Circular Economy in Commercial Real Estate

A Study of the Design Process for Increased Reuse in Redevelopment Projects

Master's thesis in Design and Construction Project Management

IDA HOLMÉN
SIMON ANGERVALL

DEPARTMENT OF ARCHITECTURE AND CIVIL ENGINEERING
CHALMERS UNIVERSITY OF TECHNOLOGY
Gothenburg, Sweden 2023
www.chalmers.se

Master's thesis 2023

Circular Economy in Commercial Real Estate

A Study of the Design Process for Increased Reuse in Redevelopment Projects

IDA HOLMÉN
SIMON ANGERVALL

Department of Architecture and Civil Engineering
Division of Construction Management
Chalmers University of Technology
Gothenburg, Sweden 2023

Circular Economy in Commercial Real Estate
A Study of the Design Process for Increased Reuse in Redevelopment Projects
IDA HOLMÉN
SIMON ANGERVALL

Supervisor: Anita Ollár, Division of Architectural Theory and Methods
Examiner: Martine Buser, Division of Construction Management

Master's Thesis 2023
Department of Architecture and Civil Engineering
Division of Construction Management
Chalmers University of Technology
SE-412 96 Gothenburg
Telephone +46 31 772 1000

Gothenburg, Sweden 2023

Circular Economy in Commercial Real Estate
A Study of the Design Process for Increased Reuse in Redevelopment Projects
Master's thesis in Design and Construction Project Management
IDA HOLMÉN
SIMON ANGERVALL
Department of Architecture and Civil Engineering
Division of Construction Management
Chalmers University of Technology

Abstract

The building and construction industry is currently one of the industries with the most significant environmental impact. It is responsible for roughly 100 billion tons of waste yearly. The main reason is that the building and construction industry has traditionally adopted the linear concept of "take-make-waste" where products are discarded long before they have researched their end of life. One promising approach could be to adopt circular processes in line with circular economy principles, aiming to recover and reuse construction products from existing buildings rather than resorting to demolition and disposal. Therefore, this thesis aimed to research how the introduction of circular processes in redevelopment projects affects the design process and how to facilitate this transition. The research was conducted in collaboration with Sweco and entailed 15 qualitative interviews covering both pilots and more ordinary routine projects in commercial real estate.

The research concludes that reuse in the Swedish building and construction industry is still at an early stage. Large-scale reuse implementation is mainly hindered by the fragmented market since sourcing reuse from other projects then becomes both time-consuming and unreliable. Besides, there are no set routines and methods for approaching reuse in redevelopment projects. The study revealed effects on the design process by introducing reuse practices, which resulted in three models. One provides an overview of the changed design process with guidance for when additional activities related to reuse should be performed, and the second proposes a step-by-step process for conducting inventories and setting project goals related to reuse. The third model suggests an order of prioritization for reuse actions in redevelopment projects. Following this, results suggest that on-site reuse within the property and, in some cases, just-in-time reuse from the local area can be profitable. This points to a significant future potential for off-site reuse, sourced from other projects, to become increasingly profitable as the market matures and logistical solutions are established.

Keywords: commercial real estate, construction industry, redevelopment, circular economy, reuse, environmental sustainability.

Acknowledgements

This thesis was carried out at Chalmers University of Technology in the spring of 2023. We would like to thank our supervisor, Anita Ollár, for her immense support and guidance throughout the development of this thesis.

We would also like to thank Sweco for a rewarding collaboration, and especially our supervisor, Jan-Olof Cavanna, for his endless enthusiasm and encouragement, and for giving us invaluable contacts in the industry. Finally, we would also like to thank all the respondents who participated in this study for their time and willingness to share their knowledge, reflections, and insights. Without their contributions, this study would not have been possible to complete.

Ida Holmén & Simon Angervall, Gothenburg, June 2023

Contents

List of Figures

List of Tables

Glossary

Since this study is based on the Swedish construction industry, Swedish terms related to the design process are utilized throughout the report. This is mainly because the terms do not exist in English and direct translations are inaccurate.

Behovsanalys	Needs analysis
Bruttoarea (BTA)	Gross area
Bygghandling	Detailed design and construction documents
Förfrågningsunderlag	Tender documents
Programhandling	Program documents
Renovering, ombyggnad, tillbyggnad (ROT)	Redevelopment projects
Systemhandling	Project planning documents
Totalentreprenad	Design-build contract
Utförandeentreprenad	Traditional contract (design-bid-build)

1 Introduction

Since the beginning of the industrial revolution, humans have lived in a linear economy with a *“take-make-waste”* mindset, where products are used for their purpose once and then discarded as waste (Esposito et al., 2018). This one-directional concept of mass production and consumption causes severe environmental consequences as it requires significant depletion of natural resources, generates large volumes of waste, and consumes vast amounts of energy (Esposito et al., 2018). Like most industries, the building and construction industry has traditionally applied this linear concept of *“take-make-waste”* and hence has a significant role in environmental impact (Benachio, 2020).

Today, the construction industry is considered one of the largest waste-generating industries in the world, producing approximately 100 billion tons of waste each year (United Nations Environment Programme, 2022). In addition, the construction industry is heavily dependent on the use of virgin materials and energy consumption, accounting for over 40% of the world’s extracted resources and contributing to around 37% of all energy and process-related CO2 emissions (Breene, 2016; United Nations Environment Programme, 2022). In Europe, the construction industry accounts for similar figures, generating more than 35% of Europe’s produced waste, consuming over 50% of the natural resources, and is responsible for roughly 35% of all emissions (European Commission, 2021; European Environment Agency, 2018, 2022). Looking at a national level, as in Sweden, the construction industry also has a significant environmental impact, accounting for 21% of all the emissions and generating around 40% of the produced waste within the country (Boverket, 2023a, 2023b).

Although the Swedish building and construction industry has shifted its focus towards a more sustainable built environment in recent years, much effort has been put into reducing energy consumption during the operational phase, while the construction phase tends to be somewhat ignored (Boverket, 2018). Nevertheless, studies show a significant sustainability potential in the construction phase, suggesting that applying reuse could potentially save up to 18 000 tons of waste, 21 000 tons of CO2 emissions, and SEK 600 million each year when renovating Swedish office premises (Andersson, 2018).

Despite this, it is still a common practice to demolish and dispose of existing building products long before the products reach their end of life (Gerhardsson, 2019). At the same time, Sweden follows a waste hierarchy plan, stating that society should primarily encourage the reuse of existing building products while preventing the production of waste (Swedish Government, 2022). The fact that there are no well-established methods or routines for reuse in the construction industry indicates a significant waste of resources and points to a clear potential for improvement. It has been estimated that roughly 90% of existing buildings in Europe will still stand in 2050 and therefore have great value as material banks, with 35 million buildings needing renovation by 2030 (Sweco, 2023).

A shift towards a more circular industry, following the principles of circular economy, could be a sustainable approach for the construction industry. The circular economy aims to create more value for resources through circular practices, such as reuse and recycling, rather than the traditional pattern of *"take-make-waste"* (Ellen MacArthur Foundation, 2015). A circular system would minimize resource waste, improve product utilization, and reduce CO2 emissions, providing an opportunity to limit the environmental impact (Lindholm, 2018). Therefore, a more circular construction industry, aiming to reuse building products, could potentially counteract future sustainability challenges and achieve a much more sustainable built environment (European Commission, 2014).

1.1 Aim and Research Questions

Considering the building and construction industry's significant climate impact, it must undergo major transformations of traditional, linear practices to evolve into a more sustainable industry. This thesis aimed to contribute to the research on circular economy in the building and construction industry by investigating strategies to facilitate and implement circular practices in the form of reuse. This aim is realized by studying the concept of reuse, how it is currently implemented in the industry, and how it impacts the traditional design process. To support the aim, three research questions were constructed:

- **RQ1:** What is the current state of reuse practices in the Swedish building and construction industry?
- **RQ2:** How does the design process change when reusing building products within a property or between properties?
- **RQ3:** How can the introduction of reuse practices be facilitated and successively increased in redevelopment projects?

1.2 Scope and Delimitations

This thesis was conducted in a Swedish context, mainly focusing on office buildings since this type of property tends to undergo frequent redevelopments due to reorganizations and tenant turnover. Billions of SEK are invested each year in redeveloping new offices, where it is common to dispose of products without assessing the existing condition. At the same time, it has been shown that significant economic and environmental savings can be made when renovating an office with reused products, which made this area interesting to investigate further.

Depending on the type of product being reused, the reuse process may look quite different. For this reason, the scope is limited to reuse practices for building products, thus excluding the reuse of furniture and structural elements. Furthermore, when addressing circular processes, this thesis does not differentiate between direct reuse, upcycle, and downcycle methods.

Another delimitation is the impact on the design process and project organization due to contract types. Depending on the contract, clients, consultants, and contractors may have different roles and legal responsibilities, which further influence the reuse implementation. Due to the complexity of contracts, this thesis has not considered the impact of different contract types. Instead, future research focused on this specific area is proposed.

2 | Theoretical Framework

This chapter aims to provide an overall understanding of the background information necessary to proceed with and understand the study. First, the concept of circular economy is presented. Secondly, the design process from a Swedish context is discussed, followed by the final section on reuse.

2.1 Circular Economy

A circular economy (CE) is defined as *"an industrial system that is restorative or regenerative by intention and design"* (World Economic Forum, 2014, p. 15). The concept of circularity rests on three principles: (1) the elimination of waste and pollution, (2) the circulation of products and materials, and (3) the regeneration of nature (Ellen MacArthur Foundation, 2015). The overarching aim of CE is to create more value for each unit of resource through a circular and renewable approach rather than the *"take-make-waste"* pattern of a traditional linear economy. As resources are finite, the linear system is increasingly challenged by increased and volatile resource prices and supply disruptions, thus favoring a transition towards circularity (Ellen MacArthur Foundation, 2015; World Economic Forum, 2014).

CE in the built environment gives rise to the concept of circular buildings, defined as *"buildings that are designed, planned, built, operated, maintained, and deconstructed in a manner consistent with CE principles"* (Pomponi & Moncaster, 2017, p. 771). Following this, circular building strategies emerge to design for durability and adaptability, which emphasizes a long-term focus and extends the service life of a building (European Commission, 2020a). Furthermore, waste reduction may be promoted through design for disassembly and deconstruction, which intends to maximize value retention at the end of life and facilitate the circulation of resources (Cruz Rios et al., 2015). Combined, design for adaptability, durability, disassembly, and deconstruction create improved conditions for future reusability (Cruz Rios et al., 2015; European Commission, 2020a).

The European Commission (2008) established the waste hierarchy model in the Waste Framework Directive, see *Figure 2.1*, which describes an order of preference for waste management that encourages circularity. The model aims to preserve product values through waste prevention, reuse, and recycling of materials and products or other ways of recovery, such as energy recovery. Waste should only be sent to landfill as a last resort (European Commission, 2008).

Figure 2.1: Waste hierarchy (based on European Commission, 2008).

The hierarchical model gives a general order of priority for how to approach CE and implement circular product flows (European Commission, 2008). Similarly, the top two steps of the hierarchy may be developed and adapted to the context of the building and construction industry and form a reuse hierarchy for buildings (White Architects, 2018). This developed hierarchical model, see *Figure 2.2*, then gives a general order of priority for how to approach CE and implement circular product flows and reuse in a building context, specifically (White Architects, 2018).

Figure 2.2: Reuse hierarchy (based on White Architects, 2018).

The reuse hierarchy model states that the initial approach to consider in a project is to retain a building's structure and floorplans, which essentially corresponds to the top tier of the EU waste hierarchy, waste prevention (European Commission, 2008; White Architects, 2018). The following steps recommend reuse within the property, sourcing reused products from other ongoing projects, and upcycling, i.e., transforming and reusing discarded products for new purposes. White Architects (2018) further suggested leasing arrangements that promote circular flows, also known as reverse logistics, where suppliers take greater responsibility for their products. Only as a last resort should new products be purchased. If so, it is important to plan for a long service life and prepare for future reuse from the very beginning of the design process. This means incorporating durable and adaptable design elements and considering disassembly plans (White Architects, 2018).

2.1.1 EU Taxonomy

The EU taxonomy is a classification system with an established list of economic activities that may be defined as environmentally sustainable (European Commission, 2020b). This is an important tool to scale up sustainable investments, protect investors from greenwashing, and support sustainability shifts within companies. The taxonomy establishes six environmental objectives with corresponding criteria that determine whether an economic activity qualifies as environmentally sustainable (European Commission, 2020b). Thereby, the taxonomy can establish the degree to which an investment is environmentally sustainable.

The criteria for substantial contribution to the CE objective to subsequently qualify as an environmentally sustainable economic activity include, for example, to *"increase the durability, reparability, upgradability or reusability of products, in particular in designing and manufacturing activities"* and to *"increase preparing for the reuse and recycling of waste"* (European Commission, 2020b, Article 13).

2.1.2 Climate Declarations

In 2022, Boverket (2021) introduced climate declarations as a new requirement to obtain building permits for new constructions. The general purpose of this requirement is to encourage reduced climate impact in the construction phase of new buildings. Thus, the climate declaration consists of a life cycle analysis (LCA) of the construction phase according to the European standard EN 15978. This calculates the climate impact from the extraction of raw materials, transportation, and manufacturing of building products to transportation to the site and subsequent construction processes (Boverket, 2021). Results are expressed in kg CO2 equivalents, or CO2-eq, which is a unit to measure and compare emissions from various greenhouse gases based on their global warming potential (European Environment Agency, 2023). The amount of other greenhouse gases is converted to the equivalent amount of CO2 with the same global warming potential.

The statutory requirement of a climate declaration only entails the climate shield, load-bearing structures, and interior walls (Boverket, 2021). Other parts such as doors and windows are not considered in the calculations. Therefore, some companies take the climate declaration one step further by establishing climate budgets in their projects (Byggföretagen, 2022). The purpose of a climate budget is to determine target values in terms of kg CO2-eq per m2 BTA, and thereby control and reduce emissions for the project in the design process. For example, Vasakronan states in their annual report for 2022 that new construction projects may not exceed 250 kg CO2-eq per m2 BTA and 125 kg CO2-eq per m2 BTA for redevelopment projects (Vasakronan, 2022).

2.2 The Design Process

The design process is preceded by a pre-study phase, which aims to compile and describe a project's preconditions and then evaluate the feasibility (Akademiska Hus, 2021). The scope of the pre-study is dependent on the project type, and the documentation may include, for example, a needs analysis, cost estimates, project goals and vision, an environmental inventory of any existing structure, and preliminary architectural design proposals for the property (Lindström Claessen, 2017; Lunds Universitet, 2019; Upphandlingsmyndigheten, 2023). This may also set constraints for the project in terms of finances, functions, time, and sustainability (Upphandlingsmyndigheten, 2023).

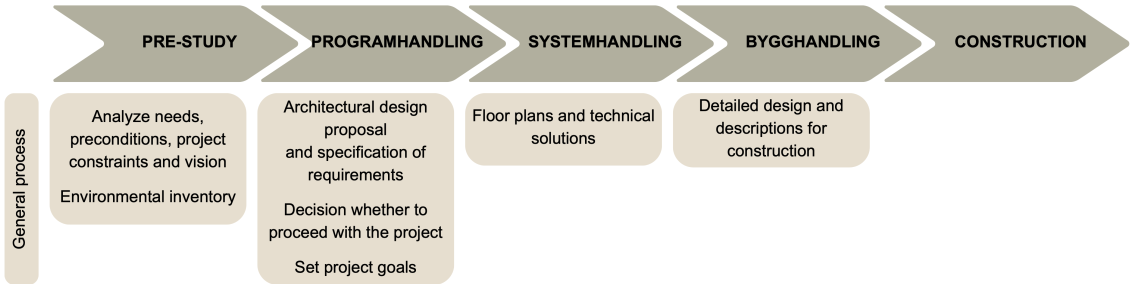

Figure 2.3: An overview of the traditional Swedish design process, including the preceding pre-study and following construction phase (authors' own figure).

In a Swedish context, the design process is usually divided into three successive phases: programhandling, systemhandling, and bygghandling, as presented in Figure 2.3 (Akademiska Hus, 2021; Lindström Claessen, 2017; Lunds Universitet, 2019; Upphandlingsmyndigheten, 2023). Each phase involves an increased level of detail, meaning that the project design becomes increasingly fixed as the project progresses. Early changes to the building's design cost relatively little, while late changes usually cost significantly more as they may require major re-design (Akademiska Hus, 2021). Thus, the scope for changes to the project design decreases further into the process.

Documents in the programhandling are produced in connection with the pre-study and the phases may even overlap since the overall purpose of the programhandling is to deepen earlier analyses and to clarify needs and functional requirements in the project (Lindström Claessen, 2017; Upphandlingsmyndigheten, 2023). In this phase, fundamental decisions are made in the project that defines goals in terms of, for example, timetable, general design, technical standards, level of digitalization, and sustainability goals and certificates (Akademiska Hus, 2021). These factors compose the final documentation of the programhandling, which also forms the basis for a cost estimate. The decision on whether the project should go ahead is usually made in either the pre-study or programhandling phase (Akademiska Hus, 2021; Lindström Claessen, 2017).

In the next phase, systemhandling, technical solutions, floor plans, and functions are further detailed and defined to fulfill set goals and requirements, as well as to optimize costs and environmental impact (Lindström Claessen, 2017). Towards the end of the systemhandling, the final product of the project is largely defined and only detailed solutions can be changed without a major re-design of the project (Akademiska Hus, 2021).

The final phase, bygghandling, is the most extensive phase of the design process and encompasses dimensions and coordination of technical solutions to create the detailed documentation required for construction (Akademiska Hus, 2021).

2.2.1 Contracts

Different contract types affect the design process and project organization dynamics since this defines when contractors and consultants are procured, and by whom (HSB, 2023; Upphandlingsmyndigheten, 2023). In a traditional contract, the client procures consultants and contractors separately, and the contractor is only responsible for the construction as specified in the tender documentation, i.e., execution responsibility (HSB, 2023). In a design-bid contract, however, the contractor is procured for both the design and construction process (HSB, 2023). Therefore, in this case, the contractor has a holistic responsibility for the project and for delivering the functions specified in the tender documents.

Depending on the contract type, the level of detail in the tender documents varies (Akademiska Hus, 2021; Upphandlingsmyndigheten, 2023). A traditional contract is usually procured based on programhandling (Akademiska Hus, 2021; HSB, 2023). In a design-bid contract, it is common for the contractor to still be controlled to a certain level by detailed requirements and the inclusion of partially projected design documents in the procurement (Akademiska Hus, 2021; Upphandlingsmyndigheten, 2023).

2.2.2 Project Goals

Another important aspect influencing the design process is the practice of setting goals. According to Locke and Latham (2002), a goal can traditionally be defined as what an organization consciously is trying to achieve. Setting specific and measurable goals within an organization increases the chances of the goal being achieved. This is because it gives the employee perspective and a better sense of direction, thus making the individual, the project team, and the entire organization more productive (Locke & Latham, 2002).

There are several ways of defining goals; however, the most efficient one, as argued by Boogaard (2021), is by using the SMART goals framework. This involves setting goals considering the following parameters:

- **Specific:** ensure that it is clearly specified what the goal entails
- **Measurable:** ensure the ability to quantify and track progress
- **Achievable:** ensure that the goal is realistic
- **Relevant:** ensure that the goal aligns with long-term objectives
- **Time-bound:** ensure accountability by setting a deadline for the goal to be accomplished

The framework is designed so that all model parameters work together to create thoughtfully planned, achievable, and traceable goals, eliminating uncertainties and other factors hindering performance (Boogaard, 2021).

2.3 Reuse

The use of reclaimed construction products involves reusing products and materials that were previously part of another construction (Park & Tucker, 2017). Therefore, the concept of reuse is often associated with using the same building material more than once, implying that the material is either reused for its original function or for a new one. Unlike recycling, the process of reuse is relatively different; elements are either directly reused or reconditioned instead of being sent to a recycling center to be transformed into newly manufactured products (Hradil, 2014). Reusing construction products and materials is considered both economically and environmentally sustainable, and compared to recycling, reuse is the more desirable option due to the minimal process and energy consumption (Park & Tucker, 2017). This is further argued by Iacovidou and Purnell (2016), who states that reuse provides an environmentally friendly alternative to disposal methods as it decreases pollution and limits the need for natural resources. Consequently, reuse requires fewer resources, less energy, and less processing compared to recycling, disposal, or production of new components, leaving room for economic and environmental benefits (Iacovidou & Purnell, 2016).

The scope of reusable construction products and materials is broad, encompassing everything from furniture and interior building products to entire structural elements (Williams, 2020). Although there is a diverse selection of reusable materials, certain products are more prone to and frequently reused than others. In a Swedish study conducted by Andersson (2022), this aspect was further investigated, where in addition to office furniture, interior building products such as floors, doors, windows, and ceiling tiles were all frequently reused.

While emphasis has mostly been on reusing stationary interior and non-structural construction products during the later years, there is a growing interest in exploring the possibility and potential of reusing structural elements. This part of the structure represents the largest share of the volume, mass, and value compared to other construction products. It is, therefore, the most valuable part to reuse, considering both economic and climate aspects (Hopkinson et al., 2019).

2.3.1 Inventory Process

To facilitate the reuse of different construction products, it is necessary to analyze which products that have the most potential to be reused (White Architects, 2021). When demolishing or, in some cases renovating a building, a considerable amount of construction products is often handled. This makes it essential to assess the reuse potential of the different products as early as possible. Typically, this assessment is performed through an inventory process that is usually conducted before construction or demolition activities. According to White Architects (2021), an inventory process can generally be divided into five different steps, as shown below:

1. *General inventory:* This first step involves gathering information about the building related to drawings, material lists, renovation, remodeling, et cetera. to get a broad understanding of the product's status within the object.

2. *Assessment of reuse potential:* Based on the data collected from step one, a categorization is developed of which building products that have the most potential to be reused and should thus be the focus during the detailed inventory process. However, steps one and two can be omitted, making step three the first step if less extensive projects are undertaken.

3. *Detailed inventory:* Step three involves a more detailed assessment of the targeted products from steps one and two. Analyzing the product's function, condition, and dimensions in order to determine the possibility for reuse.

4. *Supplementation of quality:* In some cases, the detailed inventory may need to be supplemented with additional information. This is done in step four when, for instance, further information is required regarding functional requirements, reconditioning of products, or contact with suppliers.

5. *Development of reuse strategy:* The fifth and final step is to develop a reuse plan for all the necessary practices. For example, time must be allocated for logistics, product identification, packaging, transport, storage, et cetera. in order to successfully implement reuse practices and facilitate circular usage of different products.

When investigating the potential of reusable construction products and conducting a reuse inventory, it is necessary to consider the *"shortest route"* (Björn Johansson, 2022; Lindholm, 2018). This implies seeking the shortest logistical chain for the reusable products and deciding whether the product is in good enough condition to be reused, alternatively, reconditioned on-site. If this is not an option, reconditioning elsewhere or relocating the product to nearby projects may be a solution to keep the logistical chain short (Björn Johansson, 2022; Lindholm, 2018). Should none of the previous options prove to be possible, selling the products for external reuse in other projects is also possible before resorting to disposal or demolition (Björn Johansson, 2022).

Additionally, when conducting inventories, several tools can be used to collect information, analyze, and categorize potential reusable products (White Architects, 2021). One such tool is an inventory app developed by CC Build. This application is used to assess different reusable building products and label them. It can support circular product management within an organization and register or check out goods at a reuse center (CC Build, 2023). Another helpful tool can, for instance, be 3D scanning of buildings. Based on the scanned data, three-dimensional objects are created within the building. This data can then easily be presented in construction documents and used as a basis during the design process (White Architects, 2021).

2.3.2 Potential for Reuse

Numerous studies have examined the opportunities and barriers related to reuse. However, there is still a lack of statistical information connected to the environmental and commercial potential of reusing construction products (Andersson, 2018). This gap was further investigated in a Swedish research study presented by Andersson (2022). The study identified the potential for increased reuse of various building products in Swedish office renovations from three different perspectives: product quantitative saving potential, economic saving potential, and climate-saving potential (Andersson, 2018).

According to Andersson (2022), reusing building products could potentially reduce waste generation by up to 18 000 tons per year, indicating that 18 000 tons of newly produced construction products could be avoided by reusing the existing ones from Swedish office renovation projects. It was further estimated that reuse could reduce procurement costs by SEK 600 million and decrease greenhouse gas emissions by up to 21 000 tons annually. This corresponds to a reduction of around 37% less emissions compared to using newly produced building products when renovating Swedish office premises (Andersson, 2022).

Another Swedish research study conducted by Lindholm (2018) evaluated the cost effects of reusing various interior building products in two office renovation projects, one located in Stockholm and the other in Gothenburg. The results showed that most people involved in the projects did not consider themselves affected by implementing reuse and that only certain processes were affected in terms of time and cost. Despite the increased costs for some processes, the total savings were estimated to be roughly SEK 300 000 for the Stockholm project and SEK 400 000 for the Gothenburg project (Lindholm, 2018). In addition, the reduction in greenhouse gas emissions was estimated at approximately 7 tons of CO2-eq for the Stockholm project, respectively 23 tons of CO2-eq for the Gothenburg project.

2.3.3 Barriers to Reuse

The attitude towards reuse is relatively positive within the industry, and the concept is becoming increasingly prominent (Gerhardsson et al., 2020). However, there is still uncertainty surrounding the adoption of circular processes, where uncertainty and lack of knowledge have resulted in several barriers that discourage actors from fully implementing reuse practices. Barriers and opportunities for reuse have therefore become a much-discussed topic in academia for which several studies have investigated it further (Adams et al., 2017; Gerhardsson et al., 2020; Knoth et al., 2022; Park & Tucker, 2017). According to the studies above, some of the most pressing barriers to implementing reuse could, for instance, be (1) current habits and attitudes, (2) lack of knowledge, (3) an immature market, (4) quality assurance, and (5) logistics. Barriers such as these are often seen as difficult hindrances to overcome. However, it has been recognized that many of them are interconnected, meaning that overcoming one barrier is likely to affect the others (Gerhardsson et al., 2020).

Although the general attitude toward reuse is positive, the construction industry tends to be somewhat conservative and slow in its adoption (Park & Tucker, 2017). Attitude and knowledge have therefore been seen as reasons why reuse has been met with skepticism and reluctance. This is also mentioned by Knoth et al. (2022), who argue that lack of competence often associates reuse with increased costs, lower quality, reduced functionality, and poor design, which hinders reusable products from being reused. Increased knowledge in the sector would therefore reduce misconceptions about reuse and thus facilitate the implementation of the concept (Adams et al., 2017).

Currently, the construction industry also suffers from an undeveloped market and a lack of access to reusable products (Knoth et al., 2022). There is a need to establish a more designated reuse infrastructure that enables an increased supply and demand, making it easy to view and purchase reusable products. Additionally, logistics, time, and storage are also key barriers blocking the implementation of reuse. For instance, the timing of recovering construction products from another building may not always align with the needs of the new building. Knoth et al. (2022) state that difficulties often emerge from extended scheduling due to increased deconstruction time, increased storage and transport costs, lack of storage, and differences between the location of reuse centers and the recovered components. In addition, there are also uncertainties regarding who is responsible for the quality and warranty assurance when dismantling, packaging, and transporting recovered and reusable products (Adams et al., 2017).

3 | Method

The main method of research was through an interview study in collaboration with the consultancy company Sweco. The research strategy was based on a qualitative approach, and an iterative process where the stages of data collection and analysis take place in parallel (Bell et al., 2019). This created research conditions where the understanding of the topic was increased by iterations of analyzing data and returning to data collection with new ideas for modifications and improvements. The qualitative approach was also selected since this allows for explorative, semi-structured interviews that could be tailored to each respondent to match their professional role and area of expertise (Bell et al., 2019).

In the context of this thesis, two types of projects are defined and compared: routine and pilot projects. The former refers to the most common projects undertaken by real estate companies concerning the redevelopment of commercial buildings. These projects generally comprise the majority of ongoing projects in the construction sector, that is, ordinary projects conducted by routine. In contrast, pilot projects refer to innovative and high-profile projects where, for example, new processes, technical solutions, and materials are tested to raise the level of knowledge and offer practical examples within the industry.

This thesis focuses on projects concerning adaptations and renovations of office premises, although some examples of other types of facilities and larger demolition projects followed by new constructions were also included for increased depth.

3.1 Research Process

The research process, as presented in *Figure 3.1*, started with an initial research idea. A literature scan on the topic area was conducted in parallel to dialogue with Sweco, which resulted in the formulation of research questions. Then, interviews and initial data analysis were conducted simultaneously, where materials from interviews were analyzed and interview questions iteratively refined based on the direction of results and in relation to the research questions. Parallel to this, materials from further literature review were added to the theoretical framework as the understanding of the topic area increased, and previously unanticipated findings emerged. The interview materials were then analyzed and interpreted based on the theoretical framework to draw conclusions and answer the research questions.

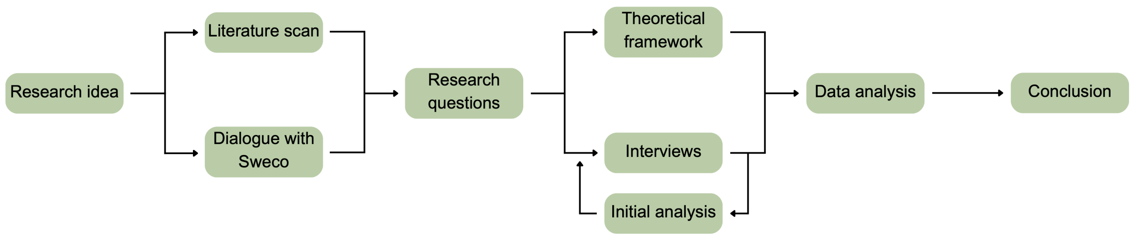

Figure 3.1: Research process (authors' own figure).

3.2 Literature Review

When conducting research, it is important to review existing literature to determine what has already been studied and established in the topic area (Bell et al., 2019). This provides a basis for the research to build upon and to construct relevant research questions. Therefore, in this thesis, the literature review focused on establishing a theoretical framework as a background for understanding concepts important to the topic area.

Relevant literature was identified mainly through Scopus and Chalmers Library databases by using different combinations of keywords, including *reuse*, *circular economy*, *building and construction industry*, and *built environment*. Furthermore, the website for the Swedish initiative for reuse, Centre for Circular Building (CC Build), was used as they list relevant publications and reports within the topic area and Swedish context.

The literature review resulted in a theoretical framework that explains the key concepts of circular economy applied to the building and construction industry, the traditional design process as performed in a Swedish context, and previous research on reuse. This forms the basis for analysis and later chapters in this thesis.

3.3 Interview Study

Data were collected from 15 semi-structured interviews, which were recorded and transcribed with verbal consent from the respondents. Qualitative research often uses a semi-structured method to focus on the individual experiences and perspectives of those being interviewed. The semi-structured approach was selected because it allowed for flexibility and exploration, with open-ended questions that could reveal unexpected information (Bell et al., 2019). This also allowed for questions to be tailored to each respondent based on their respective professional roles and project responsibilities. The differences in professions were key factors in gaining a holistic view of the current state of reuse implementation in the building and construction industry.

3.3.1 Sampling

Interview candidates were primarily selected through snowball sampling, which is a common method within qualitative research (Bell et al., 2019). Following this sampling approach, initial contact was made with a small group of people relevant to the research topic. The initial contacts then introduced and helped to establish contact with other relevant interviewees. The Sweco supervisor played a key role by suggesting suitable initial contacts for the research topic addressed in this thesis.

The identities of the respondents are anonymized, see *Table 3.1*, and will therefore be referred to with numbers, e.g., R1. Relevant information regarding their professions and involvement in either a pilot or routine project context is also described in *Table 3.1*.

Table 3.1: Overview of respondents.

Respondent	Role Description	Project
R1	Project manager for large office projects, involved in Hornsberg 10	Pilot
R2	Sustainability manager, involved in the development of digital tools for optimizing climate impact and costs	Pilot
R3	Digital strategist and BIM coordinator, implementing digital requirements for reuse in BIM, involved in Kromet/Kaj 16	Pilot
R4	Environmental sustainability and reuse coordinator, involved in Kromet/Kaj 16	Pilot
R5	Property developer, involved Kromet/Kaj 16	Pilot
R6	Architect with a focus on the design process in large redevelopment projects	Pilot
R7	Environmental sustainability coordinator, responsible for business development, digitalization, and customer relations within reuse	Pilot/Routine
R8	Environmental sustainability and reuse coordinator, mainly involved in redevelopment projects	Pilot/Routine
R9	Project manager for office premises adaptations	Routine
R10	Project manager, mainly involved in the design process for redevelopment projects	Routine
R11	Environmental sustainability consultant, mainly involved in early stages of redevelopment projects	Routine
R12	Architect and sustainability coordinator	Routine
R13	Project manager for redevelopment projects	Routine
R14	Energy and environmental sustainability consultant with a focus on climate impact calculations	Routine
R15	Head of property management projects, responsible for the management of redevelopment projects in the region	Routine

3.3.2 Projects

This thesis includes routine projects that are used as references by the respondents to exemplify situations, methods, and experiences from working with reuse in their professional roles. Therefore, routine projects were not directly selected beforehand. Respondents, selected for their relevance to the research topic, were instead encouraged during interviews to provide suitable examples from projects within the context of redevelopment projects and office premises adaptations.

This thesis also includes two pilot projects for which the approach to reuse is presented in detail. The pilot projects were consciously selected based on the studied context: a high-profile, redevelopment project with some diversity in the reuse approach, and from two of the largest real estate companies in Sweden focusing on office properties, Vasakronan and Castellum.

Figure 3.2: To the left, a picture of Hornsberg 10 before the renovation. Photograph by Castellum, republished with permission. To the right, a visualization of Hornsberg 10 after the renovation. Rendering by BSK Architects and Castellum, republished with permission.

Hornsberg 10 is an office building with 11 000 square meters of commercial space, located in Kungsholmen, Stockholm (Castellum, 2023). The property was constructed in the 1980s and was merely 35 years of age when discussions began on how to manage the property going forward (R1). Castellum investigated several options, including a renovation or demolition and new construction. Permission was given by the city to demolish the building, however with the requirement that the new building would have one less level. Therefore, Castellum opted for a renovation since this would be the more economically profitable and environmentally sustainable option (R1). Today, with rising consciousness about sustainability, demolitions have become far more restrictive as an option within Castellum according to Respondent 1. The project is especially interesting due to the 1980s architecture, which is characterized by, among other things, smaller windows, and lower ceiling heights as a trace after the oil crisis in the 1970s (Rådegård, 2022). The famous Swedish architect Gert Wingårdh stated this as the reason why many buildings from the 1980s are demolished rather than renovated (Ekberg, 2016). Therefore, the renovation of Hornsberg 10 may offer valuable insights into how to transform this kind of building.

Figure 3.3: To the left, a picture of the previous building Kromet. Photograph by Vasakronan, republished with permission. To the right, a visualization of the new building Kaj 16. Rendering by TMRW Dorte Mandrup and Vasakronan, republished with permission.

Kromet and Kaj 16 are separated into two projects, although they refer to the deconstruction of the current property, Kromet, and the subsequent new construction of Kaj 16 on the same plot in central Gothenburg (Vasakronan, 2021). Kromet was constructed in the early 1980s and while Vasakronan strives to preserve, renovate, and reconstruct old properties, it was not possible in this case (Vasakronan, 2021). The detailed development plan for the area enables a higher degree of exploitation than the 11 000 square meters of commercial space of the existing building and pre-study investigations showed that it would be difficult to retain parts of the structure (R5; Vasakronan, 2019). Instead, Vasakronan aims to reuse and recycle 100% of Kromet (Vasakronan, 2021). The new building, Kaj 16, will encompass 37 000 square meters of both commercial and residential space. Similarly to Hornsberg 10, these projects offer another approach to how to deal with properties from the 1980s.

3.4 Data Analysis

Qualitative research usually generates large, complex datasets, often in the form of interview transcripts as in the case of this thesis (Bell et al., 2019). A qualitative content analysis, also referred to as thematic analysis, is a common approach when analyzing qualitative data (Bell et al., 2019; Hsieh & Shannon, 2005). The approach to thematic analysis in this thesis was primarily inspired by Hsieh and Shannon (2005), who define this type of analysis as *"a method for the subjective interpretation of the content of text data through the systematic classification process of coding and identifying themes or patterns"* (p.1278). Thus, the process entails searching for themes and sub-themes by, for example, repetitions, similarities, and differences across the dataset with relevance to the research questions (Bell et al., 2019).

In this thesis, the qualitative data analysis software NVivo was used to facilitate the coding process and to gain a holistic view of the data. The interview transcripts were read through and coded in NVivo separately by the researchers, then compared, discussed, and coded once more together. Six themes emerged which were further divided into sub-themes, as presented in *Figure 3.4*. These formed the basis of *Chapter 4 Results*, where the first four themes are presented in both a pilot and routine project context separately. The latter two themes are presented as general observations since circumstances are similar independently of the project contexts.

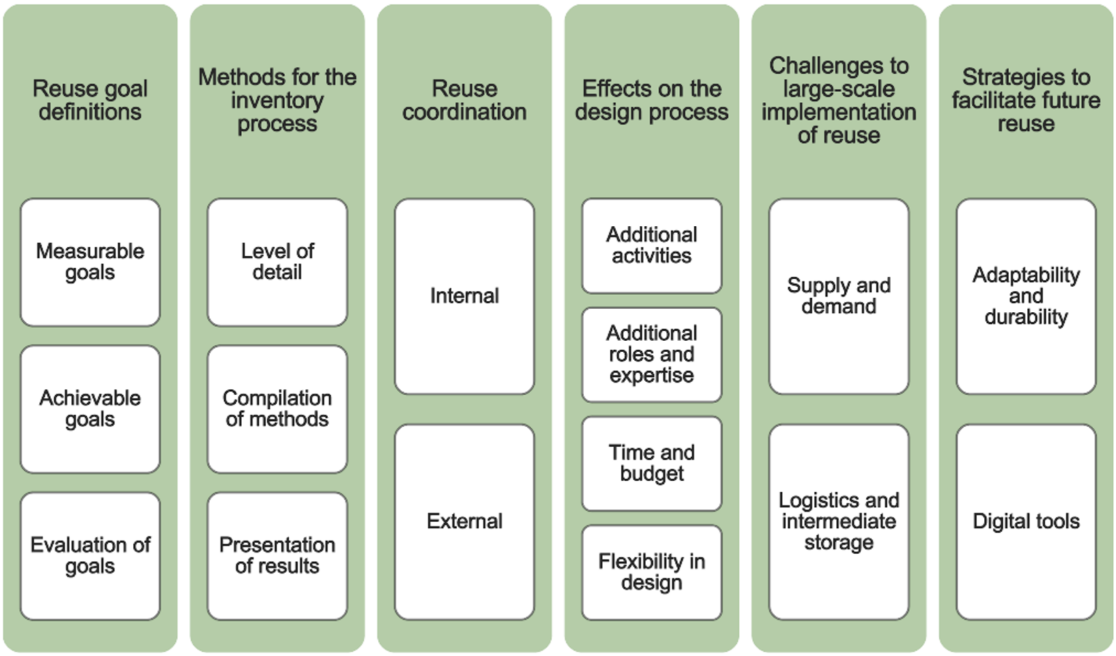

Figure 3.4: Overview of identified themes and sub-themes in the research findings (authors' own figure).

3.5 Critical Evaluation of Method

When conducting qualitative research, it is essential to consider trustworthiness as a key factor in evaluating its quality (Bell et al., 2019). Trustworthiness encompasses four elements: credibility, transferability, dependability, and confirmability. Credibility refers to the degree to which the findings are accurate and believable, while transferability assesses the extent to which the findings can be applied to other contexts. Dependability involves how well the findings can be reproduced. Lastly, confirmability examines whether the researcher's personal beliefs and values have influenced the study (Bell et al., 2019).

To ensure credibility, this thesis employed respondent validation by sharing the findings with respondents to receive their confirmation and feedback on how the data was interpreted (Bell et al., 2019). The findings were also compared to those from existing literature to further support subsequent conclusions. Quantitative research results are often limited in their transferability due to their association with a small group of individuals and contexts. Therefore, it is challenging to demonstrate that the findings and conclusions can be applied to other situations. This thesis addressed this issue by detailing two common contexts for reuse practices: pilot projects where the aim typically is to test new approaches, and routine projects where the aim is to establish methods for daily work. A critique of this approach could be that the sample only includes project contexts that already incorporate some level of reuse. As a result, this may impact how the industry's current level of reuse and the preconditions for its implementation are perceived. Although not universally applicable, this research provides a compilation of knowledge and lessons learned from the industry working with reuse and guidelines that may form a basis for further development of internal, organization-specific routines.

Bell et al. (2019) propose an auditing approach that ensures all phases of research are fully documented and included in the peer review process for increased dependability. However, it is also acknowledged that the extensive amount of data typically produced in qualitative research can impact the feasibility of this approach. In this thesis, interview transcripts were conducted and methodological decisions were thoroughly documented, but the peer reviewers did not analyze them due to the extent of materials. To ensure dependability, discussions regarding data analysis and findings took place during the draft results audit toward the end of the research. The auditing process and regular meetings with the supervisor strengthened the confirmability aspect by ensuring unbiased data analysis.

3.6 Ethical Statement

The four ethical principles in business research are, as stated by Bell et al. (2019), the avoidance of harm to participants, informed consent, protection of privacy through confidentiality, and prevention of deception.

Participation in the study was voluntary and information about the research aims and interview questions were sent beforehand in order for participants to make a well-informed decision. Furthermore, participants were anonymized to protect privacy. Only information vital to the results of the study remains, such as the professional title and area of expertise. In the case of recorded interviews, the researchers verbally asked for permission and results were presented to all respondents before the study was published to avoid misrepresentation or publication of confidential material.

Deception was prevented by continuous meetings and dialogue with the supervisor at Sweco regarding the research process and involvement in any decisions for major changes.

This thesis was conducted with no intent to advertise or otherwise promote any products or services offered by the involved companies. The aim was rather to reflect on knowledge and learnings for how to scale up solutions within reuse, to promote a circular mindset in the sector, and to transfer knowledge of current industry practice to academia.

4 | Results

The primary findings from the interview study include reuse goal definitions, methods for the inventory process, reuse coordination, and subsequent effects on the design process due to the implementation of reuse. These are presented separately according to the pilot or routine project context. Additional findings regarding challenges to large-scale implementation of reuse and strategies to facilitate future reuse are presented as general observations since circumstances are similar independently of the project context.

4.1 Pilot Projects

The findings related to the pilot project context mainly originate from the first eight respondents (R1-R8), and mainly present examples and experiences from the office building projects Hornsberg 10, Kromet, and Kaj 16, as described in further detail in *Chapter 3 Method*.

4.1.1 Reuse Goal Definitions

The overall purpose of a pilot project is to test new solutions and lead the way forward in the industry. Since there is no prior experience to use as a basis for assessments of what would be challenging yet at the same time reasonable to achieve, setting measurable and well-defined goals in pilot projects is difficult (R1; R5). This leads to non-measurable goals such as to "reuse as much as possible" within the property in the case of Hornsberg 10, and the measurable but perhaps less realistic goal to deconstruct and reuse or recycle 100% of the property Kromet (R1; R5). R4 explained that they were aware that 100% may not be achievable – it was set more as a vision for the project. Thus, the goal of 100% and to *"reuse as much as possible"* become quite similar in their aims and meanings.

> *"It is very difficult [to set achievable yet challenging goals], and that was precisely the reason why we set the goal for Kromet so high. I mean, it is very difficult to set a goal when you have never done something before."*
>
> - R5, April 5th, 2023

The best kind of reuse is to avoid deconstruction, but when faced with a situation where a building cannot be reused in its current form, Vasakronan chose to use Kromet as a pilot project to figure out how to tear down such a building as sustainably as possible (R5). This would then set a good example and experience for future, similar situations when deconstruction cannot be avoided. The current estimation is that Kromet will be reused or recycled to about 96% (R4; R5). Although the goal of 100% was not reached, R5 and R8 respectively explained that an ambitious goal is important to make the project team engaged, and this mindset may be more important than fully reaching the goal in the end. Otherwise, one may have ruled out certain things without trying first (R4). For example, Kromet had a cast-in-place concrete framework, which is usually difficult to reuse, yet it will now be crushed and reused as ballast in the new building, Kaj 16, that will be constructed on the same plot (R4).

> *"The way we reason there [...] is that if you put– let's say we know we won't be able to reuse to 100%, but we think we might be able to get to 70%. It may be reasonable, but if you say that we should reuse to 70%, you have automatically said that it is OK if we maybe only get to 50%. Somewhere you say that we should work towards this level of ambition, and it sets a tone [in the project]"*
>
> - R8, March 31st, 2023

When asked about what units are used for percentage goals, R4 explained that there is no standard and that goals can be defined differently in various projects, ranging from units of CO2-eq to mass, volume, and even the number of a certain product type. In the receiving project, Kaj 16, the goal to reuse concrete from Kromet as ballast is defined numerically in volume as 6,000 cubic meters of concrete (R14). The other goals for Kaj 16 are defined as reuse percentages of various product types, for example, 75% in volume of ventilation canals, and 100% numerically of cable ladders, cable trays, steel doors, and acoustic ceiling tiles (R4; R14).

This variation of units could make such goals difficult to interpret and compare (R8). However, R4 states that the more common unit is mass, which may not always be the best way to calculate the results. For example, the concrete structure of Kromet makes up a huge part of the percentage counted in mass given its sheer weight. Although in this case, mass and CO2-eq correlate for concrete, this may not always be the case for all products and materials (R4). R8 explains that Vasakronan, for example, used to convert all units to mass for final calculations. Now, Vasakronan is testing a shift to CO2-eq, which would focus more on the actual climate impact (R8).

The impact of reusing the concrete structure also points to the need to focus more, moving forward, on project goals that make use of larger building parts such as the framework, façade, and other elements of the climate shield (R5). However, R7 states the importance of any small reuse activity since this accumulates a lot of CO2-eq saved if it is implemented consistently in every project. Small amounts of reuse in every project could potentially outperform large-scale reuse in a selected few, which points to the importance of raising the lower level of reuse in all projects (R7).

Another point of interest is that all pilot projects covered in this thesis make some kind of final calculation for the results of reuse (R1; R4; R5). While there is not always a measurable goal to compare this to internally in the project, it may give a reference between projects and forms a basis for future reuse goal definitions.

4.1.2 Methods for the Inventory Process

Castellum procured a company that specializes in reuse to do the inventory of Hornsberg 10 (R1). Because the project organization did not have prior experience working with reuse, the specialist company presented its inventory method and initially recommended selected products to reuse (R1). However, the specialist company was later given free rein and made a detailed inventory for just about everything within the property (R1).

Project Kromet took another approach and started with a reuse potential inventory as an initial impression of what would be possible to reuse (R5). The purpose was to get an overview of the products within the property, their quantities, quality, and estimations of potential CO2 and cost savings (R4). This information was then summarized in a short report and discussed with the client, who ultimately chose what to focus on and take to the next step (R4). In the following detailed inventory, information was gathered about the exact quantity, measurement, and other significant properties of the selected reuse targets required for the development of design documents et cetera (R4). R4 emphasized the importance of this method to get an overview, then sift through, and focus on the products with the most potential for the detailed inventory. Not only does it save time and costs for the client, but the final inventory report also becomes more accessible.

> *"We look at 'what is there, and what do we deem to be the right things to focus on?' and then we also do a detailed inventory based on that. Far too many people go in and do such a detailed inventory right away and then you get a giant report of two hundred pages that no one really knows what to use it for."*
>
> \- R4, March 6th, 2023

Both the reuse inventory of Kromet and Hornsberg 10 compiled a list of reusable products in MS Excel (R1; R4). R4 mentioned a data application for smart devices that CC Build developed to facilitate this process, but they believe this was not used since, at the time, the application was quite new and not deemed stable enough. While the application was described by R4 as simple and easy to use, MS Excel is accessible to many and has good functions for sorting and overviews of identified products. A detailed inventory in MS Excel may store information such as quantities by floor, the exact placement, and measurements (R1; R4) On the other hand, an advantage of using the CC Build application would be the connected product database, which enables the application to calculate estimations for CO2 and cost savings (R4). The program would therefore carry out the evaluation work for you and determine the reuse potential of identified products, and even compile a final results report.

4.1.3 Reuse Coordination

The aim for Hornsberg 10 was to *"reuse as much as possible"* from the property by deconstruction rather than demolition of the building interiors during the renovation (R1). Thus, products that were not reusable within the new building design would instead be sent to other projects to avoid landfills. However, sourcing reusable products from other projects to Hornsberg 10 was not included in the scope (R1). Hornsberg 10 ended up reusing, either within the property or by sending to other projects, a total of 170 doors, 300 windows, 200 glass partitions, interior ceiling tiles, fittings, kitchen appliances, WC interiors, and a glass entrance door (R1).

R1 explained that Castellum works with a categorization of their properties based primarily on location, referred to as A-, B-, C-, and D-locations. A property further from Stockholm's city center, a C- or D-location, would thereby have lower rent, which also tends to correlate with tenants accepting lower standards (R1). Therefore, some products that could not be reused in Hornsberg 10, evaluated as a B-location and thus has higher set requirements, could instead be reused in C- or D-location projects. Similarly, when the exterior expression of Hornsberg 10 was modernized with larger windows, Castellum realized that it would be difficult to reuse the small windows, common in buildings from the 1980s, in another project regardless of location (R1). In this case, the reuse specialist company provided a contact in Estonia who accepted the windows and some of the glass partitions, and therefore Castellum succeeded in trying to reuse them elsewhere.

For Kromet and Kaj 16, the initial plan was to reuse from the old building to the new (R4). However, it was decided to send most reusable products to other projects within Vasakronan to avoid issues with intermediate storage, since there would be a significant time difference between the deconstruction of Kromet and the start of construction of Kaj 16 on the same plot (R4). Among the things reused in other projects were ventilation products, kitchen appliances, WC interiors, cable trays, and interior ceiling tiles (R4). Similarly to Hornsberg 10, project Kromet also sent windows to the Baltics (R5).

Coordination of reuse was primarily achieved through person-to-person communication, which requires an extensive professional network (R1; R4). In the case of Kromet, the MS Excel file was also uploaded to a space shared between colleagues in the organization that works with reuse (R4). R5 also mentioned that a positive spiral was created, where more and more people heard of the project and the possibility to receive reusable products, which increased the demand and likely contributed to the results.

The aim to source reusable products for Kaj 16 was not abandoned, although this will now require more materials from other projects than Kromet (R4; R5). Construction has yet to start, so there are no results for this part (R4). Due to unanticipated issues with financing, which require a majority of the office area to be signed by a tenant prior to the start of construction, the project is temporarily stopped and unable to progress to bygghandling before this is resolved (R4). This delay may jeopardize planned reuse, since the plan for just-in-time delivery, i.e., directly from the deconstruction site to the construction site, will not be the same (R4). Another difficulty for larger projects, such as Kaj 16, is that products must be sourced in larger quantities (R4). One way of facilitating reuse is to have varying requirements based on room functions (R5). For example, a garage or technical room does not require the same modern or new production finish as other spaces. Additionally, R5 recommended that larger projects invest in a role that focuses entirely on sourcing materials. This person must be well-connected and have knowledge of current projects in the local vicinity (R5).

Both Kromet and Hornsberg 10 had contacts in the Baltics that received reusable products from the projects (R1; R4; R5). But R15 pointed out an issue with focusing too heavily on that someone should accept the products, without contemplating the transportation distances. The positive climate impact of implementing reuse as a practice would be reduced, and could even turn into a negative impact, by long transportation distances (R15). Therefore, R15 requested regulations or standards for how far reusable products may be shipped to and from a project – at least in order to claim positive climate impact and CO2 savings. The positive effects of reuse in relation to climate, but also for economic viability, are mainly achieved when reuse is implemented within the property, or between local projects, at least in the current state of today (R15).

An advantage of using the CC Build application for reuse inventories, compared to, for example, MS Excel, is the connection to their product database (R4). This connection also simplifies the advertisement of reusable products on the CC Build marketplace, to further external exchange between projects that are not part of the same organization. R7 further points out that consultancy firms are in good positions to mediate between projects they are involved in, even inter-organizationally.

4.1.4 Effects on the Design Process

By implementing reuse in a project, the design process is mainly affected by additional activities such as the inventory process and sourcing of reusable products, while also requiring new competencies and roles (R1; R4; R5; R8). Ultimately, this translates to effects on time and budget for a project. For example, at least in the state of today, reuse is more time-consuming and this together with additional professional roles in the project organization renders a higher cost for the project (R15). Labor hours are also more expensive compared to materials, which is also to the disadvantage of reuse practices when comparing reuse to virgin materials (15). Thus, reuse may not be profitable in the early stages of implementation, but when the industry adapts to this new mindset, the economic viability may change (R15).

However, reuse within a property or between projects in the local vicinity, may already be profitable since this does not require as much in terms of intermediate storage or transportation (R1; R15).

Hornsberg 10 procured a company that specializes in reuse to make an inventory of reusable products in parallel with the procurement of a demolition company (R1). The inventory process took place in the shift from programhandling to systemhandling, however, R1 stated this would have been advantageous to do earlier in connection to project initiation. The tenders from demolition companies were initially based on traditional demolition of the interiors (R1). They were then asked to make a new tender in which they would instead consider the deconstruction and arrangement of products in the property's basement for intermediate storage. Economically, the difference turned out to be minimal, and costs were even reduced since fewer new products had to be purchased (R1). Since products were reused within the property, and intermediate storage was possible in the basement, this was not as time-consuming and resulted in a positive economical outcome according to R1.

The inventory process before the deconstruction of Kromet was conducted long before the design process for Kaj 16 started (R4). Because of this, reusable products were sent to other projects instead of being stored for the construction of Kaj 16. The reasoning behind this was that it was better to reuse in other projects now, rather than to pay for intermediate storage (R4). R4 and R5 emphasize the time aspect of reuse, and to work as much as possible with just-in-time, i.e., directly from the deconstruction site to the construction site. This requires prior knowledge of upcoming deconstructions in the area to source products from, and the possibility to match the delivery to reduce or eliminate intermediate storage time (R4). R5 further recommends that large projects have a role dedicated to sourcing since this is a time-consuming activity that requires a strong personal network and local knowledge, at least in the current state of today regarding reuse implementation.

In project Kaj 16, the systemhandling was designed mainly as in a regular design process, but parts in the digital models were marked where it was deemed possible to build in a reused product (R4). The design was therefore made with some level of flexibility and tolerance, especially regarding, for example, measurements and manufacturer (R4). Instead, functions were defined in a way so that the design was flexible for either a reused or new product (R4). However, at the latest, detailed information about the reused product must be provided in the shift from systemhandling to bygghandling (R4). This way of designing with flexibility was further supported by R6 and R8 who emphasize the need for a plan B if, in the construction phase, unanticipated changes and preconditions would appear. Otherwise, there could be an increased risk of delays since production could stop due to the issue (R6). R8 continues to recommend that a reuse coordinator is assigned to the project and remains for the entire duration, from project initiation to final inspection, since this person will have the competence and project-specific knowledge to solve any issue that may arise along the way. Furthermore, the reuse coordinator will therefore keep the reuse goals on the agenda throughout the project (R8).

In general, most respondents perceive that the optimal time for the inventory process is *"as early as possible"* since this would give the project the most time to plan and design accordingly. At the latest, inventories must be performed in the systemhandling, although this may risk that demolition or deconstruction has already begun (R4; R6). The optimal time for inventories would therefore be somewhere around the stages of pre-study or programhandling (R1; R4; R6; R8).

4.2 Routine Projects

The findings related to the routine project context mainly originate from the last nine respondents (R7-R15), and present examples and experiences from unspecified projects. However, the majority of the included projects concern adaptations and renovations of office premises, as described in further detail in *Chapter 3 Method*.

4.2.1 Reuse Goal Definitions

Routine projects showed a variety of ways to define project goals and objectives. The most recurrent definition used by most respondents was somewhat more ambiguous and non-measurable goals, where the definition could be to *"try to reuse as much as possible"* (R8; R9; R12; R13; R14). However, other more concrete definitions and goals were also mentioned. R10 and R11 stated that the more common project goals they have been working with had been related to process- and product-based goals. According to both respondents, these goals provide clear guidelines and frameworks for what a project should focus on to succeed with the implementation of reuse (R10; R11).

R11 mentioned that it is generally more important to set process-based objectives and thereby focus on implementing the different processes and methods associated with reuse than just targeting which products to be reused. This would result in a much better understanding of the concept within the project organization and thus develop a greater commitment to reuse (R11). In contrast, R10 argued that product-based targets would be preferable in many smaller routine projects since reuse is not a widely established working method. This would allow the project organization to start small with the concept of reuse and then increase implementation in future projects (R10; R11). A typical process-based objective could be conducting a material inventory or developing a reuse or dismantling plan, while product-based objectives could target a specific group or quantity of products to be reused (R10; R11). *Figure 4.1* below presents the distribution of the respondents' answers related to the three different project objectives.

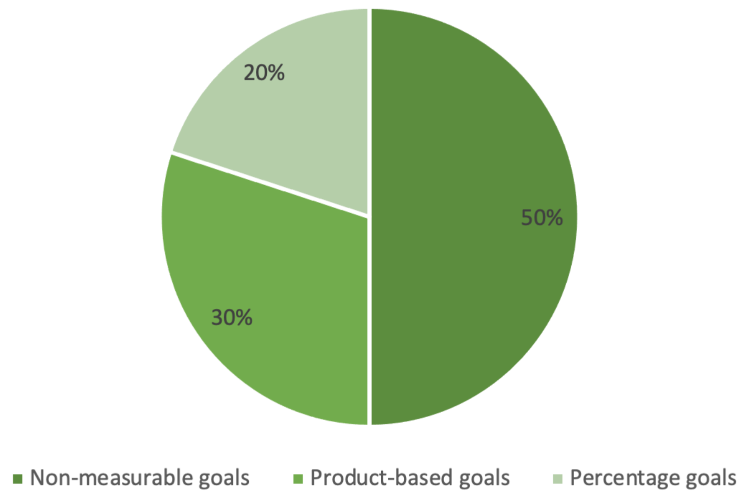

Figure 4.1: Overview of how the respondents (R7-R15) implemented reuse goals in their projects (author's own figure).

Concerning pilot projects, R8 mentioned a percentage goal definition, implying an objective of reusing 100% of an entire building. The goal was then broken down into smaller sub-goals to achieve 100% reuse more easily. However, according to R8, a project goal of this type is not a reasonable goal to expect to achieve in routine projects, as it implies a significant workload for the project team and requires many resources. This was further supported by R7, who believed that a project goal of 100% reuse is neither something to strive for in routine projects, as most of the constructions often contain hazardous materials, a certain percentage is usually disposed of when sorting as well as the objective is difficult to follow up and measure.

> *"I do not think it is preferable working with 100% reuse goals in routine projects, it is pilot and prestige projects that work like that. [. . .] There are large municipal property owners with large property portfolios where many properties are in poor condition and in need of ongoing renovation. It is not reasonable to think that you can reuse everything in them."*
>
> \- R8, March 31st, 2023

In addition, ambiguous goals such as *"to reuse as much as possible"* were neither to be recommended by R8. Such an objective would be considered a *"fuzzy goal"* or a *"buzz goal"* that is difficult to follow up, measure, and determine whether it is progressing or achieved. This was also an underlying argument for a significant proportion of respondents who stated that a goal for routine projects should instead be based on measurable objectives that can be measured and evaluated (R7; R8; R9; R12; R13). For instance, R7 suggested reusing 100% of the products from the conducted inventory, or as mentioned by R12, aiming for reusing a specific type of building product. Although most respondents suggested using measurable goals, not all have been working with measuring or following up on objectives. Only R14 mentioned this, stating that follow-ups were performed continuously during project design meetings to assess and evaluate whether the goals are being met.

R8 and R9 further argued that setting measurable goals may also be preferable to set high objectives within a project, which contradicts R10 and R11, who recommended starting small and successively raising the bar. Higher-set goals are claimed to increase the level of ambition within the project organization and create a higher standard (R8; R9; R14). The commitment to reusing and the level of ambition within a project organization have a decisive impact on the extent reuse is implemented in the project. According to many respondents, low levels of project goals often set the tone for reuse inventories, decreasing the chance for reuse (R9; R11; R12; R13; R14). However, as long as there is an interest in reuse and at least one driving force in the project organization, reuse can always be achieved to some extent, depending on the project size (R9; R12; R14).

4.2.2 Methods for the Inventory Process

For routine projects, the findings showed several ways to conduct a reuse inventory, with the process being performed differently, mainly depending on project size and goal (R7; R8; R10; R12; R14). Based on these two aspects, the respondents expressed roughly three different inventory approaches, with some considering that it is sufficient only to perform a reuse potential inventory to get an overall assessment of the property (R7; R8; R9; R10; R12; R14). Others preferred to immediately conduct a more detailed inventory and extract the specific characteristics of each product (R8; R11; R14). A combined method was also mentioned, where a reuse potential inventory was performed first, followed by a detailed inventory focused on selected products, i.e., based on the results from the reuse potential inventory (R7, R8, R9, R14, R15). *Figure 4.2* provides a holistic overview of the three inventory methods and the respondents' preferences.

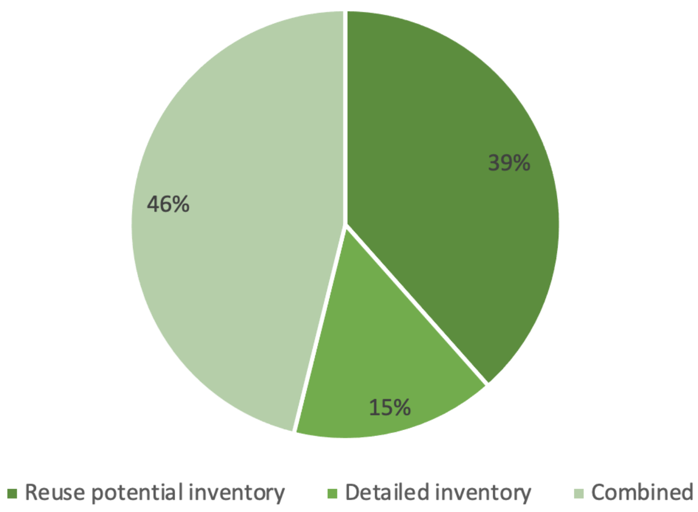

Figure 4.2: Overview of how the respondents (R7-R15) conducted reuse inventories in their projects (authors' own figure).

The environmental inventory is an already established practice within the industry when there are existing structures on the plot. The purpose is to map materials and products with hazardous compounds, which is essential information for any subsequent reuse inventory process (R11; R14). According to R7 and R14, it could initially be sufficient to base the reuse potential inventory on various documentation from the property, such as protocols, pictures, and the environmental inventory if one has been conducted recently. Further, R7 stated, *"The year a construction was built, and its geographical location can tell you a lot about a property's reuse potential,"* especially when combined with a recent environmental inventory (R14). However, if the initial documentation is insufficient or if more information is needed, a complementary site visit is required to investigate and document any missing information to the reuse potential inventory (R7; R14). Such a site visit is usually kept short and focuses on the accessibility to the site in addition to the overview assessment of materials and products (R7). Furthermore, when performing a reuse inventory, R7 and R8 stated that a product list may be used based on commonly demanded products or characteristics such as high profitability and potential for saving CO2-eq. This approach limits the scope, thus streamlining the inventory process and focusing on the resulting documentation (R7; R8; R10).

Once the necessary information is gathered, the reuse potential inventory should be summarized in a short report with a maximum of 10-20 pages, again depending mainly on project size and level of ambition (R7; R8; R12; R14). This is to provide the client with short and simple documentation encompassing the reuse potential within the property. R7 stated that a common mistake often undertaken by consultancies is to conduct an overly detailed initial inventory, which could result in an extensive report. Such an inventory is not valuable for the client and usually results in little to no reuse, as the potential reuse gets lost in the redundant documentation (R7; R8). After having compiled the documentation in either MS Word or MS Excel, as most used, a discussion is held with the client regarding the memo, future dismantling plans, and quality assurance, where the client may decide whether to continue with reuse or not (R7). If the decision is made to continue with reuse, a more detailed inventory is to be conducted on-site in order to perform a more precise material assessment (R7).

The detailed material inventory was further explained in detail by R11, who stated that this type of inventory should preferably be conducted with the project manager, architect, client, designers, contractors, and deconstruction company if possible. Initially, R11 would have a short discussion with the others about which products to focus on regarding climate savings, costs, dismantling, dimensions, energy class, lifetime, quality, quantity, et cetera. Together they would then go through the property room by room, documenting and assessing potential products to reuse. These products are then discussed based on the abovementioned criteria, and the products with the most potential are identified and documented (R11). Discussions are then held on whether the products should be reused in the project, within the organization (internal), or outside the organization (external).

When the detailed inventory is completed, once more the gathered information should be compiled into some sort of documentation together with other thoughts and comments from the detailed inventory (R11). R11 stated that if requested by the client, additional information could also be added, such as estimates of climate savings and costs of new products. The compiled documentation from either just the reuse potential inventory, the detailed inventory, or the combined inventories could then be used as a basis for decision-making on the reuse of different construction products in a project (R7; R15).

Apart from the abovementioned inventory methods, R8 also mentioned two additional ones. These involved either presuming from an internal and already inventoried storage or sourcing from another external inventory. In both of these cases, there is an already compiled documentation of potential products to reuse. According to R8, this makes sourcing material more efficient as it is possible to match potential products with project demands.

4.2.3 Reuse Coordination

Since reuse is not an established working method, coordination is currently a rather personal-based task, according to R8. This makes the whole process quite vulnerable as the person whose task is to coordinate reuse needs to be a driving force in the issue, have knowledge of the different projects going on in the surroundings, and whom to contact. According to respondents, the most common method for internally coordinating reuse between projects is currently person-to-person communication through phone calls, emails, or MS Teams Channels, either requesting reuse for their projects or informing others that there is material to be provided (R7; R8; R9; R10; R11; R12; R13; R14; R15). According to R9, larger regions, such as cities, rely more heavily on the MS Teams channels because more projects are undertaken, and more people are reached simultaneously, creating a greater rotation of products. Smaller locations tend to rely more on phone calls and emails as there are fewer ongoing projects and fewer products in rotation (R9).

It was suggested that if no project in the organization wants the provided reuse or if the sought reuse is not accessible through internal projects, the CC Build marketplace is another method for coordinating, buying, and selling reusable products (R7; R8; R9). There, it would be possible to outsource the surplus reuse for other actors to purchase or search for the desired products (R7; R8; R9). Within the CC Build marketplace, it is also possible to carry out product requests, allowing other projects and actors to match their supply with the requested reuse and exchange reuse with external projects (R7).

4.2.4 Effects on the Design Process

According to all the respondents from R8 to R15, there are additional steps when reusing that ultimately affect the design process. Activities such as material inventories and product sourcing were considered by all as additional steps, but some claimed that there are even more steps to perform. R11 and R14 argued that apart from the inventory, it is necessary to conduct plans on how things will happen practically in terms of reuse and dismantling plans. R8 considered the development of the tender documentation to be a further step due to reuse. For example, adding and developing elements related to guarantees, requirements, guidelines, limitation lists, and functional testing is essential to avoid ambiguity. Finally, possible redesigns based on the inventory were also mentioned by R12 and R13. Depending on when an inventory is performed, if done too late, selected products for reuse could affect the design and require document changes, resulting in increased project time and cost.

As additional processes have emerged, a broadening in expertise and new roles have also been required (R8; R14; R15). Such roles could, for instance, be the person performing the material inventory and, similarly, the role of the environmental inventory. The role of reuse coordinator is also a new role that has not existed before, with the task of setting project goals, developing reuse and dismantling plans, and securing that the products are being reused and not forgotten (R8; R14; R15).

Depending on a project's size and objective, respondents considered the additional activities and the requirement for new roles to have different impacts on the project's time and budget. For instance, R12 stated that with reuse, the initial time and cost would likely increase as more time and resources are often required at the beginning of a project. However, purchasing costs for new products would likely decrease as fewer products need to be purchased, which could ultimately lead to an overall reduction in project costs (R12). R11 considered that all projects, regardless of size and objectives, can succeed in reusing something and break even in time and costs. On the contrary, R9 argued that reuse currently has no positive effect on a project's time or budget since no established methods exist for working with reuse.

> *"Currently, we do not see any positive effect on either economy or time to work with reuse [...] At the moment, it is very unwise for a project manager or a builder to think about reuse because it has never been done before, new things are ordered all the time and it is the easiest way. All systems exist for that, but the systems for these circular processes do not exist, so it is much more complicated in projects because there is no right answer."*
>
> - R9, April 5th, 2023

Most respondents also mentioned the importance of conducting a material inventory early during a project's start-up (R8; R9; R10; R11; R12; R13; R14). Nevertheless, opinions differed among the respondents as to when this inventory should preferably be carried out. According to R8 and R10, a material inventory should ideally be performed as early as the pre-study. R13 and R14 suggested performing it during the systemhandling, whereas R9, R11, and R12 stated that the inventory should be performed *"as early as possible"*. The underlying reason why such a large proportion advocated an early inventory process was mainly so that the information from the inventories could be processed before the detailed design. This gives both architects and designers time to analyze and consider the reuse information well before the documents need to be finalized (R8; R9; R10; R11; R12; R14). As pointed out by R12, it is sometimes easier for architects to design a building with reuse as there is something to develop some idea from.

If an inventory is not to be done in an early stage, this may lead to late processing of the reuse information, resulting in little to no reuse (R10). As exemplified by R10, they had established specific dimensions for kitchen furniture within a project. However, the information regarding the inventoried kitchen was received when the project was in the review phase, with dimensions that differed from those in the design. As a result, the redesign had not been possible, which meant that the project could not reuse as many products as intended. R10 then stated that the information concerning reuse is needed *"as early as possible"* within a project, preferably already in the pre-study, to enable as much reuse as possible. In contrast, R9 claimed that depending on the project's size and goals, receiving information regarding the material inventory as late as during the bygghandling is possible. It is during this phase that the information regarding the reusable products should be incorporated into the building model and get an ID tag (R9).

In order to successfully implement reuse, the necessity to operate with flexibility and open documents was also mentioned (R8; R10; R11; R12). According to R11 and R12, working with open documents would allow designers to assign different construction product ID tags within the building model, describing their properties and whether a product could be replaced with reuse. In addition, having relaxed requirements in project files would also ease the implementation of reuse according to R11. This could be working with varying requirement classifications in different parts of a building instead of having the same requirement everywhere. R11 stated that a door into storage or a toilet room might not have the same fire nor sound classifications as other doors in a facility. This would thus facilitate the reuse of different construction products as the supply would increase, providing a much wider range of reusable products to choose from (R11). As for the perspective of flexibility, R12 further argued that, to implement reuse on a larger scale, one must shift the mindset in the industry to become comfortable with setting details later in projects.

> *"We must bring about a system change. We cannot draw in earlier stages exactly how things should look, but only when you are in detailed planning and maybe even adaptation on the construction site do you know how the detail should look and we are not really in that mindset yet. [...] there is a huge difference between those who pay for the construction and own the house and those who say: 'This is no problem, this will be fine, everything is easy' and so on. Then the client asks: 'OK, where do you have the practical example of this being done at this scale?' and then it is often empty. So, it feels like there is a big gap between what we say we can do and what we can show we can do."*
>
> - R12, March 21st, 2023

4.3 General Observations

This section presents findings for current challenges to large-scale implementation of reuse and strategies to facilitate future reuse as general observations. That is, the circumstances are generally regarded as similar independently of the project context and are therefore presented jointly.

4.3.1 Challenges to Large-scale Implementation of Reuse

A challenge mentioned by most respondents pointed towards logistics and intermediate storage (R1; R4; R5; R6; R7; R8; R10; R14). While some argued that intermediate storage was a better way to work with reuse, others preferred just-in-time (R1; R4; R6; R8). According to R1, it is believed that Castellum, at least in the greater Stockholm area, intends to implement the use of intermediate storage in dedicated warehouses. This would make it possible for Castellum to control the quantity and quality of its own stored material. R1 argued that when working with large-scale projects, such as pilot projects, it is usually difficult to source and ensure the right number of products with the same quality, often leading to difficulties in obtaining enough reuse.

> *"What I find so difficult is that if you see a picture of 50 glass pieces, of these 50, maybe half or even more have various defects. It is always difficult to get it together [...]. I think it is probably better to handle as much as possible of your own material yourself."*
>
> - R1, March 21st, 2023

R6 claimed that just-in-time is not a reliable method to manage reuse in projects since the logistical solutions and the market for reuse are not yet fully developed. R6 continued to provide an example of when they were to design a brick wall based on four different brick types. Unfortunately, the project had to be canceled as they could not find enough material to proceed with the design. It was believed that this was due to the market, but according to R6, it was also partly due to the fact that there is no logistical system for the market to be built upon. In contrast, R4 and R5 stated that they prefer to only work with just-in-time. According to both respondents, the challenge of intermediate storage is the management of large volumes of reuse, which ultimately risk leading to damages. By instead working with just-in-time, minimizing storage and transport time, there is less risk of damages occurring (R4; R5).

In addition, reverse logistics and thereby increased responsibility by the suppliers were also mentioned as an alternative solution (R1; R7; R15). According to these respondents, suppliers of building products such as gypsum boards, interior ceiling tiles, or windows are starting to provide the option to reclaim and recondition their original products. The manufacturer may offer to visit the construction site and dismantle their own products or accept deliveries of already dismantled products (R1; R7; R15). The products are then reconditioned and resold through the same channels that building, and construction companies use today. As stated by R15, large-scale implementation of reverse logistics would make reuse more accessible to projects, since quality assurance is provided by the original manufacturer and the current fragmentation of the reuse market would be mitigated if supply becomes more reliable through already established channels. *Figure 4.3* below presents the distribution of the three different logistical solutions mentioned by respondents.

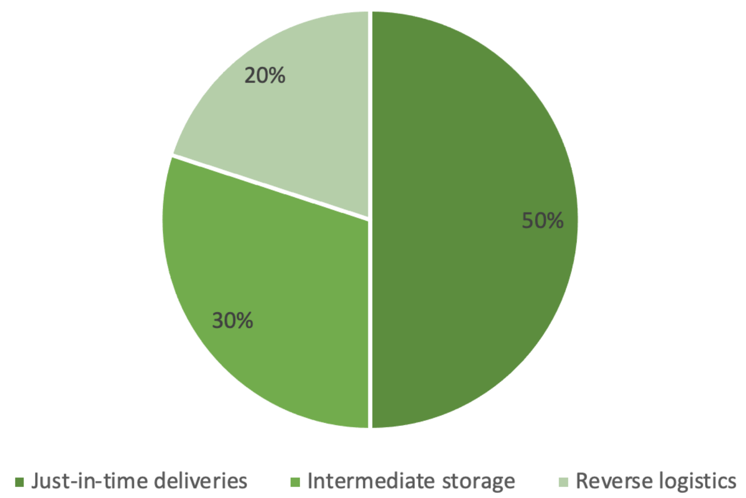

Figure 4.3: Overview of how the respondents (R7-R15) propose that logistics for reuse should be managed (author's own figure).

As some of the respondents mentioned, the reuse market is currently fragmented as it is challenging to obtain the right things at the right time, especially with larger volumes of reuse (R1; R4; R5; R6; R14). The quality assurance for different materials also tends to differ, as it is usually up to the seller to do the assessment (R7). As stated by R7, when sourcing reuse from other actors, such as via CC Build, it is difficult to know where the materials come from, which type of building it was part of, its quality, and to arrange deliveries or pickups. This makes the process of sourcing reuse from external actors uncertain, as the material could have come from anywhere (R7).

Additionally, R14 mentioned that since the market is fragmented and there is no industrial coordination, searching for reuse can be both time-consuming and expensive, often resulting in low profitability. As consultancy hours are expensive and construction materials relatively cheap, there are currently little to no positive effects of working with reuse externally rather than saving CO2-eq (R15). However, as R15 points out, even this may be an alteration of truth. Depending on how far the reusable products must be transported, reuse can even lead to a negative climate impact (R15). Nonetheless, it has been shown that internal reuse within projects can already have a positive economic impact (R1; R15). As the industry is getting increasingly familiar with the concept and methods of reuse, it is probable to become economically viable on a larger scale (R14; R15).

According to R1 and R15, since there is a tougher market in 2023, real estate companies are struggling with a much lower investment budget than anticipated. This creates challenges for companies where reuse could be a potential solution as fewer new products need to be purchased. Investing in reuse, especially in redevelopment projects, can create quick increases in value for real estate companies in times of recession, while at the same time accelerating the rate of reuse implementation in the industry (R1; R15).

> *"A challenge for all real estate companies now is that we do not have as much money anymore [...] We do not have the same investment opportunities, which means that we have to reuse materials because we cannot buy new. If we were to do that for all adaptations [of office premises], if we would just tear out and insert new – it does not work. Then, of course, we do not want to do that climate-wise either, but we cannot do it in the same way as it was done before, because we do not have the financial muscle anymore."*
>
> - R1, April 6th, 2023

4.3.2 Strategies to Facilitate Future Reuse

According to R14, there is a lot of potential for reuse in the future as the upcoming revision of climate declarations could potentially include larger redevelopment projects. This means that, for example, renovation projects would be obliged to conduct a new climate declaration and report the climate impact caused during the construction phase, similar to current requirements for new construction projects. In addition, there are also ideas of introducing limits or reference values for redevelopment projects, meaning that a project would not be allowed to exceed a certain level of climate impact. Furthermore, since most of the redevelopment projects are currently performed on older buildings that generally consist of less climate-friendly products, it will be necessary to reduce the impact of the products already present in the construction (R14). According to R14, industry actors would then turn to reuse, as reuse would be the best option for low climate impact products.

The overall objective for Vasakronan is to be completely climate-neutral by 2030 (R9). To achieve this, it is necessary to know how much CO2-eq is emitted during the operational and construction phases (R9). For the construction phase, climate budget analyses are now developed for all projects regardless of budget, estimating the climate impact of different products and allowing projects to either choose to reuse or purchase new, more climate-neutral products (R9). R9 then stated that during the upcoming year, the goal is to expand the climate budget analysis and gather knowledge of the most beneficial products to reuse. This would enable them to set goals to continuously halve the budget until emissions reach zero. Similarly, reference values in relation to the BTA were mentioned by R9 and R14. The respondents stated that reference values were developed regarding kg CO2-eq per m2 BTA for different building projects. These values could then be used as reference points or targets for different construction projects and evaluations (R9; R14).

Another strategy could include working with adaptable construction layouts, such as modular designs or design for deconstruction. For instance, R1 described how the new floor plans in Hornsberg 10 are designed as modules, increasing adaptability and facilitating future office premises adaptations between tenant contracts. This requires a higher initial investment since installations are put into walls with reduced intervals but means that inner walls may be changed to create different types of floor plans more easily. For example, if a future tenant would want to have more conference rooms and private offices or a more open office plan. Castellum also made conscious material choices for adaptability and durability, for example, thicker wooden floors that can be sanded down several times rather than a glued carpet that would have to be discarded (R1).

> *"What we are doing is that we are taking a greater investment now [. . .] but this also means that we get a completely different lifespan of the property than if we were to build a traditional office where we had told the tenant 'Yes, we can design together with you'. This is where we often make a mistake in letting the tenants' control how our offices should look."*
>
> - R1, April 6th, 2023

Digital twin models and Carbon Cost Compass (C3) could also be strategies to facilitate future reuse. According to R7, it will be possible to use digital twins to store information about reused products and develop maintenance plans for facilities in the future. This information could then be used for digitalized reuse coordination with the possibility of circulating products and planning reuse for a building many years in advance (R4; R7; R9). Furthermore, the C3 program is instead used when designing, offering the possibility to design either a new building or a renovation project based on reuse, thus giving an estimate of the effects effect on both cost and climate impact (R2). According to R2, C3 is rather a cost and climate analysis program than an information storing, showing clients that circularity and low-carbon construction does not have to be expensive in contrast to new construction. Moreover, R3 mentioned the approach of setting digital requirements, meaning that designers would be able to mark in BIM which products are possible to replace with reuse. This would ease the work for designers to control errors as both requirements and information are directly visible inside the models, as they could otherwise be misinterpreted or lost in the extensive project documents (R3).

5 | Discussion

This chapter combines the research results with findings from existing literature to provide new insights related to the research questions. The discussion is divided into three sections, each exploring a research question in detail separately.

- **Section 5.1:** What is the current state of reuse practices in the Swedish building and construction industry?
- **Section 5.2:** How does the design process change when reusing building products within a property or between properties?
- **Section 5.3:** How can the introduction of reuse practices be facilitated and successively increased in redevelopment projects?

5.1 Current State of Reuse Practices in Sweden

As seen from the findings, there are differences between pilot and routine projects that can affect the reuse implementation. Since pilot projects tend to have ambitious goals, push boundaries, and are usually larger, they are often given more time and larger budgets. This means that projects of this type can spend a lot of time and resources searching for reusable products internally and externally, sourcing them, and planning them into the design, facilitating a high reuse implementation. In contrast, routine projects do not operate with the same high-level goals, are generally smaller, have tighter budgets, and have less time. The preconditions for introducing reuse are therefore much more limited. On the other hand, routine projects have significantly shorter lead times than pilot projects, where reuse decision-making can be established much faster, contributing to quicker implementation of reusable products.

The results showed that setting goals was an essential part of implementing reuse. Pilot projects tend to set objectives related to 100% reuse, while routine projects rather choose to formulate it as to *"reuse as much as possible,"* as indicated in *Figure 4.1*. This suggests that the overarching objective is generally similar between the project types, but rather that the differences lie in the follow-up. According to the results, fifty percent of the respondents, who work in a routine project context, apply non-measurable goals. Most respondents acknowledge this as an issue, which is further emphasized by the SMART framework that advocates for specific, measurable, achievable, relevant, and time-bound goals (Boogaard, 2021). Consequently, most exemplified goal definitions only apply relevance and, to some extent, time boundaries due to the inherent characteristics of a building project.

Similarly, the goal of 100% reuse that is common in pilot projects is neither specific nor achievable, as stated by several respondents. However, as pilots aim to push boundaries, such a target is not unreasonable as there are rarely previous examples to use as a basis for estimations of what makes an achievable goal – pilots are there to prove what is achievable. Thus, in contrast to routine projects, there is a need to measure results to implement reuse on a broader scale. At the same time, there is also an inherent desire from the involved companies to measure outcomes in order to boast about success for public relations (PR) reasons.

It was further mentioned that a single person pushing the issue of reuse could sometimes be enough to encourage routine projects to try to implement processes related to the concept. If this is successful, it can inspire others within the project organization to proceed to work with the concept and thus create a snowball effect for reuse in future projects. Even if this may be the case, a routine project cannot rely on enthusiasts to successfully implement the concept. There is a need to establish well-functioning procedures or framework that supports practices to facilitate reuse on a broader scale. The impression may be conveyed that the enthusiasm and general implementation of reuse is rather high in routine projects since results show similarities to pilot projects. However, this may be due to the sample of this thesis which mainly includes respondents who actively work with reuse. Therefore, results indicate the possibilities for reuse in a routine context, while it may not reflect the general level of implementation throughout the industry.

In accordance with Knoth et al. (2022), findings indicated that the market for reuse is still immature due to fragmentation and a lack of well-established infrastructure. Searching for reusable products can therefore be both time-consuming and expensive, regardless of whether it is a pilot or routine project. As the quantities required for reuse tend to be of larger volumes for pilots respectively smaller volumes for routine projects, pilot projects often encounter difficulties in not finding and obtaining enough reusable materials. Routine projects face similar issues yet further encounter challenges such as the expenses of searching for reuse, sometimes exceeding the savings from cheaper material. So, as mentioned in the results, reuse is currently not considered a viable approach in terms of budget or time in either of the project types. At the same time, it is indicated that in the long run, a negative impact on time and budget today should be regarded as an investment in competence for tomorrow. This means that as market practices become more established, such as less fragmented and more reliable access to reuse in the future, the economic profitability should change for the better, resulting in increased implementation of the concept.

Regarding sustainability, reuse was not always considered to have a positive impact on the climate. Sourcing materials and products from long distances could mean that the emissions of transporting exceed the CO2-eq saved from reusing. Considering Kromet and Hornsberg 10, shipping windows to the Baltics may have looked sustainable, however, the question remains whether it was a net positive climate impact. Somewhere it is not just about *"getting rid"* of products and reusing them elsewhere to get a *"good"* result in the individual project. It is rather about the bigger picture of creating sustainable material flows in the vicinity of the individual project, where transportation distances are short. Standards should therefore be set for how far reuse may be transported between projects in order to still maintain a climate-neutral or climate-friendly impact.

As pilot projects tend to be high-profile, have ambitious goals, and push limits, PR aspects may become a problematic issue. For instance, when the success and achievements of a project become too important in relation to what should really be a transparent evaluation and learning from actual results. Since companies' sustainability image often is synonymous with their high-profile projects, they may have an inherent need to express the results in a way that more or less reflects positively on the company, thus leaving out the parts that may not be as positive. One such example could be the transportation aspect, implying better sustainable measurements than what it actually is. Pilot projects can therefore be considered as important for sustainability focus and can sometimes act as catalysts to accelerate the implementation of sustainable concepts in the construction and building sector. However, at the same time, they risk being part of *"greenwashing,"* which ultimately does not contribute to raising the lower level of reuse, particularly in routine projects. Nevertheless, as suggested by the European Commission (2020b), the introduced EU taxonomy may act as an important tool to implement sustainability concepts and prevent greenwashing.

5.2 Effects on the Design Process

The most prominent additions to the design process are activities related to the reuse inventory. Three types of inventories are generally observed throughout the interview study referred to as an environmental inventory, a reuse potential inventory, and a detailed inventory. Most respondents thereby describe inventory methods and experiences of utilizing them in projects that support the process suggested by White Architects (2021). This may be combined into a general idea of the reuse inventory as a step-by-step funnel process with an increasingly targeted focus and an increasing level of detail, see *Figure 5.1.*

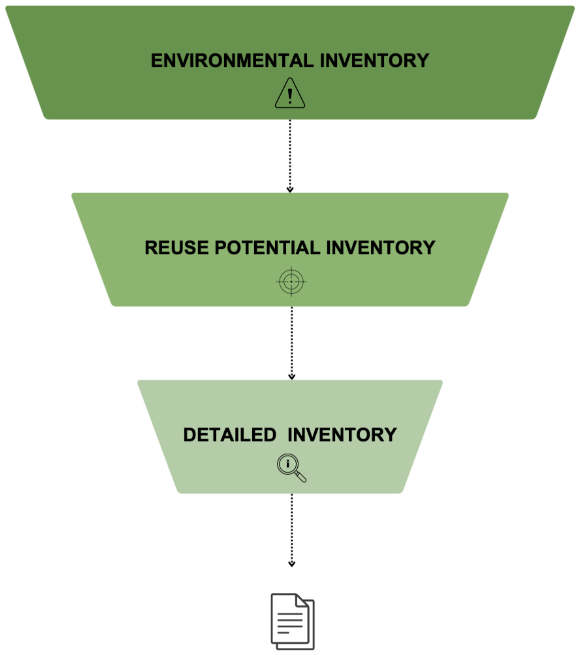

Figure 5.1: The inventory funnel process has three main objectives: (1) identifying and removing hazardous materials, (2) identifying products with the highest potential based on factors like CO2 savings and economic value, and (3) gathering detailed information required for construction with the selected reuse targets. This process generates a report that outlines the reuse options, including dismantling procedures (authors' own figure).

However, one major difference stands out as respondents emphasized the importance of a general overview to assess reuse potential, while White Architects (2021) suggested this step may be omitted. Even respondents who typically did not perform a reuse potential inventory before a detailed inventory expressed this as the desired working method. Time was pointed out as a limiting factor to performing a funnel process for the inventories, while not doing so also could result in time and resources spent on the wrong things, which would inhibit the results. Given the sheer size of a detailed inventory that would otherwise be the result, the funnel was expressed as especially important for larger projects. Therefore, it may be debatable where precisely the line should be drawn for smaller projects to skip steps, as suggested by White Architects (2021).

The environmental inventory is also pointed out as more significant to respondents, while it is not as clearly mentioned in connection to reuse in the reviewed literature. According to the respondents, a recent environmental inventory, the geographical location, and the approximate year of construction of a building can be enough to make a first assessment of reuse potential without requiring a site visit. Therefore, this thesis suggests clearly stating the environmental inventory as a vital part of the reuse inventory process that should be performed early to allow for a preliminary assessment.

Results indicate that reuse affects the design process in several ways, including additional activities such as inventories and sourcing of reusable products, as well as the mindset and approach to building design and detailing. These additional activities and professional roles in projects in turn put higher demands on time and budget, which must be balanced with potential economic savings from reusing instead of buying new. However, in smaller routine projects, some respondents perceived only minor changes to the way they worked. Meanwhile, respondents in the larger pilot projects described an increased complexity due to, for example, larger quantities to either sift through the inventory funnel process or to identify and source from other projects. This implies a correlation between the scale of the project and the subsequent level of effects on the design process, which suggests that reuse is easier to implement in a routine project context. On the other hand, one should at the same time keep in mind other differences in project constraints between a pilot and routine context, such as time and budget as previously mentioned, and the current situation regarding economic viability. Only on-site reuse and, in some cases, just-in-time reuse from the local vicinity have been mentioned by respondents as profitable. Reasons for this include less time and resources spent searching for supply and logistical solutions.

The additional activities may be grouped according to on-site and off-site reuse as parallel processes and are presented in *Figure 5.2*, which builds onto the traditional Swedish design process as described in the theoretical framework. Most respondents advocated for inventories to be conducted *"as early as possible"*, which in some cases were further specified around project initiation, either in the pre-study or, more commonly mentioned, in the stage of programhandling. It was also emphasized to intertwine the processes of setting goals and conducting inventories – to let the reuse potential inventory guide what goals were set and conversely let these goals focus the detailed inventory. According to the respondents, this step-by-step method would save and focus resources on *"the right places"* instead of aimlessly conducting extensive, detailed inventories on the spot.

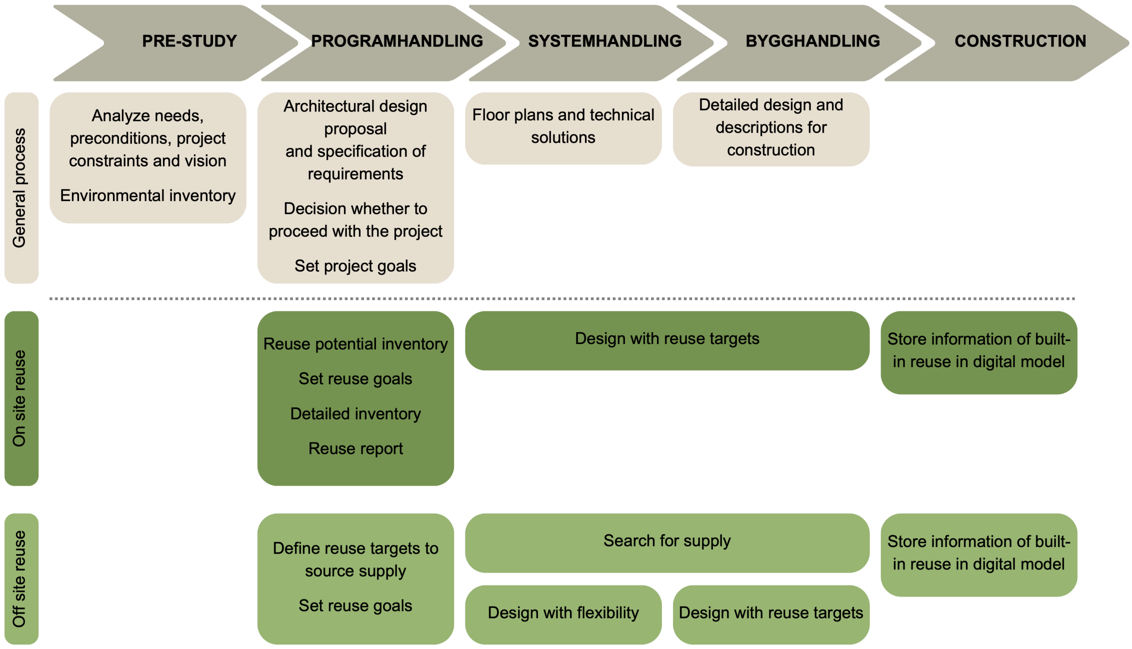

Figure 5.2: Implementing reuse practices introduces two new processes for on-site and off-site reuse activities. These processes run parallel to the traditional Swedish design process, as depicted in the theoretical framework. The key difference between these processes is the demand for flexible design. This is because detailed information about reuse targets is provided at different stages in the design process since the on-site process has direct supply while the off-site process includes searching for supply elsewhere.

Similarly, for off-site reuse, goals and target products would preferably be set around the same time as for on-site reuse. Some respondents also pointed to a level of flexibility where architects could design as usual but mark certain products in the digital model, which could be either reuse or new, depending on supply. The earlier reuse targets are selected, the earlier search for supply may commence, and the more likely the project is to succeed. The key point for off-site reuse is to remain flexible in the design documents for as long as possible, which is a new mindset that needs time and practice to grow comfortable with. Other recommendations that may be drawn from the respondents are to keep flexibility in the building permit documents, with room for a plan B should anything disrupt the reuse plan, and to store information regarding built-in reuse in BIM.

5.3 Strategies to Facilitate Reuse

Personal commitment often becomes a decisive factor in any change process, such as shifting towards a circular economy in the built environment by implementing reuse in projects. Therefore, how reuse is introduced in new project groups is also important to set a positive attitude toward the concept and create a basis for successively increasing the level of implementation. Thus, the apparent contradiction between some respondents arguing for high-set goals and others advocating for starting with smaller goals may not necessarily be a contradiction, depending on the interpretation. It could prove beneficial to start simple and focus on establishing a new mindset and methods in a project team that has not previously worked with reuse through low-set goals, while the following successive increase in the level of implementation is better promoted through high-set goals.

Low-set goals may set a tone in the project for a lower ambition level, as argued by some respondents. However, the introduction of reuse may be facilitated through easier initial goals since they are more likely to be accepted and achieved. With a positive outcome, a spiral may be created as the successfully implemented reuse practices are more likely to be repeated in the next project and possibly be introduced to others. Furthermore, if measurable goals are set, they may act as reference values to compare projects and facilitate a successive raise of the bar. Nevertheless, high-set goals should still be achievable, as stated by the SMART framework for defining project goals (Boogaard, 2021). Apart from aligning with the company's long-term objectives, to apply relevance in accordance with Boogaard (2021), industry-wide reference values should be implemented for various building and project types expressed in kg CO2-eq per m2 BTA since this would promote the overarching objective to lower climate impact in production. For example, reference values could be an addition to the climate declaration to provide an aim that promotes conscious choices – not only an after-the-fact calculation.

As a guideline, setting goals related to reuse should be performed as an intertwined process in which inventories and goals are further detailed. Thus, project goals related to reuse may be defined based on the reuse potential inventory, which in turn guides the selection of reuse targets for the following detailed inventory in accordance with the reuse inventory funnel process previously presented in *Figure 5.1*. The project team may also consult *Figure 5.2* for a general understanding and overview of when different activities related to reuse should take place. It is further highly recommended, and supported by several respondents, to have a reuse coordinator that is present in the project, from the early stages throughout the construction, to monitor the reuse implementation and keep it on the agenda. Without an appointed role responsible for the reuse goals, results may be inhibited as time and budget may become increasingly important and pressing aspects toward the later stages of a project.

Regarding how projects should approach the reuse concept and prioritize actions, the research findings point to on-site reuse within the property as easier to implement and with a significant impact on CO2 savings as well as already proven economic gains. This is further supported by the reuse hierarchy, stated by White Architects (2018). The reason for this, as mentioned both in findings from research and existing literature, is that the current challenges to large-scale reuse implementation in the building and construction industry are dominated by a fragmented market situation and logistical issues. An off-site approach that source reuse from other projects in the local area with a just-in-time delivery solution may also be profitable, according to gathered empirical data. This points to significant future potential for off-site reuse becoming increasingly profitable as the market matures and logistical solutions are established.

The reuse hierarchy model by White Architects (2018) further suggests leasing products, which is not mentioned in the findings as a common practice in the industry. Therefore, this thesis suggests a revised and simplified model, see *Figure 5.3*, based on the research findings, where leasing is removed as a prioritized action. Furthermore, upcycling is considered part of reuse since this thesis does not differentiate between these circular concepts. It is also noticed that the reuse of floorplans and, consequently, the structure of a building may be separated to further differentiate between levels of reuse. For example, this would remove the possible ambiguity of how the renovation of Hornsberg 10 should be evaluated according to the model since floorplans were not reused, but the structure was retained.

Figure 5.3: A revised reuse hierarchy, based on White Architects (2018), providing an order of prioritization for reuse actions in a redevelopment project.

Nevertheless, since demand controls supply, there is a need for actors to increase demand for reuse to a much greater degree in order to drive the development of an inter-organizational market for reuse. This will not happen overnight, and respondents described several occasions when planned reuse had to be changed to new products due to a lack of supply. Still, by introducing the possibility to implement reusable products in the design, for example, by marking products that may be replaced by reuse in BIM, demand is created even if the plan does not always succeed. Thus, flexibility in design and keeping both a plan A and B could increase success rates of reuse implementation in projects while at the same time facilitating future reuse by driving market supply. Furthermore, climate declarations and subsequent new digital tools such as C3, used to make conscious choices to optimize costs and climate impact, may also facilitate future reuse when similar programs are introduced industry-wide.

6 | Conclusion

This thesis aimed to contribute to the establishment of circular processes in the building and construction industry by investigating the current state of reuse practices, its effects on the design process, and how to facilitate implementation on a large scale. This chapter presents answers to the research questions related to this aim and their contributions to industry and academia. Furthermore, this chapter provides suggestions for future research.

RQ1: What is the current state of reuse practices in the Swedish building and construction industry?

Based on the research conducted in the framework of this thesis, it was found that the current state of reuse in the Swedish construction industry is still at an early stage. Several actors support the transition towards circularity and reuse; however, some significant challenges still exist. Since the market for reuse is fragmented and there is no well-established supply and demand, obtaining reusable products is difficult. In addition, methods, routines, and guidelines concerning reuse have yet to be established and developed in the industry, further complicating the concept's implementation. However, despite these challenges, as the concept of reuse continues to be explored, the implementation of reuse should change for the better as methods and guidelines are progressively being developed for future projects.

Pilot projects play a crucial role in promoting sustainability in the industry and serve as examples for others to follow. Therefore, pilot projects need to consider their public relations impact and refrain from actions hindering the overarching goal of establishing sustainable material flows, such as transporting reuse materials over long distances.

RQ2: How does the design process change when reusing building products within a property or between properties?

By compiling experiences from the respondents, new activities, professional roles, and a new mindset and approach to design could be linked to effects on the design process. This means an added inventory process is recommended to be implemented as a step-by-step funnel process with an increased focus and level of detail, as shown in *Figure 5.1*. In addition, *Figure 5.2* offers an overview of the design process with guidance for when these reuse activities should occur to increase the chance of success. Furthermore, there is a need for an industry-wide change of mindset and approach to design, where flexibility is increased, and details are set later in the process. This would considerably increase the probability of finding and sourcing reusable products from other projects and drive the development of an inter-organizational reuse market necessary to enable reliable off-site reuse flows.

Generally, reuse requires more time, at least in the current situation with challenges such as the fragmented market for reuse, which impedes the sourcing of off-site reuse. Therefore, this can also negatively affect the project's finances if it is not balanced with the financial gains of reusing instead of buying new products. Results indicate that on-site reuse within the property and, in some cases, just-in-time reuse from the local area can already be profitable. This points to a significant future potential for off-site reuse to become increasingly profitable as the market matures and logistical solutions are established.

RQ3: How can the introduction of reuse practices be facilitated and successively increased in redevelopment projects?

Based on the empirical findings in this thesis, some general guidelines may be formed to facilitate the introduction of reuse practices in project teams that have not previously worked with reuse and successively increase the level of implementation. These are as follows:

1. Approach reuse in redevelopment projects according to the revised reuse hierarchy, as presented in *Figure 5.3*, which proposes an order of prioritization for reuse actions.

2. Follow the reuse inventory funnel process as presented in *Figure 5.1.* Project goals related to reuse may be defined based on the reuse potential inventory, which in turn guides the selection of reuse targets for the following detailed inventory.

3. Use the SMART framework or similar to set project goals and ensure that results are followed-up and presented after the project is finalized to enable comparisons and continuous improvements.

4. Start small to focus on establishing a new circular mindset and methods in project teams that are new to reuse. Then, employ high-set goals while still considering the aspects of SMART to drive commitment and ambition.

5. Use the changed design process model, presented in *Figure 5.2*, as an overview of the additional activities related to reuse with recommendations for when they should be conducted.

6.1 Contributions to Industry and Academia

This thesis provides insight into current reuse practices and the state of implementation in the Swedish building and construction industry. The findings establish that the fragmented reuse market and lack of routines for logistical solutions remain the key barriers to further implementing circular processes. This points to a state where on-site reuse practices are largely profitable to implement in any project, while further actions are required to enable off-site reuse on a larger scale. Flexibility in design is emphasized as a solution to increase demand for reusable products without jeopardizing the project and drive the development of an inter-organizational market for reuse.

The research also revealed effects on the design process by introducing reuse practices, which resulted in two models. One provides an overview of the changed design process with guidance for when additional activities related to reuse should be performed, and the other proposes a step-by-step process for conducting inventories and setting project goals related to reuse. This thesis provides a basis for organizations to develop internal methods and routines to introduce reuse as a common practice in all projects.

6.2 Future Research

This study identified several opportunities for future research. Firstly, as a reflection on this thesis' choice of a qualitative interview study as a method, further insights into the current state of reuse implementation could be gained from a quantitative approach. As this study targeted redevelopment projects that implemented reuse to some extent, readers may get the impression that routine projects in the industry operate with reuse practices at a relatively high level. This conclusion may not be drawn from this thesis' respondent sample. Therefore, a quantitative research approach with a larger sample representing the industry would be interesting to provide an overview of the extent to which reuse is implemented in projects.

In the development of this study, the impact of contract types on the design process and the organizational dynamics of a project was discovered as an area that requires further research. Future research questions may concern how contracts influence the implementation of reuse and how requirements and project documents should be formulated to promote reuse throughout the chain of actors.

As a final reflection, findings in this thesis point to an emerging practice of implementing reuse differently depending on the socio-economic status of the area. For example, reuse deemed inadequate for Swedish standards was sent to the Baltics, and it was suggested that properties located further from city centers could accept lower standards and consequently accept reuse deemed inadequate elsewhere. This may be a result of reuse being discussed and evaluated solely based on environmental sustainability and economic viability. Therefore, it would be valuable to the building and construction industry to investigate reuse from a more holistic perspective on sustainability, including environmental, economic, and social aspects.

References

Adams, K. T., Osmani, M., Thorpe, T., & Thornback, J. (2017). Circular economy in construction: current awareness, challenges and enablers. *Proceedings of the Institution of Civil Engineers - Waste and Resource Management, 170*(1), 15-24. https://doi.org/10.1680/jwarm.16.00011

Akademiska Hus. (2021). *Riktlinjer för projektering.* https://www.akademiskahus.se/globalassets/dokument/tekniska-publikationer--bilder/riktlinjer-projektering-211101.pdf

Andersson, J., Gerhardsson, H., & Stenmarck, Å. . (2018). Potential och lösningar för återbruk på svenska kontor. *IVL Swedish Environmental Research Institute.* http://urn.kb.se/resolve?urn=urn:nbn:se:ivl:diva-214

Andersson, J., Moberg, S., & Loh Lindholm, C. (2022). Klimateffekter av återbrukade byggprodukter och möbler. *IVL Swedish Environmental Research Institute.* http://urn.kb.se/resolve?urn=urn:nbn:se:ivl:diva-4007

Bell, E., Bryman, A., & Harley, B. (2019). *Business research methods* (5th ed.). Oxford University Press.

Benachio, G., Freitas, M., Tavares, S. (2020). Circular economy in the construction industry: A systematic literature review. *Journal of Cleaner Production, 260,* 121046. https://doi.org/https://doi.org/10.1016/j.jclepro.2020.121046

Björn Johansson, F. P., Malin Belfrage, Sarah Grahn, Lise-Lotte Larsson Kolessar,. (2022). *Återbruksguide för kontor.* https://ccbuild.se/media/rbcn3g5r/%C3%A5terbruksguide-f%C3%B6r-kontor.pdf

Boogaard, K. (2021). *How to write SMART goals.* Retrieved 12th May 2023 from https://www.atlassian.com/blog/productivity/how-to-write-smart-goals#:~:text=What%20are%20SMART%20goals%3F,within%20a%20certain%20time%20frame.

Boverket. (2018). *Hållbart byggande med minskad klimatpåverkan.* https://www.boverket.se/globalassets/publikationer/dokument/2018/hallbart-byggande-med-minskad-klimatpaverkan.pdf

Boverket. (2021, 30th September). *Klimatdeklarationens omfattning.* Retrieved 9th May 2023 from https://www.boverket.se/sv/klimatdeklaration/gor-sa-har/omfattning/

Boverket. (2023a). *Bygg- och fastighetssektorns uppkomna mängder av avfall. Boverket.* Retrieved 11th March 2023 from https://www.boverket.se/sv/byggande/hallbart-byggande-och-forvaltning/miljoindikatorer---aktuell-status/avfall/#:~:text=Inom%20byggsektorn%20uppkom%20det%20i,stora%20m%C3%A4ngden%20gruvavfall%20r%C3%A4knats%20bort

Boverket. (2023b). *Utsläpp av växthusgaser från bygg- och fastighetssektorn.* Boverket. Retrieved 11th March 2023 from https://www.boverket.se/sv/byggande/hallbart-byggande-och-forvaltning/miljoindikatorer---aktuell-status/vaxthusgaser/#:~:text=Bygg%2D%20och%20fastighetssektorn%20svarade%202020,stora%20utsl%C3%A4pp%20utomlands%20genom%20importvaror

Breene, K. (2016). *Can the circular economy transform the world's number one consumer of raw materials?* World Economic Forum. Retrieved 11th March 2023 from https://www.weforum.org/agenda/2016/05/can-the-circular-economy-transform-the-world-s-number-one-consumer-of-raw-materials/

Byggföretagen. (2022). *Byggutmaning: Klimatbudget - en guide för dig som vill minska byggprojektets klimatutsläpp.* https://byggforetagen.se/app/uploads/2022/01/Byggutmaning_Klimatbudget_-27012022.pdf

Castellum. (2023). *Lindhagensgatan 133.* Retrieved 28th April 2023 from https://www.castellum.se/nyproduktion/lindhagensgatan-133

CC Build, (2023). *CC Build Inventeringsapp.* Retrieved 15th March from https://ccbuild.se/

Cruz Rios, F., Chong, W. K., & Grau, D. (2015). Design for Disassembly and Deconstruction – Challenges and Opportunities. *Procedia Engineering, 118, 1296-1304.* https://doi.org/10.1016/j.proeng.2015.08.485

Ekberg, H. (2016, 1st August). Bra arkitektur är byggnader som inte rivs på flera hundra år. *Lokalnytt.* https://www.lokalnytt.se/artiklar/1813/bra-arkitektur-ar-byggnader-som-inte-rivs-pa-flera-hundra-ar

Ellen MacArthur Foundation. (2015). *Towards a circular economy: Business rationale for an accelerated transition.* https://ellenmacarthurfoundation.org/towards-a-circular-economy-business-rationale-for-an-accelerated-transition

Esposito, M., Tse, T., & Soufani, K. (2018). The circular economy: An opportunity for renewal, growth, and stability. *Thunderbird International Business Review, 60*(5), 725-728. https://doi.org/https://doi.org/10.1002/tie.21912

European Commission. (2008). *Waste Framework Directive 2008/98/EC.* https://environment.ec.europa.eu/topics/waste-and-recycling/waste-framework-directive_en

European Commission. (2014). *Towards a circular economy: A zero waste programme for Europe.* E. Commission. https://ec.europa.eu/environment/pdf/circular-economy/circular-economy-communication.pdf

European Commission. (2020a). *Circular economy principles for building design.* https://ec.europa.eu/docsroom/documents/39984

European Commission. (2020b). *EU taxonomy for sustainable activities,* Regulation (EU) 2020/852. https://finance.ec.europa.eu/sustainable-finance/tools-and-standards/eu-taxonomy-sustainable-activities_en

European Commission. (2021). *Buildings and construction.* European Commission. Retrieved 10th March 2023 from https://single-market-economy.ec.europa.eu/industry/sustainability/buildings-and-construction_en

European Environment Agency. (2018, 2019). *Waste Generation.* European Environment Agency. Retrieved 11th March 2023 from https://www.eea.europa.eu/airs/2018/resource-efficiency-and-low-carbon-economy/waste-generation

European Environment Agency. (2022). *Greenhouse gas emissions from energy use in buildings in Europe.* European Environment Agency. Retrieved 11th March 2023 from https://www.eea.europa.eu/ims/greenhouse-gas-emissions-from-energy

European Environment Agency. (2023). Carbon dioxide equivalent. Retrieved 9th May 2023 from https://www.eea.europa.eu/help/glossary/eea-glossary/carbon-dioxide-equivalent

Gerhardsson, H., Lindholm, C. L., Andersson, J., Kronberg, A., Wennesjö, M., & Shadram, F. (2020). Transitioning the Swedish building sector toward reuse and circularity. *IOP Conference Series: Earth and Environmental Science, 588*(4), 042036. https://doi.org/10.1088/1755-1315/588/4/042036

Gerhardsson, H., Lindholm, C., Ahlm, M.,. (2019). Arbetssätt för ökat återbruk i lokalanpassningar. *IVL Swedish Environmental Research Institute.* https://www.diva-portal.org/smash/get/diva2:1552277/FULLTEXT01.pdf

Hopkinson, P., Chen, H. M., Zhou, K., Wang, Y., & Lam, D. (2019). Recovery and reuse of structural products from end-of-life buildings. *Proceedings of the Institution of Civil Engineers - Engineering Sustainability, 172*(3), 119-128. https://doi.org/10.1680/jensu.18.00007

Hradil, P., Talja, A., Wahlström, M., Huuhka, S., Lahdensivu, J., & Pikkuvirta, J. (2014). *Re-use of structural elements: Environmentally efficient recovery of building components.* https://publications.vtt.fi/pdf/technology/2014/T200.pdf

HSB. (2023). *Vad är ett förfrågningsunderlag?* Retrieved 5th May 2023 from https://www.hsb.se/stockholm/forvaltningstjanster/projektledning-och-byggledning/inventering-och-upphandling/vad-ar-ett-forfragningsunderlag/

Hsieh, H. F., & Shannon, S. (2005). Three Approaches to Qualitative Content Analysis. *Qualitative health research, 15,* 1277-1288. https://doi.org/10.1177/1049732305276687

Iacovidou, E., & Purnell, P. (2016). Mining the physical infrastructure: Opportunities, barriers and interventions in promoting structural components reuse. *Science of The Total Environment, 557-558,* 791-807. https://doi.org/https://doi.org/10.1016/j.scitotenv.2016.03.098

Knoth, K., Fufa, S. M., & Seilskjær, E. (2022). Barriers, success factors, and perspectives for the reuse of construction products in Norway. *Journal of Cleaner Production, 337,* 130494. https://doi.org/https://doi.org/10.1016/j.jclepro.2022.130494

Lindholm, C., Gerhardsson, H., & Stenmarck, Å. (2018). Återbruk av möbler och interiöra byggprodukter Utvärdering och arbetsguide baserat på erfarenheter från IVL:s lokalanpassningar. *IVL Swedish Environmental Research Institute.* http://urn.kb.se/resolve?urn=urn:nbn:se:ivl:diva-2859

Lindström Claessen, E. (2017, 16th June). Byggprocessen – så funkar den. *Akademiliv.* https://akademiliv.se/

Locke, E., & Latham, G. (2002). Building a Practically Useful Theory of Goal Setting and Task Motivation: A 35Year Odyssey. *American Psychologist - AMER PSYCHOL, 57,* 705-717. https://doi.org/10.1037/0003-066X.57.9.705

Lunds Universitet. (2019). *Byggprocessen i nio steg.* https://www.konstnarliga.lu.se/sites/konstnarliga.lu.se/files/2021-01/Byggprocessen%20i%20nio%20steg.pdf

Park, J., & Tucker, R. (2017). Overcoming barriers to the reuse of construction waste material in Australia: a review of the literature. *International Journal of Construction Management, 17*(3), 228-237. https://doi.org/10.1080/15623599.2016.1192248

Pomponi, F., & Moncaster, A. (2017). Circular economy for the built environment: A research framework. *Journal of Cleaner Production, 143,* 710-718. https://doi.org/10.1016/j.jclepro.2016.12.055

Rådegård, I. (2022, 9th September). Så kommer energikrisen påverka stadsbilden: ”Mer solceller och tak med växter”. *SVT.* https://www.svt.se/kultur/arkitekturskribenten-om-energikrisen-kommer-byggas-solceller-och-tak-med-vaxter

Sweco. (2023). Urban Insight: *Building the future through circular data.* https://www.sweco.se/wp-content/uploads/sites/3/2022/05/Urban-Insight-by-Sweco_Building-the-future.pdf

Swedish Government. (2022). *Miljöbalken 1998:808.* Sveriges riksdag. Retrieved 10th March from https://www.riksdagen.se/sv/dokument-lagar/dokument/svensk-forfattningssamling/miljobalk-1998808_sfs-1998-808

United Nations Environment Programme. (2022). *2022 Global Status Report for Buildings and Construction: Towards a Zero-emission, Efficient and Resilient Buildings and Construction Sector.* https://wedocs.unep.org/handle/20.500.11822/41133

Upphandlingsmyndigheten. (2023). *Upphandlingar under ett byggnadsverks liv.* Retrieved 3rd May 2023 from https://www.upphandlingsmyndigheten.se/branscher/bygg-och-anlaggning/upphandlingar-under-ett-byggnadsverks-liv/byggide/

Vasakronan. (2019). *Lilla Bommen – ett färgstarkt spektrum i ständig förändring.* https://www.arkitekt.se/app/uploads/2019/09/Inbjudan-till-prekvalificering-Kromet.pdf

Vasakronan. (2021). *Att återvinna och återbruka ett helt hus.* Retrieved 2nd May 2023 from https://vasakronan.se/aktuellt/att-atervinna-och-aterbruka-ett-helt-hus-ar-det-verkligen-mojligt/

Vasakronan. (2022). *Annual Report 2022.* https://wwwvasakronanse.cdn.triggerfish.cloud/uploads/2023/04/vasakronan-annual-report-2022-3.pdf

White Architects. (2018). *Arkitektens återbruksmetodik.* https://ccbuild.se/media/k0jmheee/wrl_arkitektens_Ãěterbruksmetodik_2018.pdf

White Architects, B. D., Wingårdhs, Lokalförvaltningen Göteborgs Stad. (2021). Inventering för återbruk: *Arbetsgång för identifiering och värdering av återbruk.* https://ccbuild.se/media/xitj3prk/pm-inventering-f%C3%B6r-%C3%A5terbruk_recirculate.pdf

Williams, F. (2020). Virtuous circles: Can reusing building materials in new projects go mainstream? *Architects' Journal.* https://www.architectsjournal.co.uk/news/virtuous-circles-can-reusing-building-materials-in-new-projects-go-mainstream

World Economic Forum. (2014). *Towards the Circular Economy: Accelerating the scale-up across global supply chains.* https://www3.weforum.org/docs/WEF_ENV_TowardsCircularEconomy_Report_2014.pdf

DEPARTMENT OF SOME SUBJECT OR TECHNOLOGY
CHALMERS UNIVERSITY OF TECHNOLOGY
Gothenburg, Sweden
www.chalmers.se

CHALMERS
UNIVERSITY OF TECHNOLOGY