remanufacturing process usually starts when they receive used furniture from clients, as illustrated in Figure 8. Once the items arrive at the facility, each one is carefully evaluated to determine its condition. Depending on how worn it is, the furniture will either be set aside for minor refurbishment, such as fabric replacement or cleaning, or it will go through a more comprehensive remanufacturing process. This can involve disassembling the piece, reglueing joints, repairing or replacing damaged wood parts, sanding, repainting, and re-upholstering.

The company distinguishes between "easy" refurbishments, such as minor cleaning or textile updates, and full refurbishments, which involve disassembly, reglueing, reupholstering, and repainting. A notable feature of their operations is the modular design of some furniture lines, such as converting the "Day" model into a "Dino" chair, allowing part interchangeability.

The CEO emphasised the importance of customer involvement throughout the process, especially when estimating costs for large orders. A challenge arises when customers provide underused chairs as representatives, skewing cost and time estimates. This misrepresentation complicates the cost and time estimates. Therefore, to manage this, Gärsnäs involves customers early in the process and relies on detailed documentation and clear communication to define project scope and pricing.

Another critical area is logistics. Like other SMEs, the transport of single items is costly and often inefficient, leading the company to explore local refurbishment as a more practical alternative, especially for clients located far from the facility. Gärsnäs is also exploring digital tracking solutions such as product passports with QR codes to improve traceability and serviceability in the future.

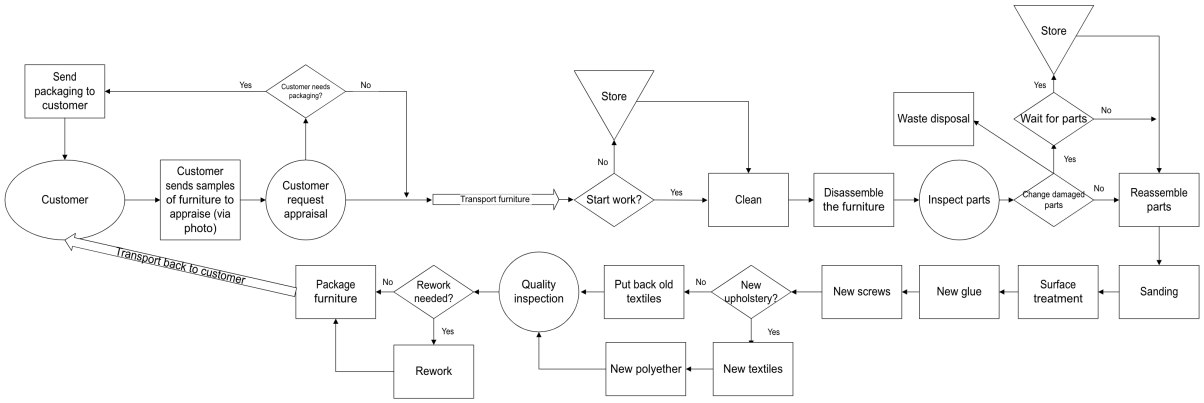

Figure 8: Flowchart of Gärsnäs' remanufacturing process of a chair

The Gärsnäs furniture remanufacturing process, presented in Figure 8, shows a systematic and well-integrated sequence of activities that combine sustainability with operational efficiency.

4.1.3 Interview with Gemla Möbler

Based on the interview with Gemla's range manager, one of the key challenges in the remanufacturing process is internal logistics. Although the company offers transport through logistics partners, managing the movement, storage, and packing of furniture within the factory is time-consuming and does not directly add value from the customer's perspective. Another major bottleneck is in the upholstery department, where only two employees handle all the reupholstering tasks. This creates delays during larger restoration projects. The company also faces difficulties when incoming items arrive in a worse condition than expected, often requiring additional repairs or part replacements that were not initially planned.

Despite these challenges, Gemla maintains a strong focus on sustainability and continues to develop its remanufacturing operations. Restoration work is integrated into the company's regular production flow, and all activities are performed in-house, ensuring high quality and control. The company has also begun to explore the use of abrasive blasting technology to increase the efficiency of surface treatment. However, it has yet to be permanently implemented.

The chair remanufacturing process of Gemla Möbler is illustrated in the flowchart in Figure 9. The process begins when a customer requests the restoration of used furniture. Gemla arranges transport through their logistics partners and receives the furniture at their production site in Diö. Once the furniture arrives, the company assesses whether the restoration process can begin immediately or if the item needs to be stored until production capacity becomes available.

The initial inspection is where the structural integrity and condition of the furniture are examined. A key insight from this stage is that Gemla prioritises ensuring the construction is stable before moving on to aesthetic work. If the structure is too compromised, the company may decline the project. For accepted pieces, the next step is disassembly, which often includes replacing screws, reglueing joints, and repairing or replacing wooden components to restore the original strength of the frame.

Following disassembly, the item is cleaned, and surface treatments are considered. Customers can choose between retaining a vintage appearance or a new finish. Obtaining certain finishes, such as oil treatments, can be difficult when old lacquer remains on the surface, which poses a technical limitation. If upholstery work is required, the next step is to remove the old padding and fabric. Then, new upholstery is applied using only natural materials such as horsehair, latex, and wool. The choice of fabric or leather is made in consultation with the customer, allowing for a high degree of customisation. After reupholstering, the furniture undergoes final assembly and a quality check to ensure it meets Gemla's standards. Finally, the piece is packaged and returned to the customer. In some cases, the company provides temporary replacement chairs during the three to five-week restoration period.

Each restored piece comes with a renewed five-year guarantee, equivalent to newly manufactured products, underscoring the company's commitment to longevity and quality. Gemla states that with proper usage and remanufacturing, furniture can last forever.

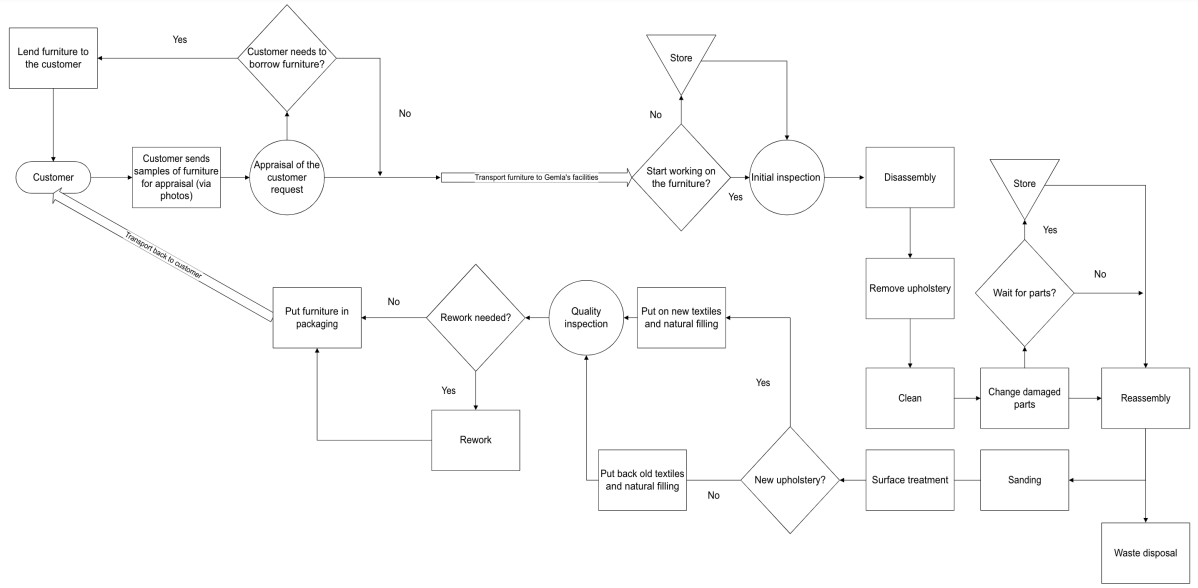

Figure 9: Flowchart of Gemla's remanufacturing process of a chair

4.1.4 Interview with Balzar Beskow

Balzar Beskow has developed an integrated remanufacturing process, with a strong focus on local supply chains and environmentally friendly practices. Based on the interview with the co-owner, the company shows a structured approach to refurbishment that emphasises product quality.

The company receives used furniture primarily through customer requests for refurbishment. The process begins with an initial evaluation, often supported by photographs or physical inspection of the product. After that, the refurbishment process proceeds with the packaging and transportation, as shown in Figure 10.

A major challenge highlighted was disassembly. When joints are tightly glued and structurally intact, the risk of causing damage during disassembly is high. In such cases, minimal intervention is preferred. The company is transparent about what can realistically be restored, especially when furniture is used and damaged a lot. On the other hand, the large production facility, covering approximately 7,500 square meters, is considered advantageous because it supports efficient internal logistics. Moreover, manual sanding is used to preserve wood grain, and the company avoids abrasive blasting for this reason.

The company is developing digital product passports with QR codes. These will contain information about product specifications, material origin, and care instructions to support future remanufacturing or refurbishment needs. Moreover, the company already offers extended warranties, typically five to ten years, on remanufactured products, further supporting their goal of product longevity and value retention.

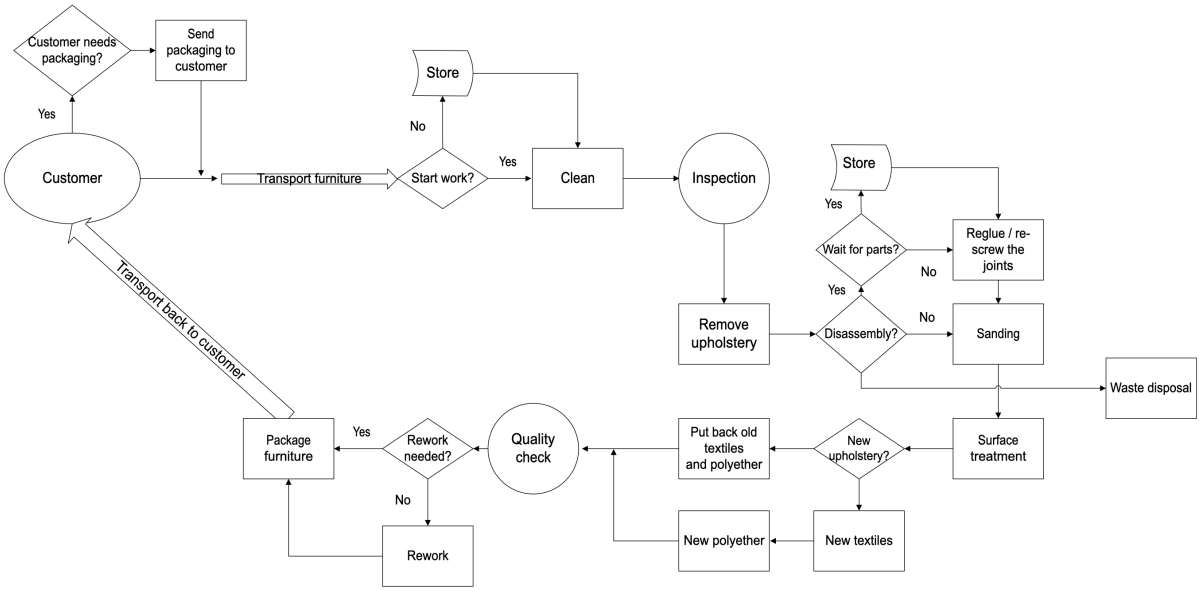

Figure 10: Flowchart of Balzar Beskow's remanufacturing process of a chair

This process, illustrated in Figure 10, highlights Balzar Beskow's methodical and quality-oriented remanufacturing approach that complements its brand identity and sustainability objectives.

4.1.5 Interview with Götessons

Götessons is focusing its circularity efforts through the LOOP system, a take-back scheme designed to retrieve used furniture. The system is still developing, and more product groups are constantly being added.

One key challenge is the complexity of handling returned items since there is no steady flow of returns. Transportation logistics, including the packaging and handling of bulky and varied items, lack standardisation, resulting in inefficiencies in the logistics. The sustainability developer noted that marketing and communication play an essential role in promoting the value of the LOOP system to customers. Moreover, the company depends on the retailers to communicate with end customers to obtain used furniture.

A key insight from the interview was the importance of clear terminology. Terms such as "reuse," "remanufacture", and "recycle" are not always interpreted uniformly by customers, which leads to mismatched expectations. Götessons is addressing this by improving how these concepts are explained in their marketing. Therefore, marketing is considered essential to make customers aware of circularity to make the LOOP system successful.

Götessons currently limits refurbishment to their own products to maintain quality standards. The company sees potential in expanding the LOOP tack-back system. The sustainability developer emphasised that creating long-term value from the LOOP system will depend on data-driven environmental impact analysis, such as LCA, and technological enablers like digital product passports. Also, partnerships with companies that are developing innovative solutions are essential in the near future to improve the remanufacturing process. These tools and strategies will help both the company and customers track materials and understand the impact of choosing remanufactured options.

4.1.6 Interview with Maze Interior

Maze Interior has a different sustainability perspective and a way of working that is different from the other five case companies. While the company provides limited refurbishment services on request, these offerings are not yet systematically integrated into their business model. Such services are economically and environmentally viable only when the remanufacturing volumes are sufficient to justify transportation costs and production line integration.

For example, they usually use recycled steel, which drastically minimises the environmental impact compared to virgin steel. Regarding wood materials, the company prioritises certified wood from local sources over recycled alternatives, citing cost prohibitions and limited availability of recycled wood products as the main reasons behind this decision. Also, this approach emphasises traceable supply chains to ensure environmental responsibility.

Their design philosophy incorporates transport optimisation and modularity to facilitate disassembly, repairs, and component upgrades. Upholstery presents a specific challenge, with potential improvements identified in removable cushions and covers to enhance refurbishment scalability.

Digital product passports were identified as a potential solution to enable third-party furniture refurbishment by providing essential technical specifications. However, implementation poses significant resource challenges for smaller enterprises, such as Maze Interior.

Maze Interior exemplifies a business with established foundations for circularity through material sourcing and design strategies. While comprehensive remanufacturing is not currently central to operations, the company continues to explore furniture life extension opportunities and to be prepared for evolving regulatory requirements in this industry.

4.2 Quantitative Data Findings

The main focus of this subchapter is to present the data which is used for the analysis of the impact of the remanufacturing process. This data provides insights that can be used to help answer the third research question by comparing the data from the EPD to the outcomes of the calculations of the remanufacturing impact. It is worth noting that datasets and reasonable approximations are also used to aid in answering the third research question. The data used are the following:

- Datasets, 4 data points: fibreboard density of 730 kg/m3, wood density of 600 kg/m3, foam density of 50 kg/m3, and wool density of 35 kg/m3.
- Approximations, 4 data points: Transportation of raw material 333 kg/km, Transportation of furniture 2107 kg/km, amount of wood replaced of 0.3 kg, and the average lifetime of a remanufactured wooden chair of 5 years.
- Data from EPD, 3 data points: Amount of steel (0.09 kg), varnish and paint (0.24 kg), and plastic used (0.01 kg).

The datasets' data are from Bianco et al. (2021). The reasonable approximations are based on the interviews, which include how much material (wood, metal, etc.) is replaced. Also, the average transportation distance is related to the process of remanufacturing. To add transparency, it was made obvious in the interviews that transportation of furniture was made equally frequent to the Malmö, Göteborg, and Stockholm regions. So, the average of transportation data is based on the data sent by Gärsnäs.

To give meaning to the outcomes of a remanufactured chair from the circular LCA calculator, they will be compared to the outcomes of producing a new chair from the EPD Light & Easy 4594:

- GWP (excluding biogenic carbon)= 14.30 kg CO eq.
- Acidification = 0.109 Mole H+ eq.
- Freshwater Eutrophication = 0.00089 kg P eq.
- PM / Respiratory inorganics = 0.0055 unit: disease incidence.
- Human Toxicity = 4.65×10 CTUh
- Freshwater Ecotoxicity = 1009.574 CTUe

5 Analyses

In this chapter, the thematic analysis of the interviews and observations is presented.

5.1 Thematic analysis

The thematic analysis of the interviews helps identify the key steps and critical activities. Through the identification of common codes brought up in the interviews, which match the predefined codes in 3.1 Research Design, trends describing key steps and critical activities can be found. Codes generated through the thematic analysis of the interviews are illustrated in Table 2, creating themes to help deepen the understanding of the remanufacturing process.

Table 2: *Codes and their respective number of mentions*

Codes	**Number of mentions**
Refurbishment/Remanufacturing	99
Price/cost	59
Material (wood, textile, glue)	43
Transportation/Logistics	39
Quality/Guarantee	37
Environment/Circularity	27
Design	26
Upholstery	21
Collaborations & partners	18
Challenges	15
Work on own vs others	15
Sanding	14
Product pass/QR codes	13
Chemicals	12
Disassembly	12
Technology	12
Storage	7

The initial codes are employed to generate themes that act as main categories of the codes. After applying the codes to the transcripts of the interviews, similar codes were grouped together, and a concise name was given to that group. These categories are considered the main topics or patterns in the interviews. Table 3 presents these themes in an organised manner. The themes in Table 3 are the interpretation of the findings of the interviews, revealing important patterns which represent both solutions, challenges, or key steps.

Table 3: *Themes based on codes*

Codes	**Themes**
Design Disassembly	Modularity
Quality/guarantee Price/cost Chemicals Materials Challenges	Product and supply characteristics
Sanding Upholstery Remanufacturing/refurbishment Work on own vs others	Labour activeties
Transportation/logistics Storage Collaboration and partners	Logistics
Environment/circularity	Sustainable Considerations
Technology QR code/Product pass/stamps	Technology

The identification of the themes with the combination of the observations is necessary to aid the identification of key steps that help the mapping of the remanufacturing process, and to identify the critical activities and insufficiencies in the process. This helps improve the remanufacturing process as a whole.

Based on Table 3, the modularity theme is generated by combining the design of the furniture and the disassembly of the different parts. To make the disassembly process easier, a more modular design can be implemented, which will help to replace broken parts more easily or even combine different parts to create a new piece of furniture. Incorporating modularity into furniture simplifies the remanufacturing process and improves sustainability.

The codes of quality/guarantee, price/cost, chemicals, materials, and challenges represent product and supply characteristics. These codes form the foundation of the process of remanufacturing itself. Understanding and managing these characteristics is essential to satisfy the customer and optimise the process.

As for the activities performed during the process itself, the codes of sanding, upholstery, remanufacturing/refurbishment, and companies working on their own products vs not refurbishing other companies' products are all categorised under the theme of labour activities. Skilled labour is necessary to perform quality refurbishing work and to make the furniture look as good as new. Identifying labour as a theme highlights the importance of human input in remanufacturing. Therefore, training and standardising processes related to labour strengthens and improves remanufacturing efficiency, which is the motivation for why this is an important theme.

In terms of logistics-related activities, such as transportation, packaging, storage, and collaboration and partners, are categorised under the theme of logistics. Since remanufacturing involves transporting and moving furniture, it probably has many insufficiencies and delays. Therefore, by recognising logistics-related activities as an independent theme, the process map can better identify systemic challenges and find opportunities to streamline flows.

As for the theme of sustainable considerations, it comes from combining the solutions of environment and circularity with overcoming challenges in remanufacturing. Identifying sustainable considerations as a theme highlights how remanufacturing can be considered a strategic advantage in today's market. Therefore, considering the strategic side of this theme helps to meet circular economy goals, attract conscious customers, and/or satisfy legal requirements. Moreover, if this theme is not addressed properly, companies risk losing competitiveness or reputation, which is the motivation of why this is an important theme.

Lastly, the theme of technology includes the different technologies involved in the remanufacturing process, and they are QR codes, product passports, and product remanufacturing stamps. These codes support transparency, traceability, and data sharing. Other technologies, such as sandblasting and robotic sanding, were mentioned as well. In the end, technology also reduces human error and supports decision-making. As a theme, it highlights the digital backbone required to scale remanufacturing efficiently and transparently.

Based on the themes identified in Table 3, aggregate dimensions were formed to categorise the themes as seen in Table 4, in a similar manner to the way the themes were formed. The two dimensions offer a deeper level of understanding of what is required to make the remanufacturing process without any inefficiencies or critical activities, and the enablers which improve the process by improving these enablers. By distinguishing between the organisation's process potential and its operational requirements, the framework highlights where improvements can be made to reduce critical activities, enhance efficiency, and support more sustainable remanufacturing systems.

The first aggregate dimension, called operational requirements, covers the topics of labour activities, logistics, and product and supply characteristics, all of which are related to the daily operations of the remanufacturing process. This means that this dimension is for the key steps and critical activities of the remanufacturing process.

These themes highlight the key operations that must be performed continuously to carry out the remanufacturing process successfully. These are manual processes, characterised by being skill-intensive, that often become critical activities in remanufacturing if not properly resourced or planned. These themes highlight the key operations that must be constantly performed to carry out the remanufacturing process successfully. Therefore, it is crucial to optimise these areas to enable scalability and consistency in remanufacturing output, as well as to reduce inefficiencies and critical activities. The themes captured in this dimension help answer research question 1.

The other dimension is process potential. It captures the foundational strengths and enablers that allow companies to effectively improve the remanufacturing process. In other words, this dimension is about improving the remanufacturing process potential. It is composed of the themes of modularity, sustainable considerations, and technology, all of which are closely related to improving the overall performance, responsiveness, and strategic value of the remanufacturing process.

These themes represent the capabilities that organisations need to build or strengthen to improve their remanufacturing practices. Improving these areas not only enhances process efficiency but also increases the strategic value of remanufacturing. The themes captured in this dimension can be the main topics which answer research question 3. The interviewees mentioned these topics during the interviews either as a future investment opportunity or as part of their current operations. In both cases, this means that companies have a potential that can be improved, which in turn improves the remanufacturing process.

Table 4: *Aggregate dimensions from interviews*

Themes	**Aggregate dimensions**
Product and supply characteristics Logistics Labour activities	Operational requirements
Modularity Sustainable considerations Technology	Process potential

Figure 11 is a generic flowchart with all the steps identified in the remanufacturing process of a wooden chair with as many details as possible, as suggested by Gilbreth and Gilbreth (1921), and it goes hand in hand with the definition of remanufacturing by Sundin (2004). This flowchart is based on the flowcharts of the remanufacturing processes of the case companies, mentioned in the findings chapter. Next to the symbols, inspired by Damelio (2011), numbers are added to make it easier to refer to a specific step of

the process. In the following, a description of each step is provided. Therefore, identifying key steps of the process is enabled using the generic flowchart (Kalman, 2002; Kumar & Phrommathed, 2006).

1. The customer marks the beginning and the end of this process.
2. In this step, the customer has contacted the company for remanufacturing and needs to send a photo or a sample of furniture to the company so that the workload and cost can be planned.
3. At this checkpoint, the company receives material from the customer, and based on that, estimates the amount of work and the cost of remanufacturing.
4. If both parties agree to go through with the remanufacturing, the companies can offer additional services to the customer, such as sending them appropriate packaging for the transportation or lending them furniture until the furniture returns to the customer.
5. This step symbolises the process of providing the extra service to the customer in terms of sending them packaging materials or lending them spare furniture until the remanufacturing is done.
6. This arrow symbolises the transport of the furniture to the factory for remanufacturing, and this is done via lorries.
7. When the furniture arrives, the companies can either start working on it directly or store the furniture on site until they are ready to begin the remanufacturing.
8. This symbolises the step of storing the furniture.
9. When remanufacturing work begins, the furniture is inspected, cleaned, and disassembled, including the removal of upholstery.
10. The parts that are deemed to be worn out or broken need to be changed.
11. New parts are either already readily available or not available. If the parts are not available, they have to be manufactured or delivered from a supplier.
12. The furniture needs to be stored until the new parts arrive.
13. When the new parts arrive or the old parts can be used again, they will be reassembled again.
14. After the furniture has been reassembled again, it is sanded down to smooth out surfaces and remove old varnish and paint.
15. After sanding, the furniture is repainted or revarnished.
16. This is a decision point where it is decided whether a new upholstery should be placed on the furniture.
17. In this step of the process, old leather or textile is placed on the furniture.
18. If the original textile is used, it is also possible to reuse the old filling.
19. In this step, new leather or textile is placed on the furniture.
20. If a new textile or leather is added, it is also possible to add a new filling.
21. After remanufacturing is done, the waste needs to be disposed of. This includes taking scrap metal to the recycling plant or burning the leftover wood.
22. Before the furniture is sent back to the customer, a final quality check is performed.
23. From the quality assessment, a decision is made whether or not rework is needed.
24. This part of the process symbolises the rework that is needed if the quality assessment is not passed.
25. Before the furniture is sent back to the customer, it needs to be packaged.
26. This arrow symbolises the transportation back to the customer.

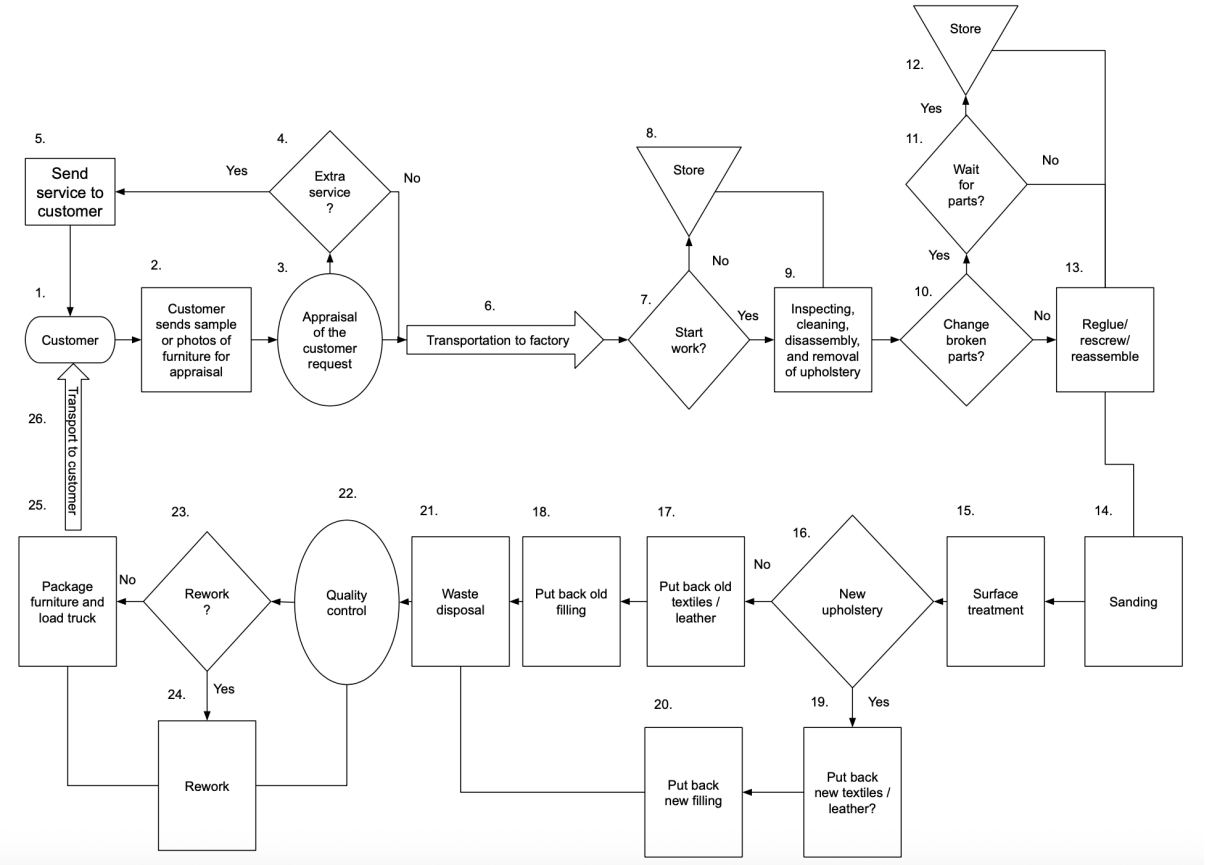

Figure 11: Generic flowchart of the remanufacturing process

5.2 Remanufacturing Impact Analysis

The input values used to calculate the environmental impact from the remanufacturing process are based on data collection in the form of BOMs, EPDs and Excel sheets containing information about the products from the case companies. The impact is estimated using the circular LCA framework illustrated in Figure 12. This framework is the product of the flowcharts in 4.1 in the findings chapter, with the LCA card shown in Figure 5 in 3.1 Research design.

The data collected from the BOMs and EPDs of the companies is used to evaluate the environmental performance of the remanufacturing process within Swedish furniture SMEs. The means of performing these calculations is an Excel-programmed environmental impact calculator. It was originally developed by Bianco et al. (2021), and has been modified and tailored to focus exclusively on the C1–D3 stages of the life cycle as illustrated in Figure 12. This means that it aligns with the remanufacturing phase as defined in this study. The metrics included in the environmental impact calculator are derived from the interviews and observations, which made it clear what to exclude and ensured that all relevant data used in the calculations are related to stages C1-D3.

The goal of this customised LCA tool is not to assess the entire lifecycle of a product but rather to develop a practical, scalable method for companies to evaluate the environmental gains, or trade-offs, when choosing remanufacturing strategies over conventional production or disposal.

Based on the analysis, flowcharts of the steps included in the remanufacturing process are produced and identified. It is made clear what is included when remanufacturing furniture, and this has enabled the creation of a circular LCA framework, as highlighted in Figure 12[4]. In this figure, the remanufacturing process is defined from C1 to D3 and highlighted within the red boundaries. It accounts for the environmental impact of the transportation back to the producer, the labour required to remanufacture

[4]This figure was inspired by the work of International EPD System (2021) and Damelio (2011).

the furniture at the plant, the packaging, transport back to the customer, and the use phase of the furniture.

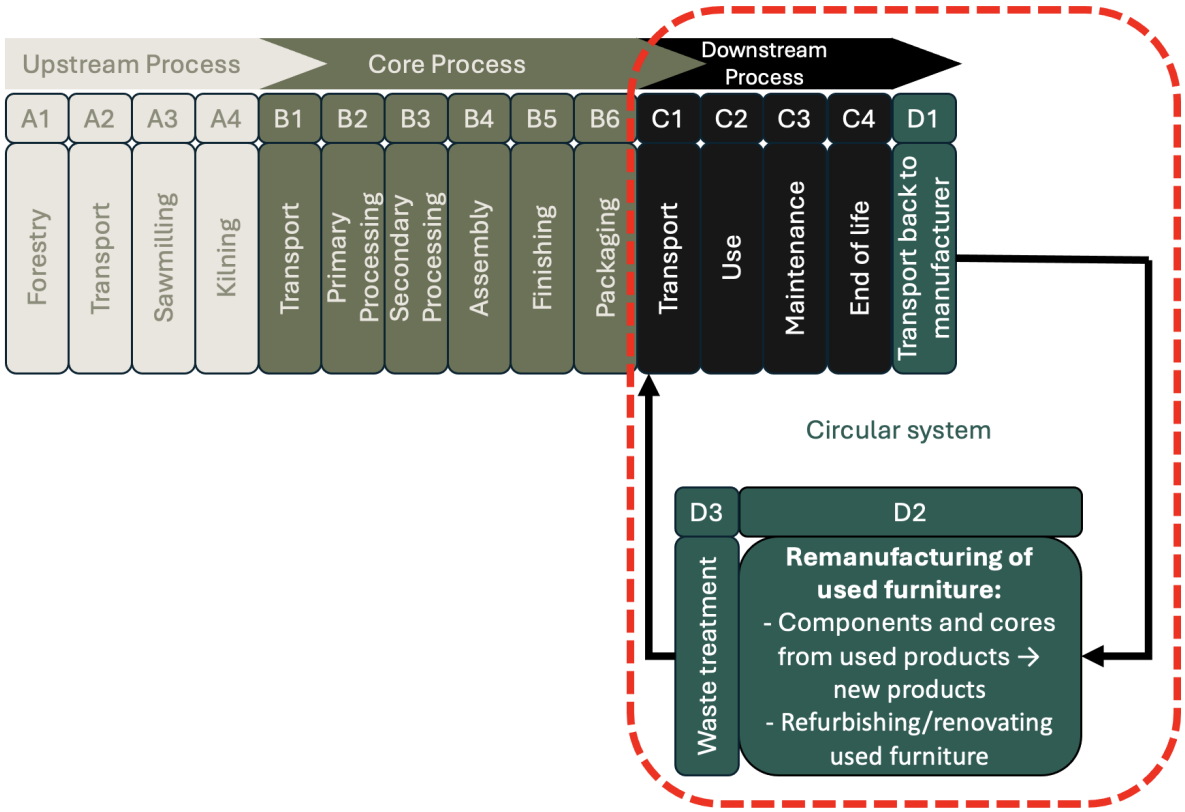

Figure 12: Circular LCA card and with remanufacturing process circled in red

Figure 12 works as a framework to understand what is taken into consideration when quantifying the environmental impact of a generic piece of remanufactured furniture, in this case, a wooden chair. This framework is the main piece that helps answer research question 2. It is used to understand and visualise which part of the process is important to focus on and quantify.

From these steps and building on research by Bianco et al. (2021), an environmental impact quantification calculator, tailored for a circular material flow in the furniture industry, is programmed. This calculator accounts for the environmental impact of remanufacturing a generic wooden chair and is included in the appendix.

The values presented in chapter 4.2 are extracted from Gärsnäs's EPD, datasets, and approximations are used to calculate the impact of remanufacturing of a simple wooden chair. The reason for using Gärsnäs's EPD is that it is for a generic wooden chair, and because most of the other companies would take back Gärsnäs's furniture and remanufacture it. Therefore, it is used to estimate the impact. It is worth noting that the circular LCA calculator can be used by other companies to estimate the impact of different furniture pieces.

The circular LCA calculator, which can be used as a CE framework (Niero & Kalbar, 2019), is used to estimate the environmental impact of remanufacturing in different categories similar to Bianco et al. (2021), including the following:

- The Global Warming Potential (GWP) is a measure of how greenhouse gas emissions contribute to climate change.
- Acidification assesses the potential of emissions to acidify ecosystems.
- Freshwater eutrophication is related to nutrient enrichment in freshwater, which can result in algal blooms and damage to aquatic ecosystems.

- Particulate matter (PM)/respiratory inorganics reflects fine particle emissions, which contribute to air pollution and can cause serious respiratory problems.
- Human toxicity determines the potential for chemical emissions to cause cancer in humans over a lifetime.
- Freshwater ecotoxicity estimates the potential harm caused by chemical emissions to freshwater aquatic organisms.

Figure 13 summarises the estimated impact of remanufacturing a wooden chair. In the calculations, it is assumed that 10% of the wood is replaced, as well as all the metal screws. Moreover, the sanding of the surface and the subsequent removal of the finishing/varnish is also accounted for, as well as the revarnishing/ refinishing. The model also quantifies the impact of the transportation of spare parts and the final remanufactured product from and to the customer and the treatment of all generated waste. Moreover, it is worth highlighting that the model includes the total impact of three remanufacturing cycles performed five years apart. This means that the model can use a functional unit of 15 years, which is the estimated lifecycle of a newly produced chair. Thus, it is ensured that it is a justified comparison between the remanufactured chair and the newly produced one.

Remanufacturing Impact	GWP (excluding biogenic carbon) [kg CO2 eq.]	GWP (including biogenic carbon) [kg CO2 eq.]	Acidification [Mole H+ eq.]	Freshwater Eutrophication [kg P eq.]	Particulate matter/respiratory inorganics [kg PM2.5 eq.]	Human toxicity (carcinogenics) [CTUh]	Freshwater ecotoxicity [CTUe]
TOTAL IMPACT (AVERAGE LIFETIME)	**2.466756**	**0.077497479**	**0.0162679**	**0.000897497**	**0.004139442**	**5.81146E-07**	**111.2438**
TOTAL IMPACT (15 YEARS, in comparison to a new piece of furniture)	**7.400268**	**0.232492436**	**0.0488037**	**0.002692492**	**0.012418326**	**1.74344E-06**	**333.7315**

Figure 13: A screenshot from the circular LCA calculator of the environmental impact of the remanufacturing process of a generic chair.

The total impact presented in Figure 13 is based on the following data:

- Wood (0.3 kg in SEMIFINISHED PRODUCTS and 0.3 kg in D2 Remanufacturing): Each 0.3 kg contributes approximately 0.23 kg CO2 eq. (excluding biogenic carbon) and -0.93 kg CO2 eq. (including biogenic carbon). The negative value for GWP (including biogenic carbon) is plausible for wood products due to the temporary storage of atmospheric carbon in the wood biomass. It is a plausible approximation that 10% of a chair is replaced on average, so 0.3 kg is a reasonable amount for the wood components replaced or added in a chair remanufacturing process, where the replaced part is burned.
- Steel (0.09 kg in SEMIFINISHED PRODUCTS and 0.09 kg in D2 Remanufacturing): Each 0.09 kg contributes approximately 0.37 kg CO2 eq. This impact per kg is higher than Wood, which is typical for steel.
- Acrylic Varnish (0.24 kg in Finishing): Contributes approximately 0.56 kg CO2 eq. This is a significant contributor among the listed materials.
- Transportation:
  - Raw Material Transport (393 kg/km): $\tilde{0}$.055 kg CO2 eq.
  - Furniture Transport (C1 & D1 - 2107 kg*km): $\tilde{0}$.36 kg CO2 eq. Transportation impacts can be significant, and these values depend on the accuracy of the mass and distance inputs.
- Waste Treatment (D3):
  - Paint Incineration (0.24 kg): $\tilde{0}$.27 kg CO2 eq.
  - Scrap Steel (0.09 kg): $\tilde{0}$.0013 kg CO2 eq. The much lower impact of scrap steel processing compared to primary steel production is plausible.

– Wood Landfill (0.3 kg): $\tilde{0}$.018 kg CO2 eq.

The fact that the GWP (including biogenic carbon) is positive, despite the negative contribution from wood, suggests that the emissions from other materials, processes (like varnish, steel, transport), and end-of-life treatments outweigh the biogenic carbon storage benefit of the wood. This general behaviour can make sense.
It is worth noting that the values presented in Figure 13 can be obtained by using the same inputs presented above using the circular LCA calculator, which can be downloaded and used using the instructions in Appendix 9.7.

6 Discussion

This section aims to provide an answer to the research questions. It is split into four subchapters, one for each research question and one chapter for a discussion of the research method.

6.1 Results Discussion

This subchapter presents the answer to the three research questions and discusses the analysis related to each research question.

6.1.1 Research Question 1

Highlighting key steps and critical activities in the remanufacturing process, the interviews and observations suggest a commonality of activities that seem more important compared to the rest. Firstly, the critical activities are highlighted, and within these activities, key steps are highlighted and explained.

The first one that stands out is the cost and workload appraisal. Although this activity is not considered time-consuming, it is critical to get it right to avoid the domino effect that can be caused further in the process flow if this activity is not done correctly. This is something that the co-owner of Ekdahls, the CEO of Gärsnäs, the range manager of Gemla, the co-owner of Balzar Beskow, and the sustainability developer at Götessons agree on. Time-consuming consequences of an inaccurate workload appraisal for remanufacturing are typically disruptive to the planned workload. As more work is needed to finish the project, the cost increases, which can lead to extra negotiations with the customer over price.

This activity includes the second and third steps, as shown in Figure 14, which highlights the key steps in what are considered critical activities in the remanufacturing of a chair. This activity has a few layers of complexity that most of the interviewees seem to agree on. To expand on this, both the co-owner of Ekdahls, the CEO of Gärsnäs, the range manager at Gemla, and the co-owner of Balzar Beskow express the same view on the importance of involving the customer and of establishing how much the remanufacturing will cost and how the customer wants it done, while at the same time estimating the workload. The sustainability developer at Götessons agrees on this but also adds that the systems should be good enough to assess if a piece of furniture can be sold again without any remanufacturing if the company has this type of circular resale channel. In addition, properly establishing the cost and workload seems particularly important because it can create delays in the process. Both the CEO of Gärsnäs and the range manager of Gemla expand on this by agreeing on the fact that if the furniture arrives to them for remanufacturing in a condition that did not meet the one established from the appraisal, they might have to renegotiate the price with the customer since the workload gets higher than originally expected. All of the above seems to be related to the findings of Tveit et al. (2021), in that it is costly to evaluate whether furniture is suitable for remanufacturing. This is related to the theme of the thematic analysis of *product and supply characteristics*, which is part of the operational dimension of *operational requirements*, which confirms the need for these requirements as an enabler for the process, meaning that it cannot exist without it.

Extending the discussion on involving the customer and the expectations that need to be mutually established between the customer and the company, the co-owner of Ekdahls, the CEO of Gärsnäs, and the co-owner of Balzar Beskow all highlight the striving to deliver a quality result to the customer. They all agree that even though quality is important, it is not always possible or feasible to remanufacture furniture to a *brand new* condition. However, the value is preserved as best as possible (Circular Sweden, 2025). The most important thing is to live up to the guarantee that they offer on their product. Similarly to properly establishing the workload and cost, this aspect of the first key step is also related to the thematic analysis theme of products and supply characteristics of the operational requirements dimension. Thus, this is also an enabler for the process of remanufacturing.

A second critical activity that is highlighted in the interviews is logistics, or activities related to logistics and internal logistics. This includes steps 5, 6, 8, 12, 25, and 26, as shown in Figure 14. This is something that the co-owner of Ekdahls, the CEO of Gärsnäs, and the product & purchase manager at Maze Interior all highlight. They acknowledge transportation to be challenging in terms of environmental impact and cost. Also, transportation requires extra handling and leads to non-value-adding

activities such as packaging and loading the furniture on and off the truck. This is something that the sustainability developer at Götessons and the co-owner of Ekdahls point out, and the co-owner of Ekdahls further states that not all freight companies handle furniture and that it requires specialised packaging; hence, step 5. Moreover, the CEO of Gärsnäs, the range manager at Gemla, and the co-owner of Balzar Beskow state that they use their own trucks together with a third party to make this part of the process more manageable to gain more control. Also, transportation can lead to additional steps or services, as explained by the CEO of Gärsnäs, in the sense that customers sometimes need packaging sent to them for transportation. Furthermore, the research by Tveit et al. (2021) further underlines the cost of transportation and the non-standardised work associated with it as a challenge for furniture remanufacturers. Transportation falls under the thematic analysis theme of *logistics*, in the requirement dimension and is considered an enabler for remanufacturing.

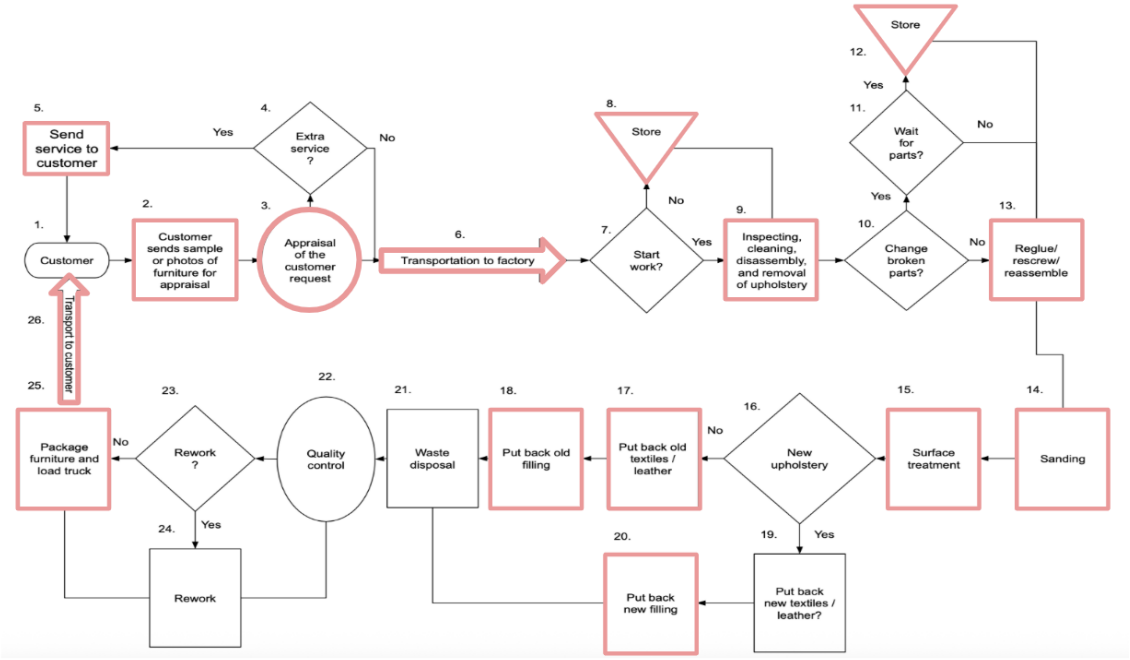

Figure 14: Generic flowchart of the remanufacturing process with key steps highlighted

Lastly, the last critical activity is manual labour, which includes steps 9, 13, 14, 15, 17, 18, and 20 in Figure 14. These key steps seem to be considered crucial to get right in terms of quality. It is clear that all of the companies in the data collection that offer remanufacturing as a service seem to have these steps in common. Expanding on this, the CEO of Gärsnäs states that glueing is important to get right to achieve the desired quality. Similarly, the co-owner of Balzar Beskow describes handling glued joints as important to the quality in the sense that it can be unnecessary to reglue a joint if it is not entirely loose. Furthermore, sanding is also a critical step. From the interviews, it is made clear that if the furniture sent for remanufacturing is very old or comes from another company, additional precautions for the workers must be taken into consideration because the varnish or paint might contain chemicals that are hazardous for humans to inhale. Therefore, the workers use protective gear when sanding the surfaces. According to the co-owner of Balzar Beskow and the range manager of Gemla, changing the upholstery is time-consuming. For each chair that comes in that needs new upholstery, the nails have to be removed and then put back again. If the number of employees in this department of the process is low, this becomes a time-consuming problem because the removal of the nails has a high throughput time. Furthermore, sanding can also be considered a time-consuming problem because it also has high throughput, as pointed out by the CEO of Gärsnäs, the range manager of Gemla and the co-owner of Balzar Beskow. Also, the co-owner of Ekdahls highlights another problem with sanding when using machines instead of manually doing it. Certain materials, such as particle boards, can damage the sanding machines, which, of course, causes further disruptions in the process. Although some steps in this activity are time-consuming, the remanufacturing process cannot exist without them. Moreover, these steps are operational and deeply tied to customer value perception. This means high-quality craftsmanship

in sanding or upholstery can determine whether the remanufactured item is seen as equivalent to new, thus directly affecting customer retention and product longevity. In the same way as the other critical activities, this one also falls under the thematic analysis theme of labour in the operational requirements dimensions, making it an enabler for the process.

Thus, to answer the first research question: What are the key steps and critical activities involved in the furniture remanufacturing process?, based on the analysis, three key steps have been identified:

1. Cost and workload appraisal (steps 2 and 3 in Figure 14).
2. Logistics and internal logistics (steps 5, 6, 8, 12, 25, and 26 in Figure 14).
3. Manual labour (steps 9, 13, 14, 15, 17, 18, and 20 in Figure 14).

6.1.2 Research Question 2

After identifying the key steps and critical activities of the remanufacturing process, the environmental impact of this process is estimated to investigate whether remanufacturing used furniture is better than manufacturing new furniture from virgin materials.

To answer the third research question: How can the environmental impact of the remanufacturing process be assessed?, the estimation of the environmental impact of the remanufacturing process is compared with the data of producing a new chair from virgin raw materials, as seen in Table 5. This is done to show how the estimations are calculated and what they mean in the remanufacturing setting.

Table 5: *Comparison of environmental impact categories between a remanufactured and a new chair*

Impact Category	**Remanufactured Chair (circular LCA calculator)**	**New Chair (EPD)**	**Change & Insight**
GWP (excluding biogenic carbon) [kg CO_2 eq.]	7.4	14.3	↓ 48% lower (fewer raw materials used)
Acidification [Mole H^+ eq.]	0.0488	0.109	↓ 55% lower (reduced industrial inputs)
Freshwater Eutrophication [kg P eq.]	0.0027	0.00089	↑ 3× higher (multiple rounds of refinishing)
PM / Respiratory inorganics [kg PM2.5 eq.]	0.0124	0.0055	↑ Higher (multiple rounds of sanding and varnishing)
Human Toxicity (carcinogenics) [CTUh]	1.74×10^{-6}	4.65×10^{-7}	↑ 3.75× higher (cumulative toxic exposure from refinishing)
Freshwater Ecotoxicity [CTUe]	333.73	1009.574	↓ 66% lower (fewer raw materials used)

The results and comparison with the EPD of "Light & Easy chair 4594" are as follows. For the GWP categories, the remanufactured chair (15 years) has an estimation of 7.400268 kg CO2-eq, whereas the newly produced chair has an impact of 14.30 kg CO2-eq according to the EPD. This means that remanufacturing a chair three times and extending its life to 15 years has almost half the impact of a newly manufactured chair. This number makes sense because most of the emissions in furniture come from the extraction of raw material, which is very little in the case of remanufacturing.

As for acidification, the remanufactured chair has a value of 0.0488 mol H+-eq in comparison to a new chair, which has 0.109 mol H+-eq. This is a drop with more than half the impact from the manufacturing of a new chair.

Regarding freshwater eutrophication, the remanufactured chair has performed worse with a value of 0.0027 kg P-eq, which is three times the impact of a newly produced chair with a value of 0.00089 kg P-eq. This is a feasible estimate, as the remanufactured chair has multiple rounds of sanding and finishing. So, the remanufactured chair generates more waste and requires more sanding and painting in its 15-year lifetime, with three rounds of refurbishment compared to one round of painting for a new chair. The comparison between a remanufactured and a newly produced chair is useful to give meaning to the values so that the impact is justified.

Estimating PM/respiratory inorganics, the new chair reported a lower impact than the remanufactured chair. The arguments are similar to those used to explain the arguments of freshwater eutrophication values. However, this category is more challenging to analyse since the new chair's value is reported in a different unit. However, the value of a remanufactured chair of 0.0124 kg PM2.5 eq looks higher than the new chair impact value of 0.0055 disease incidence estimated from the EPD. These values make sense due to the amount of sanding, varnishing, and transportation required for the remanufactured chair. Therefore, it is considered a heavy-duty refinishing process with high PM emissions.

Moving on to the toxicity categories, the human toxicity (carcinogens) value of a remanufactured chair is considerably higher than the value of a new chair. With a value of 1.74344 × 10 CTUh for a remanufactured chair vs 4.65 × 10 CTUh for a new chair. This means that human toxicity is 3.75 times higher

for a remanufactured chair. This higher impact can be attributed to the fact that the remanufactured chair requires more sanding and varnishing over the 15-year period. On the other hand, the freshwater ecotoxicity of a remanufactured chair is 333.73 CTUe, which is around a third of the value of a newly produced chair with a value of 1009.574 CTUe. This is explained by the reduced extraction and primary production of the materials used to manufacture the chair.

In summary, to answer the research question, the environmental impacts of key steps in the remanufacturing process can be effectively identified by modelling material inputs, process emissions, and waste output throughout the extended lifetime of the remanufactured chair and comparing them with the EPD data for a newly produced chair.

The comparison with the EPD reveals that remanufacturing significantly reduces climate impact and acidification potential while slightly increasing emissions in categories such as freshwater eutrophication and PM due to repeated refinishing steps. These results demonstrate that remanufacturing can offer substantial environmental benefits, particularly by avoiding emissions from raw material extraction and primary production. Its impacts can be meaningfully interpreted by aligning the output of the circular LCA calculator with benchmark values from the standardised EPDs or C2C scope of an LCA (Bjørn & Hauschild, 2018; Llorach-Massana et al., 2015). Knowing that remanufacturing has less impact on the environment encourages customers to collaborate more with the producer to assume more responsibility over their furniture throughout the life cycle of the furniture and to improve their decision-making regarding environmental, social and economic impacts (Sonnemann et al., 2018). This approach ties into conforming to EPR regulations using GSCM practices.

6.1.3 Research Question 3

After discussing how operational requirements in the thematic analysis are considered the critical activities, the dimension of process potential is discussed in this subchapter in a prescriptive and forward-looking approach with an analytical link to both the theory and data analysis.

Firstly, time-consuming consequences of an inaccurate workload appraisal for remanufacturing are typically disruptive to the planned workload. As more work is needed to finish the project, the cost increases, which can lead to extra negotiations with the customer over price and a domino effect on the steps coming afterwards. Here, the use of technology has the potential to strengthen the process against this, since QR codes, digital stamps, blockchain technology, and DPP can streamline the appraisal by tracking the identification and materials of the product. This is something that is coherent with European Union (2024b), the decision-making list mentioned by Jensen et al. (2023). Therefore, as for the way to improve the appraisal activity, several recommendations are suggested targeting Swedish SMEs. The first one is the use of digital tools. The use of DPP and QR codes makes it easier to track the changes that have been performed on the product. Moreover, the use of visual aids such as short videos of the worst, medium, and best conditions of the batch might be needed, and with the help of an appraisal expert, this stage should be streamlined. Another solution is developing a checklist as part of a standardised appraisal protocol and sending it to the customer so that the customer can perform an initial screening before the appraisal expert confirms the result. This can help shift the effort to the customer and speed up the process.

Moreover, the use of modularity can potentially make this process clearer when it comes to which parts need changing by only looking at the damaged parts using pictures, as some companies do at the moment, or by sending instructions on identifying the damaged parts. This means that by improving the process potential dimension, the process of remanufacturing can be improved while at the same time preparing the business for upcoming regulations (European Union, 2024a). Moreover, as the legislation associated with EPR develops, it is made clear that circular flows and the increased use of practices such as remanufacturing become inevitable. Therefore, it is recommended to make the assembly and disassembly easier. It is made evident from the interviews and observations that disassembly and reassembly are crucial steps, and sometimes the customer just wants a new upholstery or textile to cover the furniture. If this is easily changeable, the remanufacturing process is simplified, and the customer might not need to send the furniture back to the company to get a new textile for it. Instead, the customer can simply buy the textile themselves and easily put it back on the furniture. Also, having joints of wood that can easily be disassembled is beneficial because the remanufacturing process requires that some parts be changed. If this can be made easy for the workers, time can be saved, and the process can be made more efficient. These claims are coherent with the practices of EPR according to Naturvårdsverket (2023), as well as the benefits highlighted by Erixon (1996) and Tseng and Wang (2014). This means that throughput time goes down as a consequence of changing parts quicker, thus making continuous product renewal easier.

Manual labour activities are also related to technology issues, design for disassembly and modularity themes in the process potential. Improving process potential will minimise the impact of manual labour and improve the remanufacturing process as a whole. Regarding technology-driven recommendations related to manual labour that are worth investing in, several options exist. This includes automated sanding systems. As for robots and machines, it could be rewarding to invest in high-precision sanding robots or CNC-based prep machines to reduce manual labour during remanufacturing. This is especially useful for SMEs with capacity constraints in labour-intensive stages. Lastly, modular design systems can be used to help reduce the complexity of new products and to make them more modular and circular. Such investments can reduce or even eliminate the critical activities currently experienced by Swedish furniture manufacturers, both for remanufacturing and production in general.

In the data collection phase, some companies attributed this to the fact that no standard operating procedures exist when handling, packaging, and loading furniture. To resolve this, some companies have taken more control over this part of the process by engaging in partnerships with other companies. This means that they become less reliant on a third party to handle transportation, and they can work out their own systems and standard operating procedures to streamline the work, which is in line with the practice of environmental control in organisational design. Moreover, logistics issues are consistent with the claims made by Alvarenga et al. (2015), Bocken et al. (2016), Singh (2024), and Tveit et al.

(2021), that material recovery is difficult and that a recommendation to resolve this is to set up take-back programmes and closed-loop systems, which also enables furniture companies to comply with EPR regulations.

Another insight from the data collection was that some companies prefer to only work on their own furniture, and that they prefer it if other companies stick to the same principle. It is also made clear that some companies exist that solely focus on remanufacturing furniture for their customers. This brings both challenges and opportunities. On the one hand, there is a concern that the quality of the product can be compromised because it might not be remanufactured in a way that respects the initial design. From an environmental point of view, it is more beneficial if the furniture can be remanufactured closer to the customer. To resolve this, a recommendation that both guarantees quality and minimises the environmental impact is for companies to establish partnerships with each other. An example of this is if a furniture producer provides training on how to restore their products in the correct way to a furniture remanufacturer. This enables a guarantee of higher quality for the remanufactured furniture, as well as a reduced environmental impact, as the transportation distance can be reduced.

Overcoming the different specific challenges for each company is important to address. These problems are usually specific to the company, but solutions can improve the process in a different company that has not identified it as a problem yet. Improving circularity and reducing the environmental impact in general is beneficial for all companies. For example, it can be a problem if the environmental impact of remanufacturing is greater than the production of new furniture. However, this is not the case, as we can see from the discussion of the answer to research question 2. Another problem can be if the circular flow is inconsistent and has long lead times. This is related to the theme of sustainable considerations as part of the process potential dimension, where it is indicated that applying various lean methods to the remanufacturing process aids in achieving the circular economy goals by minimising waste and eliminating inefficiencies. This is consistent with the idea of implementing lean-driven sustainability initiatives to improve product quality, reduce lead times, and increase customer satisfaction (Bocken et al., 2016; Cherrafi et al., 2018; Mostafa & Dumrak, 2017; Ruben et al., 2018; Shah & Ward, 2007).

Another strategic recommendation related to the technology theme is the PaaS model. Adopting the PaaS model can shift the ownership of the product to the manufacturer through leasing or rental contracts. This gives the manufacturer control over the entire lifecycle of their product, simplifying the remanufacturing process and ensuring an even flow, which is considered a problem for all companies. Benefits can be expected to be seen in the appraisal and retrieval stages, since the manufacturer has all the information related to the product, as Garrone (2024) points out. PaaS significantly increases the feasibility of remanufacturing by ensuring that materials remain in circulation for longer periods. Furthermore, maintaining ownership encourages companies to include more modular designs, and to start designing for circularity to increase the lifetime of furniture and to make the remanufacturing process easier (Circular Sweden, 2025). Another benefit of adopting the PaaS model integrated with reverse logistics is that it allows manufacturers to create a consistent and predictable flow and workload (Tveit et al., 2021). Moreover, a replacement of the products can be offered directly until the remanufacturing process is over, similarly to how Gemla is currently working, which is beneficial to the customer.

To answer the third research question: How can furniture companies improve the remanufacturing process? It is important to consider the following recommendations: Streamline appraisal with digital tools and modularity. Modular design for easy disassembly. Investing in related technology. Improve logistics. Encourage inter-company partnerships. Adopt the Product-as-a-Service (PaaS) model. Collectively, these improvements support a more robust, efficient, and regulation-ready remanufacturing process.

6.2 Methods Discussion

This subchapter highlights and discusses the methods used in this research. This is useful to understand the shortcomings and strengths of the methods of this research.

The first argument to increase the validity of this research is to perform more observations, optimally, for all companies. More observations yield more data and a more comprehensive understanding of the process that interviews might miss due to a lack of actual visual input. More unbiased data usually reveals deeper insights into key steps and critical activities. However, Götessons's factory is in Poland, and the researchers are in Sweden at the time of writing this research. Therefore, it is not feasible to make observations due to monetary reasons and time constraints. As for other companies, since SMEs usually have a few employees working on remanufacturing, their time is very limited, and observations can cause disruption to the production and operations. However, a sufficient degree of saturation in the data collected from the interviews is deemed to have been achieved. It is clear that the interviews provided similar themes and, broadly speaking, comparable key takeaways that allowed for an adequate degree of resolution when analysing and discussing the findings. Thus, it can be argued that the result would remain largely unchanged had more interviews been conducted.

Another argument that can increase the reliability of the research is to collect the data from the companies instead of asking the companies for the data which they collected themselves. This would provide data that is collected in a standardised way, eliminating bias and minimising errors in analysing the data. Unfortunately, the time frame of this research does not allow for collecting first-hand data from scratch. Moreover, to improve the analysis of the quantitative data, which was used to answer the third research question, the impact of remanufacturing could have been calculated and analysed using LCA software. However, software such as OpenLCA was considered at the beginning of this research. Unfortunately, it was discovered that it is very difficult to use software to calculate remanufacturing that is circular in the way defined for this research. This is because OpenLCA is designed for a linear approach to processes and for the production of new products, and to compare them with circular scenarios, instead of remanufacturing operations. Therefore, an Excel sheet was developed using data from different data sets as a circular LCA calculator, which provided good and feasible estimates of the impact of the remanufacturing process.

Another potential point for improvement to this research is to analyse a broader range of products and their corresponding flowcharts using the circular LCA calculator. This can aid in strengthening the arguments for the generalisability of the findings, and companies can also determine which product groups to focus on to reduce the environmental impact. For example, this can mean that the company targets this group in their product development and incorporates the practices related to design for sustainability. The circular LCA calculator is available to everyone and can be used by all companies to benefit and develop their knowledge and strategic decisions. It is also worth mentioning that this approach focuses on the environmental impact only and does not account for cost or profit.

7 Recommendations

This chapter aims to present practical recommendations for all companies in general and the case companies in particular to improve furniture remanufacturing.

The first recommendation is for the case companies to use the flowcharts to visualise their remanufacturing process as a starting point. After that, consider what is identified as key steps and critical activities for the remanufacturing process. Understanding the process in detail establishes the foundation required for evaluating the impact and identifying areas for improvement.

Another recommendation is to use the circular LCA calculator attached to this research on different product groups to assess, on an environmental level, whether it is worth remanufacturing or producing new products. The insights from the circular LCA calculator can also be used to investigate which remanufacturing steps have the most negative impact and target them for improvement. Furthermore, marketing departments can use the concept of remanufacturing as a selling point and inform their customers that they can reduce their carbon footprint by pursuing remanufacturing instead of purchasing new products. This means that the outputs from the circular LCA can serve as a basis for transparent communication with customers and help companies validate claims about reduced emissions by remanufacturing. Moreover, repeated use of the circular LCA calculator across product batches allows companies to track progress in reducing environmental impact and identify best practices and set benchmarks with greater detail.

Lastly, consider applying the targeted recommendations in the answer to RQ 3. This proposes how SMEs can increase process potential, efficiency, and sustainability. Moreover, this helps in making the remanufacturing process regulation-ready and forward-oriented. This is helpful for many companies since most of the furniture companies in Sweden are SMEs.

8 Conclusion

This chapter presents the conclusions derived from the research questions, proposals for future research, and discusses the limitations of the study.

8.1 Key Conclusion

In conclusion, the remanufacturing process is mapped, analysed, and assessed to further argue for circular economy practices, particularly within Swedish SMEs. This means that by mapping the process of some case companies, analysing case studies, and assessing the environmental impact, several insights were generated. The benefit of mapping the process of remanufacturing is to aid in identifying critical activities, such as cost and workload appraisal, logistics and internal logistics, and manual labour, that are necessary to have in order to be able to remanufacture furniture. Also, the identification of key steps of these critical activities. All of these steps seemed to be common among all the companies studied in this research. Moreover, assessing the impact of remanufacturing helps companies to assess whether it is worth remanufacturing a certain product group or if it is better to produce a new one instead. Also, it helps companies to reduce their environmental impact and identify best practices related to the remanufacturing process. Moreover, this research provides valuable insights on remanufacturing and circularity in the furniture industry by providing a new and user-friendly circular environmental impact calculation method, including a circular LCA card. This potentially contributes to the scientific community and to academics interested in these topics.

Furthermore, a tool for conducting an environmental impact assessment on circular products has been produced. In this particular research, it was only used to assess the impact of remanufacturing a generic wooden chair, but it can be used for other types of furniture as well. It gives an estimate of environmental impact, including global warming potential, acidification, freshwater eutrophication, PM/respiratory inorganics, human toxicity, and freshwater ecotoxicity. This is useful because it can serve as a basis for transparent communication, aiding companies in supporting their claim about reduced emissions by remanufacturing used furniture instead of producing new furniture.

8.2 Limitations of the Study

While this research generated some valuable insights, there are a few limitations that need to be acknowledged. It is worth mentioning that this research focused only on the environmental impact and did not consider the other two pillars of sustainability, social and economic (Elkington, 1997). This means economic viability and profitability are not considered in the assessment of furniture remanufacturing. Moreover, the main item was a simple wooden chair. Examining different product groups may yield different results and is worth studying.

Even though six case companies are included in this research, data from observations were limited due to several reasons. Therefore, extended observations and multiple Gemba walks at the companies could have uncovered more insights and critical activities. Moreover, there is a heavy reliance on secondary data from the companies and datasets. This means that accuracy may vary, and the values are mostly approximations. Therefore, on-site data and measurements collected over a longer period of time would improve the reliability of the findings, but it would take much more time. Moreover, one interview per company was conducted. It would have been more insightful to conduct at least two interviews per company, where the second interview can be with an operator at each company.

All of this might affect the generalisability of the findings. The finding that is affected the most would be the answer to the research question regarding the critical activities (RQ1), where they can vary from one company to another, and it depends on the size of the company as well. Moreover, more calculations need to be analysed using the circular LCA calculator to generalise the results and to be more certain regarding the impact of remanufacturing.

8.3 Further Research

Throughout the duration of this research, some ideas for further research have sprung to mind. The first proposal is to investigate the potential cannibalism that can occur when remanufacturing is upscaled

and how this potentially can affect the sales of newly produced furniture and the overall economic result of a company. Even though the environmental benefits of remanufacturing are clear, it is essential that the business model is sustainable from an economic point of view.

Furthermore, investigating how modularity can be integrated into furniture design to further enable circular flows seems relevant. It has been made clear that having parts that can be easily removed and changed is an enabler for easier remanufacturing, and it facilitates circular flows in general. Thus, this can be a "game changer" for businesses wanting to become more sustainable.

Lastly, it was made clear in this research that transparency and traceability are important, especially considering regulations such as the extended producer responsibility. Therefore, it can be interesting to research the role that blockchain technology can play in this regard.

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9 Appendices

Here, the summary of each interview can be found.

9.1 Interview summary 1 - Ekdahls Möbler

On 11/3, an interview with the co-owner of Ekdahls möbler was conducted. In the interview, topics such as remanufacturing, refurbishment, sustainability, use of chemicals were discussed.

First, some background of the company was given from the co-owner, who states that he is running the company together with his brother and that they have one part-time worker and someone they contract on an hourly basis when they enter extra busy periods of work.

Furthermore, he states that the majority of their furniture is purchased via retailers such as Kinnarps, Senab, and Input interiör. Therefore, the majority of the time, these retailers contact Ekdahls regarding remanufacturing and refurbishing furniture and are involved as a relayer between the customer and Ekdahls. He mentions that a trend for the last two years is that customers want to buy new cushions, upholstery, and seat pads for the furniture. He explains that many of their products allow for this type of renewal, where they only supply the fabric without replacing the wooden structure. However, this part of their business is very small, and it is uncommon for a customer to ask them to remanufacture their furniture. Especially that they are asked, for example, to refurbish the frame of a chair. Since the retailers have direct contact with the customer, he says that it is not uncommon that some of the renovations are made by a third party, in the form of a local company. Therefore, the furniture is not always brought back to the original producer, and instead, a local upholsterer or furniture maker is tasked with the refurbishment. Furthermore, the co-owner states that there are businesses that do not produce any furniture of their own, and that instead only do restorations and refurbishment of old furniture. Also, he explains that since remanufacturing and refurbishment are not currently vital parts of their business, he does not think this is problematic, at least not until this part of the business becomes larger. He expands on this and says that, from an environmental point of view, having local companies make the refurbishment is the best option since it minimises the negative effects of transportation.

On the other hand, he says that he has noticed that some of their competitors are very focused on creating their own take-back systems for refurbishment and remanufacturing, and that they consider this a vital part of their business. Of course, he says, there are companies with the opposite philosophy that want to stick to the core of their business, which is to be good at manufacturing new furniture, and that these companies do not mind that their furniture is being remanufactured or refurbished by someone else.

According to him, when a piece of furniture is remanufactured or refurbished, the customer sends the product to them through a transportation company. When asked about how long the average distance for transportation is, he estimated it to be around 350 kilometres (the average distance from Skillingaryd to Stockholm, Göteborg and Malmö). The furniture needs to be cleaned of dirt and fat with degreasing or cleaning agents, and he explains that they use regular water and soap for this. In the event that the customer wants a new paint job or a new varnish, the wood is sanded until the surface becomes matte for the new lacquer to be applied. Depending on the condition, either one or two layers are applied. He highlights that furniture that can be taken disassembled is easier to clear and to sand compared to a "one-piece" furniture, which is more time-consuming and requires more work. It is made clear that during this process, the structure is inspected to ensure that it is intact. If there are loose joints, they might need to be glued back together, and repairing wood joints can be tricky, as once the wood has been glued and broken apart, it does not always hold well with regular wood glue. In such cases, a two-component adhesive can be used instead.

On the topic of which steps in the process are most important, the co-owner states that it is crucial to assess the product's condition and that this sometimes can be difficult based on pictures alone. If the volumes are large, they ask the customers to send down some of the products as an example, and then they can more easily determine the cost and how much work is required. A key takeaway from this process is that the customer is involved so that Ekdahls and the customer can establish how the customer wants the furniture restored and that they can set a price for the remanufacturing of it. For

instance, the wood can have an indentation that is difficult to treat, and therefore, they need to establish if the customer is happy with the furniture not quite being "as good as new". He also states that quality is important and that they need to make sure that the furniture can be used for many years into the future after remanufacturing and refurbishment. He expands on this and says that for the process of refurbishing a solid wood table, the process is simple and that they can be sanded down to look and perform to the same standard as a newly produced one.

On the topic of challenges related to remanufacturing, he states that laminated surfaces with a particle board core make remanufacturing more difficult because when they attempt to sand them down, the machine is likely to break. Therefore, in some cases, it might be easier and more cost-effective to completely replace the surface rather than trying to repair it. Also, cost becomes a consideration when, instead of sanding the laminate down, they opt to replace it. Furthermore, he identifies transport as a big challenge for remanufacturing and refurbishment. He says that if a customer sends back one chair alone, it might cost up to 1000 SEK, which makes it impractical. Also, making sure that the furniture can be sent back without any damage is also a challenge with transportation, and that assembled furniture takes up a lot of space, which in itself makes the transportation less efficient. For these reasons, there are many transportation companies that do not handle loose furniture. Therefore, he highlights local refurbishment shops as a better solution from an economic and environmental standpoint.

In terms of taking material from an old piece of furniture and using it to create a new one, he states that it is possible to, for example, take a solid wood tabletop and use it to build a smaller table. But once again, he says that the laminated particle board is less applicable because of cost and the fact that it can damage the machine when it is sanded down. He also returns to furniture that is easy to disassemble, making it easier for material such as boards and planks can be sawed, sanded and have work done on the edges, thus giving them more possibility to reuse the material for something else. Also, he states that polyether foam padding can be reused in new furniture and that some already use recycled polyether in their furniture. Lastly, he states that a key challenge is finding skilled labour, particularly for specialised tasks like lacquering. There is a general lack of training programs in these areas. If more people were trained in furniture refurbishment, it would be easier to expand remanufacturing efforts.

When tracking the furniture, he states that there is more discussion about implementing digital product passports where a QR code can be scanned to access product information and recommendations for maintenance and disposal. Today, they use the order number for the furniture, and they can see the original specifications in their system. On the other hand, Ekdahls have tested QR code systems in collaboration with industry groups but have yet to implement this technology on a larger scale.

The co-owner also mentions that sustainability regulations and consumer preferences influence the material choices. He says that furniture in public spaces such as government buildings and hospitals has legislated requirements for material and surface treatments, and that they need to comply with the directions of Möbelfakta and Svanen. Regarding chemicals, Ekdahls do not use PFAS in adhesives or finishes. However, in healthcare environments, polyurethane coatings are sometimes necessary because water-based alternatives do not withstand frequent alcohol-based cleaning. While polyurethane finishes are safe for the end-user, they pose risks during application, requiring strict protective measures for workers. Also, he says that there are European standards that furniture needs to follow in terms of quality in the sense of durability, stability, etc., and that furniture is tested by a third party if it complies with the standards. This is especially true for furniture sold to municipalities and regions.

9.2 Interview summary 2 - Gärsnäs

On the 20/3, 2025, an interview with the CEO of Gärsnäs AB was conducted. In the interview, topics such as remanufacturing, refurbishment, sustainability, and the use of chemicals were discussed.

On the topic of furniture refurbishment, Gärsnäs offers different types of services. The "easy" type of refurbishment, he explains, is when the customer just wants the furniture cleaned, for instance, when a shoe mark is removed from the textile of the furniture. Also, do what they call "full" refurbishment, which is when the furniture is taken apart, reglued, given new upholstery, etc. They are equipped to handle all types of refurbishments, but the normal one, according to the CEO, is that the customer wants a new polyether and textile on the chair, as well as repainting it. Furthermore, the CEO distinguishes between refurbishment and remanufacturing, and explains that they have products such as the one called "Day" that can be remanufactured into a "Dino" chair, as parts between these chairs are interchangeable.

Furthermore, he explains that it is key to involve the customer in both the remanufacturing and refurbishment processes to establish what the customer wants and what the cost is. When elaborating on this, it can be difficult because if the order is large, the customer is asked to send two chairs to represent all of their chairs, and from that, estimate how much time and how costly the refurbishment is. The frequently occurring problem with this part of the process is that the customer sometimes picks out chairs with the least amount of wear and tear. Therefore, the cost and time estimations become inaccurate. This is extra time-consuming because the dialogue with the customer is prolonged, and the refurbishment process in the factory is also prolonged.

The CEO identifies a particular challenge for them regarding remanufacturing and refurbishment, in that other furniture carpenters sometimes have done work on furniture that they send back to the factory. Then, the furniture is often returned with some modifications from the previous renovation. For instance, there can be screws in certain places where they are not supposed to, be or use the wrong glue. Both of which cause problems for Gärsnäs when refurbishing the furniture, as keeping to their guarantee becomes more difficult.

When elaborating on which steps in the remanufacturing and refurbishment are key to get right, he says that getting the right quality from, for instance, glueing is crucial because they need to meet the five-year guarantee that they provide the customer with.

A solution to the problem of having other furniture carpenters modifying Gärsnäs' products, which the CEO proposes, is to have partners who are certified and trained in how the work should be done, so that the customer does not have to send the order down to Scania every time.

For transportation, the CEO explains that they have their own transportation system for customers who are in a close enough vicinity. However, if the furniture is located a long distance from Gärsnäs (Umeå, for example), they might instruct customers to get proper packaging from a retailer nearby or send the packages to the customers before the furniture is shipped down. After the furniture has been refurbished, it will be sent up to the customer again in the same package. He explains that they are always very much involved in the transportation and that they always try to book the pick up and drop off to time it with other orders. The transportation is conducted by a third party, and the goal is to never drive with an empty truck, he says, but in reality, the truck is empty approximately around 20% of the time. The truck is shared with another company, and whenever it is scheduled to drive somewhere, Gärsnäs tries to match that destination with their orders. For transportation over longer distances, they use the services of Schenker.

In regards to challenges related to transportation, he states that cost and lead time are a challenge for long-distance transport. Apart from that, he says that their transportation process is well worked out and that it is not considered a challenge because they use furniture-specialised transport.

When discussing the ability to track the furniture, he explains that they have been using a QR code on each piece of furniture for four to five years. He explains that it is something that they will keep doing to comply with the European standards for digital passports.

The CEO states that most of the remanufacturing and refurbishment takes place in the workshop in

Gärsnäs, but that they sometimes order products externally that are assembled together with the renovated furniture. In most cases, most of the finished refurbishments and remanufacturing are made in-house, but sometimes, partners closer to the customer can do the job for Gärsnäs, and in other instances, Gärsäs goes directly to the customer and does the work there.

Since Gärsnäs always is renovating their own products and never someone else's product, they seldom experience any delays in the process. Only if they need to order a product and it does not arrive in time can it cause a delay. Also, old products that have been out of production for many years, the in-house company is lacking and can be a problem when remanufacturing the furniture.

Furthermore, he explains that the process of remanufacturing and refurbishment is complex in itself, and each product is different, which is one of the most pressing challenges. Therefore, it is difficult to always do the same thing. The goal is to always do the same thing, but with different products, and to make it as standardised as possible.

Gärsnäs does not use PFAS chemicals and strives to use water-based varnish and glue as much as possible. However, sometimes there are specific requests from the customer that the furniture needs to be able to perform in certain environments, and therefore, it is required to have chemicals that Gärsnäs usually would not use. Also, sometimes if Gärsnäs receives furniture that another carpenter has worked on, it can be sprayed with hazardous chemicals, which the workers at Gärsnäs have to deal with. For instance, they might need to use special equipment such as masks, which would not be necessary if the chemicals were water-based instead. This extra precaution also arises when old furniture from, for example, 30 years ago, should be refurbished because it is not possible to know what it has been sprayed with.

The CEO mentions incorporating robots to help streamline certain parts of the refurbishment process. He explains that they have tested robots to sand down wooden chairs to prepare them for a new paint job. The manual sanding process is time-consuming and is usually considered a bottleneck, and having a robot to do this can help improve the process.

In terms of returning the refurbished product in the original condition, he explains that there are some mixed opinions about this. Some people even think it is important to provide a product even better than the one before. Expanding on this, he says that he personally does not think it is essential, however, it is crucial that the product still has a high quality and that it can be refurbished again in 10-15 years time. The furniture should be able to stay in this "loop" for at least 50 years. This, he says, is a matter of cost and that it is too expensive to make the furniture better than it was before. The most important thing is to provide what the customer specifies and to live up to that quality, while balancing cost. The cost can get so high that it is more expensive compared to a new piece of furniture, if it is refurbished in a way that makes it better compared to the way it was before.

For the quality of their products, they aim to comply with Svanen and Möbelfakta, and they run their own test on their products to make sure that the quality is up to standard. For this, they have a machine that for chairs puts a load of 150 kilograms on them and then a pressure is applied to the back of the chair. For the furniture to pass this test, it should be able to withstand at least 100000 cycles of this stress, he explains.

9.3 Interview summary 3 - Gemla Möbler

On the 21/3 an interview with the range manager at Gemla was conducted. In the interview, topics such as refurbishment, remanufacturing, sustainability, customer collaboration, transportation, and process challenges were discussed.

He started with the background on Gemla. He explained that it is a small company with around 16 employees and an in-house production facility. He also explained his role and that he works with sales, marketing, and product development together with the owner, operating from Stockholm.

Gemla has a long history of refurbishment under its service brand "Gemla Original Restoration," which has been part of the business since the 1990s. Initially developed during an economic downturn, the service became a way to offer customers a cost-effective alternative to new furniture. Today, the company restores up to 1,000 chairs per year. The company mainly refurbish their own model but does not mind refurbishing other brands upon request after the inspection stage. The company has streamlined the process, which typically involves dismantling, repairing the structure, sanding, updating upholstery, and applying surface treatments.

remanufacturing in the sense of using parts of old furniture to create something new is rare. The focus is instead on restoring pieces to a condition comparable to when they were new, preserving the original design and quality. The most important step in their refurbishment process is inspecting the furniture. After that, reinforcing the structure of the furniture is important to ensure that the joints and wooden components are secure before aesthetic restoration is done. He said that without a solid foundation, the rest of the work would be cosmetic and not make the product durable.

According to the range manager, Gemla performs all restoration work in-house and partners with logistics companies to pick up the furniture from the customer. They often provide temporary replacement chairs during the 3–5 week restoration period. He emphasises their flexibility with customers, sometimes scheduling restoration projects months in advance to suit their clients, such as during renovations or holiday closures. For large-scale projects, they also offer storage solutions for their clients. For example, until their clients finish renovation, Gemla can keep the refurbished chairs for them. He highlights the importance of aligning expectations and offering customisation in terms of surface finish, upholstery materials, and overall appearance to increase customer involvement. Pricing is transparent, with a standardised price list depending on the item and options selected. Restoration projects are planned into the company's regular production flow, balancing capacity and timelines. He said that while restoration can be customised, certain steps, such as reinforcing the structure, are non-negotiable and super important for ensuring the quality of the furniture. If a piece is too damaged or poorly built, Gemla may decline the job. Moreover, they often receive items previously refurbished by third parties, sometimes poorly, which complicates their process. For this reason, they prefer to handle all the refurbishment of Gemla products themselves.

In terms of challenges, delays typically occur when the furniture arrives in worse condition than initially described, especially if the restoration involves models not originally made by Gemla. Misjudged condition assessments based on photos can lead to unexpected manufacturing of spare parts, slowing down the workflow. He also pointed out that the upholstery department, which only has two employees, is a common bottleneck when large restoration orders require extensive reupholstery work. Moreover, Anoton states that the in-house logistics, such as receiving the products and moving them around in the factory, and packing, are considered non-value-adding activities to the customer, where these activities are necessary but they are time-consuming and the customer does not feel that. // // critical activities and delays occur when products arrive in worse condition than expected, requiring new parts to be manufactured. In terms of materials, Gemla avoids synthetic foams and instead uses natural materials like horsehair, latex, wool, and vegetable-tanned leather. Water-based lacquers are preferred, though oil finishes are increasingly in demand, but are difficult to apply to older lacquered surfaces. The company has considered technologies like abrasive blasting to improve sanding efficiency, but has not yet implemented them. Gemla does not currently use digital tracking systems but sees potential in this area. Also, Gemla is buying old furniture from customers who do not need them anymore and use them to create new furniture and sell them to other customers.

Their restoration services are conducted within the same factory as new production, making opera-

tions streamlined. While they do not have Möbelfakta certification, they send furniture to RISE for durability testing and aim to meet environmental standards. He explains that all restored furniture receives a renewed five-year guarantee, the same as new items. He also said that a Gemla chair has been restored five times over, more than a century (since 1907). He emphasises that, if an item is maintained and restored properly, it can last indefinitely.

9.4 Interview summary 4 - Balzar Beskow

On 24/3, an interview with the co-owner of Balzar Beskow was conducted. In the interview, topics such as remanufacturing, refurbishment processes, sustainability, transportation, customer collaboration, materials, chemical use, planning, and operational challenges were discussed.

He began by introducing the company and his role. Balzar Beskow is a Swedish furniture manufacturer with around 18 employees. He has guided the company toward more sustainable practices. Over the years, Balzar Beskow has transitioned from sourcing components abroad to working exclusively with Swedish suppliers close to the production facility. This has helped reduce logistics-related emissions and increased local collaboration.

The refurbishment process generally begins when a client contacts the company. Sometimes, the client is unsure whether to replace or refurbish, and Balzar Beskow will suggest the latter as a more sustainable and cost-effective option. Clients usually send in a sample item (often one in the worst condition) for assessment. The team evaluates its condition, contacts subcontractors for upholstery pricing, calculates internal costs, and provides an offer. If the customer agrees, packaging materials are sent, and transportation is arranged. Although the company owns one small truck for local tasks, it mainly relies on external logistics partners.

One of the most critical stages in the process is the initial structural assessment. If a piece of furniture is tightly glued and not already loose, disassembling it may cause more harm than good. In such cases, the joints are often left intact. He emphasised that it is essential to set realistic expectations with customers from the start. For instance, old chairs may have wear at the bottom of the legs that cannot be completely restored. These imperfections are discussed with the client before work begins to ensure transparency and mutual understanding.

In addition to traditional restoration, Balzar Beskow engages in creative remanufacturing. For example, they have reused components from discontinued product lines to build or modify new furniture. Although this is not yet a formalised system, it reflects a resourceful and circular approach. Furthermore, the company has streamlined many of its designs to use standardised components. This strategy makes maintenance and future refurbishments easier and more efficient.

The company benefits from a spacious production facility, approximately 7,500 square meters, which supports smooth internal logistics and product storage. Most refurbished furniture passes through the joinery and lacquering departments. While the in-house process is efficient, delays can occur when waiting for external materials, particularly specialised fabrics. Removing old upholstery is often a time-consuming and labour-intensive task.

For surface treatment, manual sanding is preferred. Although they have experimented with abrasive blasting, it tends to damage the natural grain of the wood. Therefore, sanding is preferably done by hand to preserve the furniture's appearance and integrity.

Balzar Beskow adheres strictly to Swedish regulations and Möbelfakta standards when it comes to chemical use. Water-based lacquers are used across most products. Solvent-based lacquers are reserved for specific cases, such as hospital furniture that requires resistance to frequent alcohol-based cleaning. All chemicals are logged in a registry, and safety data sheets are updated annually. The company avoids substances classified as harmful and actively seeks safer alternatives when necessary.

Most refurbishment work comes from customers based in Stockholm, Gothenburg, and Malmö. However, Balzar Beskow also receives orders from across Sweden, including remote locations such as Luleå. Although long-distance transportation can be more costly and carbon-intensive, the company is able to calculate transport emissions using data from their logistics providers.

Soon, they plan to add QR codes that link to mounting instructions, disassembly guides, material information, certifications, and more. This system is part of a Scandinavian initiative and is expected to become a legal requirement in the coming years. It will also allow customers to easily request refurbishment or order spare parts.

A restored product is typically expected to last between five and ten years, depending on its condition and design. For items still in production, they can confidently provide a five-year guarantee. This aligns with industry standards and reflects the company's commitment to durability and quality.

Although they have not yet completed Environmental Product Declarations (EPDs), the company is working on integrating them into their processes using LCA tools. They also continue to promote circular design principles.

9.5 Interview summary 5 - Götessons

On 9/4, an interview with a sustainability developer at Götessons was conducted. In the interview, topics such as sustainability, circularity, refurbishment, remanufacturing, and Götessons' LOOP system were discussed.

On the topic of circular flows, Götessons are mainly establishing this via their circular concept "LOOP by Götessons". The sustainability developer explains that this system allows Götesson furniture to be brought back from the customer, and materials from the furniture can be reused by resizing the frames or replacing textile covers, so the material remains in the same product rather than being used to make entirely different products. The prevailing type of furniture that this system is currently used for is office screens that typically include both desk and floor screens and are used in offices. The sustainability manager explains that Götessons, when selling a new floor screen to the customer, offers this take-back system as a way for the customer to reduce their environmental impact. While not always an order winner, it is becoming increasingly common in larger projects for customers to request or require systems that allow for the take-back of furniture.

Furthermore, the sustainability developer identifies certain challenges related to the take-back system. First, she points to the important role that the sales and marketing team plays in introducing this concept to customers and in making customers more aware of this additional benefit. Although the marketing and sale of the concept is not the challenge, raising the awareness of the customer is. This means that if the customer is more aware, spreading this concept should not be a problem. The point is that since other companies today and in the future need to keep track of their environmental impact and CO2 emissions, offering circular flows to them is beneficial from a competitive and environmental point of view because this system helps other companies become more sustainable.

Secondly, she states that internal logistics are challenging, especially in terms of packaging and handling the furniture because of the size and quantities of furniture and non-standardised goods. She points out that this is not done in a standardised way, which means extra work when handling the goods when they arrive at their facilities. Also, the sheer complexity and variation of products and processes involved in having a take-back system make it very time-consuming when sorting out which furniture to circle back. Storage is also mentioned as a current challenge: Götessons primarily manufactures "on-demand" or "made-to-order" and therefore has limited warehouse space available for storing returned goods.

Thirdly, she also points out that it is important to be specific when defining their services for the customer so that they know what Götessons means by recycling, reusing, and upcycling. This is done to ensure a clear understanding of the services being provided.

Lastly, she highlights that scaling up the volume is difficult when going from a linear flow to a circular flow, and she attributes this to the variability, complexity and irregularity of this process. She also ties this to cost, meaning that taking back a piece of furniture and putting on nicer textiles compared to the ones that sat on it before is not warranted due to it being too expensive.

Additionally, she mentions that guaranteeing the correct quality or the content in components and materials is essential when receiving returned goods. Götessons only accepts their own products in the take-back system for this reason. While they don't refurbish or remanufacture furniture from other companies, the sustainability developer expresses a positive view toward others doing so, as it benefits the environment and enables collaborative partnerships that keep more furniture in use. She also shares that Götessons has tested local partnerships, such as working with craftsmen who perform on-site refurbishments at stores, for example, by installing renovation kits.

To develop the take-back system further, she identifies a key step in that it is crucial to have a system in place to assess the quality of the product that comes back from the customer through text and pictures. This is necessary because it is important to determine if the furniture can be sold again, to assess the amount of work needed and the cost associated with evaluating the condition, and to prepare the products for resale through channels such as their website, loopshop.se.

One of the barriers to scaling the LOOP system is that Götessons only sells through resellers and does

not have direct dialogue with end users. This creates challenges in getting furniture returned. She also points out that the current recycling infrastructure is simple and widely accessible, so the LOOP system must be more convenient for customers than simply dropping items at a recycling centre. Suggestions to ease the process include offering pre-packaged return kits and well-organised transportation

From a design perspective, the sustainability developer explains that it is significantly easier to work with products that are designed for circularity from the beginning. Many products today are made with a linear mindset, which necessitates workaround solutions when trying to recirculate them. Design elements such as easily interchangeable textiles, which customers can replace themselves, help reduce handling and transportation complexity. She stresses that product development must focus on getting things right from the start, anticipating how furniture will be used, returned, and handled in future circular flows. Key considerations include sorting of parts, ease of disassembly, and smart assembly design. This type of design can be called design for circularity, as suggested by the sustainability developer

On the topic of critical activities, two main ones were identified: first, the extra time and effort needed for sorting and packaging returned furniture into trucks; second, organising and assessing deviations in the condition of returned furniture to determine what can be resold directly and what needs further work.

Lastly, when discussing technology and regulations and the implementation of digital product passports and QR codes, the sustainability developer sees potential in this technology to enable circular flows and also describes it as a big driver for this change.

9.6 Interview summary 6 - Maze Interior

On the 11/4, an interview with the product & purchase manager at Maze Interior was conducted. In the interview, circularity, sustainability, quality, design, and using recycled materials were discussed.

On the topic of circularity, the product & purchase manager states that Maze Interior offers their customers, to a certain degree, the service of refurbishment. For instance, they can provide the customer with a new paint job or finish, but it is currently not a big part of their business. Instead, they work with circularity in the sense that they use recycled material in the production of their new furniture, which she states helps contribute to a reduced environmental footprint. The product & purchase manager elaborates on this and explains that they use recycled steel for their "Bill" range of furniture, and that up to 100 % of this material is recycled for metal threads up to 8 mm in thickness, and that steel is the predominant material used in their furniture. Furthermore, roughly 26% of the recycled material comes from pre-consumption, meaning that it is recovered waste from some other manufacturing process, and that the remaining percentage is collected from post-consumption. Moreover, she explains that steel thread thicker than 8mm has a much lower percentage of recycled steel because this type of steel is often used for construction, which requires a much more durable material that is not easily obtained from recycled steel. On this, she says that they have to adapt their design and what they purchase.

When discussing the possibility of using recycled wood, she says that this is not something that they currently do. However, she states that in theory it is possible to have, for instance, a piece of wood and use it to make something new, but that there currently is a lack of this sort of material available and that the cost is very high. Even if it is practically possible, they would be forced to increase the price of the furniture to the point where it would be too high. Instead, she highlights the importance of working with certified wood that is preferably sourced close to the production.

On the topic of offering the customer the service of remanufacturing and refurbishment, the product & purchase manager sees a scenario where the furniture is transported to their warehouse in Norrköping, and from there it is shipped to their main factory. There, they can do repainting and revarnishing, and integrate this process into the normal production. She also highlights the necessity of having a high enough volume for it to be sustainable, and also highlights the environmental benefits that it can bring and prolong the life of the furniture. Furthermore, she highlights transportation, to and from customers, as the biggest challenge in terms of environmental impact.

Furthermore, discussing the role that the design of the furniture plays in terms of sustainability and recycling, she highlights the importance of considering using the right material, making it easy to transport so that the truck can be as full as possible. Furthermore, she also states that modularity can be an enabler for circularity and highlights a challenge in terms of doing reupholstery. If the filling and upholstery could be removed more easily, for instance by having zippers, this would work as an enabler for increased circularity. She elaborates on this further and foresees a future where this type of solution can be enforced by regulations.

The product & purchase manager states that Maze Interior predominantly sells furniture to private customers but occasionally to public spaces. She highlights a difference in demand between the two types of customers. For instance, in some applications in public spaces, water-based varnish and paint cannot be used. Furthermore, when discussing certain plastics, she states that plastics from a consumer point of view are undesirable, even though they might have a smaller environmental impact compared to wood, for example, in certain applications

In terms of scaling up the remanufacturing and refurbishment part of a business, it is made clear that it is easier to get a higher volume when producing furniture for public spaces such as offices, and that this is a challenge for a company that predominantly sells to private customers. Also, when discussing only working with their own furniture or other companies' furniture, she says that it is important to establish a clear purpose behind it. For Maze Interior, this would be to provide the customers with a longer life of their furniture, where the cost is more symbolic than, for instance, revarnishing it. Therefore, it could be challenging working with other companies' furniture because it might not cover their costs. She also highlighted the fact that they might not have the correct knowledge of furniture from other companies, which means that they might not be able to guarantee the correct quality. However, she elaborates on this and states that a digital product passport might be an enabler for this type of service since it can

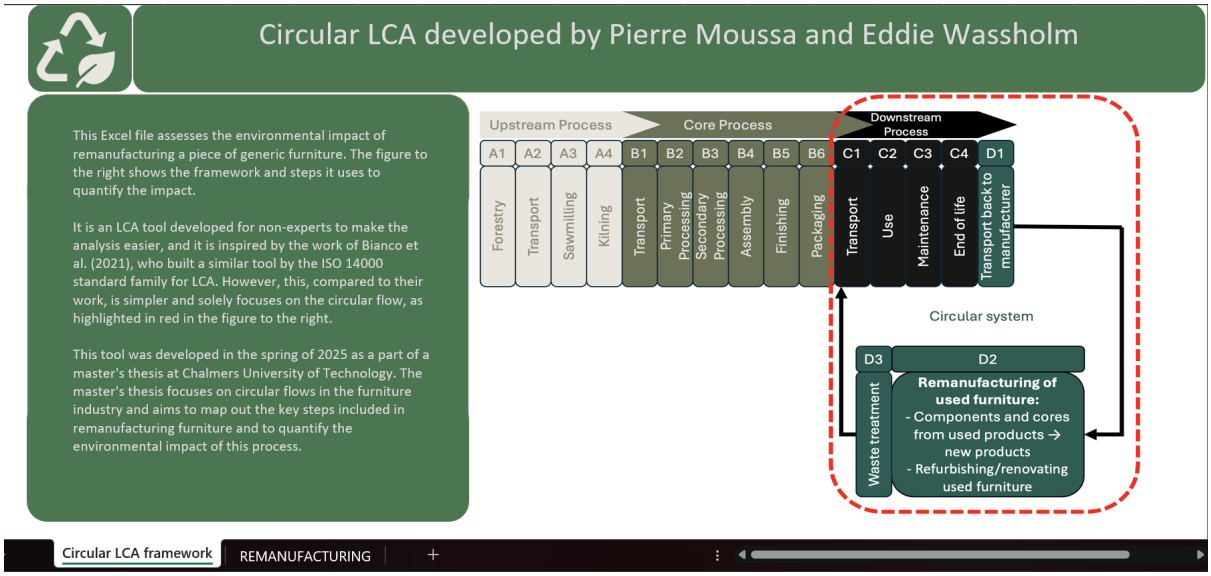
provide the proper instructions for maintenance and a bill of materials that can bridge the knowledge gap when renovating other companies' products.

On the other hand, she highlights certain challenges in implementing the digital product passport for small companies since it is very costly and time-consuming, which makes it difficult for small companies to cope.

Lastly, she mentions that sustainability indeed can be an order-winner for the customer, but it is also important to consider the economic state of the world. Customers might choose cheaper products during economic recessions, even though there is a more sustainable product available.

9.7 Excel circular LCA calculator link

The file is called Circular LCA calculator and can be accessed from https://zenodo.org/ by using the DOI: 15388444



9.8 Sample quotes table used for gathering the codes for the thematic analysis

Sample Quotes	Codes
Ekdahl: What has increased during the last years is that our customers want new upholstery, cushions and seat pads for existing furniture and many of our furniture allow for this type of renewal. However, we also do full remanufacturing of chairs but more seldom. **Gärsnäs**: "We have a lot of different refurbishments for the furniture." **Gemla**: "We call it Gemla Original Restoration... we restore up to 1000 chairs a year." **Balzar**: "We do remanufacture... sometimes use leftover parts from older furniture series to make new products."	Remanufacturing /Refurbishment
Ekdahl: We hire a third party for transportation, and they need to be specialised in furniture transportation. Not everyone wants to handle loose furniture without packaging **Gärsnäs**: "If the customer is in Gothenburg, Malmö, Stockholm... we collect them ourselves... Otherwise, the customer needs to send it." **Gemla**: "We have partners that help us... we offer to collect the furniture and return it after refurbishment." **Balzar**: "We use DB Schenker... they are really good for transportation."	Transportation/ Logistics (packaging, shipping)
Ekdahl: There is increasing discussion about implementing digital product passports, where customers can scan a QR code to access product details, maintenance instructions, and disposal recommendations. We have tested such systems in collaboration with industry groups, but we have not implemented them on a larger scale yet. **Gärsnäs**: "We've tested and tried some robot to sandblast furniture... to remove paint... because that is really time-consuming." **Gemla**: "We explored building an alternative to manual sanding... like a blasting technique." **Balzar**: "Considering building a product passport system with QR codes for disassembly, repair instructions, and more."	Technology
Ekdahl: Transportation is difficult, not all of the freight companies want to handle loose furniture and it can also be expensive as well." It is different from case to case and you need to make a decision on what is possible to do… It is a challenge the the furniture can be transported in a way that there is no damage… A key challenge is to find skilled labour, especially for lacquering. **Gärsnäs**: "Every product is unique... it's like starting over every time... we need to standardise." **Gemla**: "In-house logistics takes time, receiving, moving, packing, but clients don't see that as part of the cost." **Balzar**: "If it's not already loose, you can't redo it, trying to disassemble may break the piece." "Most delays come from subcontractors, especially fabric supply."	Challenges
Ekdahl: Since the transportation companies do not want to ship loose furniture without packaging you need to send someone or send the customer packages. It is pretty bad from an environmental point of view… its better for the environment if there is a local guy that can make the job closer to the customer. **Gärsnäs**: "We try to make logistics economic and environmental... never drive an empty truck." **Gemla**: "Clients are more willing to pay for restoration now because of increased awareness of circularity." **Balzar**: "We helped a client compare new vs. reupholstered auditorium chairs, CO_2 and cost savings led them to choose refurbishment."	Environment/ Circularity

Ekdahl: To sand down glued laminated particle boards can be difficult because the machine can break... “There is a lot of manual work to sand down the parts. **Gärsnäs**: “We’ve tested some robot... to sandblast and remove paint... because it's time consuming to do manually.” **Gemla**: "Manual sanding is hard, especially for rounded and narrow surfaces... looking into sandblasting alternatives." **Balzar**: “Sandblasting doesn’t work well, it ruins the wood”	Sanding
Ekdahl: It is more and more common that our customers want new… and upholstery on their furnitures. **Gärsnäs**: “Normal refurbish: put new fabrics on the seat or back... change the stuffing.” **Gemla**: "We have two in-house upholsterers... upholstery is often the bottleneck." **Balzar**: “Most time-consuming task is getting fabric off, it's done by hand, very repetitive.”	Upholstery
Ekdahl: From a machine stand point, having products that easily can be disassembled makes the work easier **Gärsnäs**: Observation **Gemla**: "We often restore chairs to look completely different. For example, from 1980s lacquer/beech to vegetable-tanned leather and stained wood." **Balzar**: “We now design with flexibility in mind, reusing metal bases and adapting designs.”	Design
Ekdahl: Without a doubt, it is a big positive if the furniture is possible to disassemble. Most of the furniture is glued however, which makes it more difficult and leads to more manual work. **Gärsnäs**: “We take it apart, glue it again, repaint and upholster... that's total refurbishment.” **Gemla**: "Many times we disassemble the chair, change screws, new glue joints, replace cracked parts." **Balzar**: “Most often it’s a joint or two... then we pick it apart and reassemble.”	Disassembly
Ekdahl: Regarding PFAS chemicals, we do not use them in our adhesives or finishes. However, in healthcare environments, polyurethane coatings are sometimes necessary because water-based alternatives do not withstand frequent alcohol-based cleaning. While polyurethane finishes are safe for the end-user, they pose risks during application, requiring strict protective measures for workers. **Gärsnäs**: “I don’t really know what we painted our furniture with 30 years ago... that’s a concern for our employees... we always wear masks.” **Gemla**: "Sometimes we use acid-based lacquer if necessary, but we try to avoid it." **Balzar**:"We use water-based lacquers, minimal harmful substances… We switched to safer options… solvent-based lacquer only used for hospitals.”	Chemicals
Ekdahl: From an environmental point of view it is best if someone closer to the customer can make the renovation **Gärsnäs**: “We had our own trucks before, now we share transport with another company nearby.” **Gemla**: "We work with partners for transport... and sometimes restore other companies' furniture." **Balzar**: “All suppliers are in Sweden, most within 150 km.”	Collaborations & partners

Ekdahl: **Gärsnäs**: Observation **Gemla**: “Taing 300 chairs and moving them in to storage… the hours go quickly… so it takes time” **Balzar**: “We have a large facility, storage is easy, everything on pallets... factory is built according to logical flow.”	Storage
Ekdahl: It is important to establish together with the customer what they want, most of the time, they want a furniture that is as good as new, this is not always possible because some wood might have indents for instance. **Gärsnäs**: “We always give five years guarantee on the work... same as for a new product.” **Gemla**: "We offer a five-year guarantee on both new and restored furniture." "Chairs from 1907 have been restored five times... still get a renewed guarantee." **Balzar**: “We assess every item and offer an expected lifespan, ideally five years.”	Quality/ Guarantee
Ekdahl: “ Sometimes the difference between remanufacturing/ refurbishment and new production is very small.” **Gärsnäs**: “It's very expensive to refurbish to a better condition than original... sometimes more than a new one.” **Gemla**: "Clients compare cost of new vs restoration... some are still not willing to pay to restore old items." **Balzar**: “We calculate refurbishment based on time, subcontractor cost, material replacement and provide a full quote.”	Price/cost
Ekdahl: There are companies that do not have any production of their own, instead they only focus on renovating other companies furniture… I do not think that there is a difference in the result if we or someone else do rework on the furniture… If the lead time is long, it can be extra beneficial to have an extern partner do it… One might need to educate the partner so they make the reparation in a way that the quality is right **Gärsnäs**: “We are always renovating our own products... not other companies’ products.” “If it was refurbished elsewhere, with wrong methods... it’s a problem when we get it back.” **Gemla**: "We also help restore furniture not originally made by us” **Balzar**: “We take anything we can do well, not limited to our own products.”	Work on own vs other companies’ products
Ekdahl: We have experimented and tried it on a few products and together with some projects but we are yet to implement it on a larger scale. **Gärsnäs**: “We’ve used QR codes for 4-5 years... customers can scan to get info on maintenance and repair.” “We're doing this because of European standards requiring product passports.” **Gemla**: “We’re aiming to get a better tracking system." **Balzar**: “We are going to produce our first Product Passport… We are starting a project to use QR codes for mounting, disassembly, spare parts, etc.”	Product pass/QR codes/stamps
Ekdahl: There are regulations in place for what you can use, especially for furniture in public spaces… We prefer to use water based chemicals, it is much friendlier to work with, however during the pandemic when everyone used alcohol all the time, these surfaces got damaged so for certain applications, we had to revert back to polyurethane coatings. **Gemla**: "We use water-based glue, vegetable-tanned leather, horsehair, wool, no thermoplastics." **Balzar**: “Our chipboard supplier uses 60% post-consumer recycled wood, pallets, old chairs.”	Material (wood, textile, glue, etc.)

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