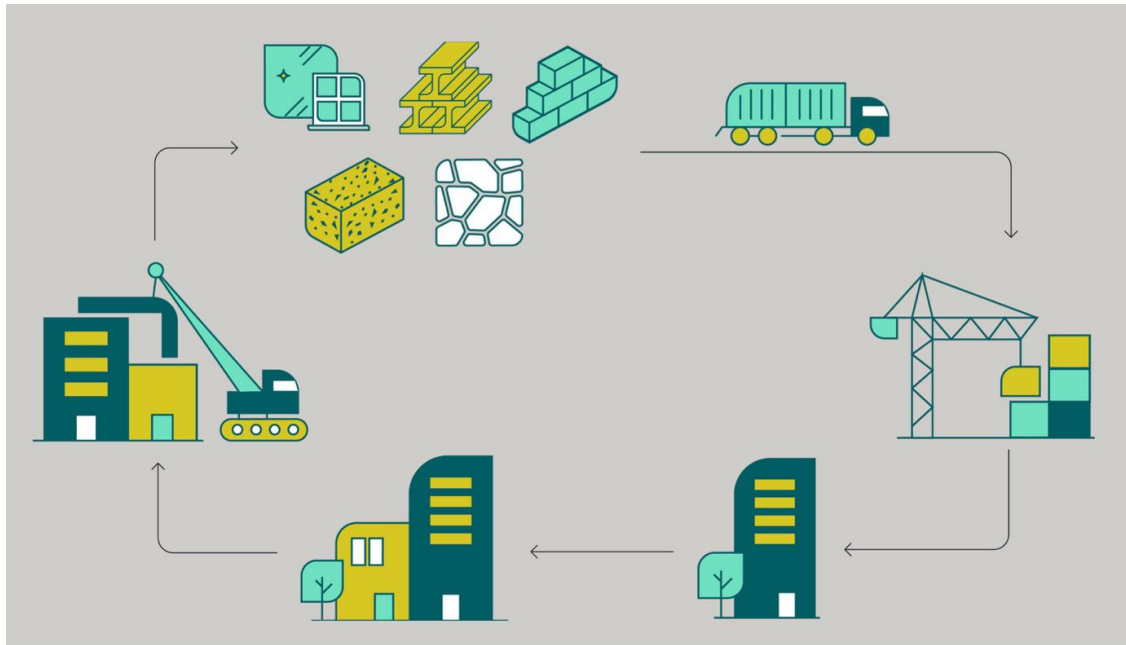




CHALMERS
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Investigating the Opportunities for Implementation of Reused Materials at a Larger Scale in New Construction

How Actors can Overcome the Challenges to Implement More Reused Materials in the Swedish Construction Industry

Master's thesis in Master Program Design and Construction Project Management

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Department of Architecture and Civil Engineering
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Master's thesis ACEX30
Gothenburg, Sweden 2023

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Abstract

Material reuse in new construction has become an increasingly important topic in recent years, as the construction industry seeks to address the environmental impacts associated with building new structures. In 2020, the construction industry emitted 9.8 million tons of CO₂ equivalents, which corresponds to 21 percent of the total emissions of greenhouse gases in Sweden (Boverket, n.d.). Construction and demolition processes lead to large withdrawals of virgin and finite resources. Extracting and processing such materials leads to large amounts of greenhouse gas emissions and other types of environmental problems (Göteborgs Stad, 2020). Reusing materials in new construction can help reduce waste and energy consumption, lower greenhouse gas emissions, and preserve natural resources. Change and measures are needed in the construction industry to reduce emissions and its enormous impact on the environment. Therefore, the construction industry faces a major challenge when it comes to making a shift from linear to circular material flows. There are various incentives by the EU and municipalities in Sweden to deal with such challenges and initiate a more sustainable approach to the built environment. As a part of making this transition, it is crucial to change from traditional linear material flows into circular flows. A major component in circular construction is reusing materials in new construction projects in order to close loops and decrease emissions and extraction of virgin materials. The purpose of the report is to review what actors in the industry can do to better meet the requirements regarding circularity in the construction industry. More specifically, the report analyzes improvement opportunities for reuse within the design and construction phases. Moreover, the current state of material reuse in construction and the readiness to further implement reuse at a large scale in new construction is examined. The reviewed literature and conducted interviews were designed to gain various perspectives of the topic and to identify potential improvement opportunities. This study provides an overview of the benefits, challenges, and opportunities associated with material reuse in new construction, highlighting the potential for this practice to promote more sustainable and environmentally conscious building practices. Main findings from the study were the importance of collaboration between the stakeholders. The suppliers carry a significant role as they possess most knowledge about the materials and can recondition, store and provide guarantees for the reused materials. From a contractor perspective, it is important to support other actors involved in the project and provide the right tools to enhance reuse when coordinating the construction projects.

Keywords: circularity, reuse, circular economy, circular construction

Undersökning av möjligheterna för implementering av återbrukade material i större skala vid nybyggnation

Hur aktörer kan övervinna utmaningarna att implementera mer återbrukade material i den svenska byggbranschen

PONTUS SVENSSON, FILIPPA TINMARK

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Sammanfattning

Materialåterbruk i nybyggnation har blivit ett allt viktigare ämne de senaste åren, eftersom byggbranschen försöker ta itu med miljöpåverkan i samband med att bygga nya strukturer. År 2020 släppte byggbranschen ut 9,8 miljoner ton CO₂-ekvivalenter, vilket motsvarar 21 procent av de totala utsläppen av växthusgaser i Sverige (Boverket, n.d.). Bygg- och rivningsprocesser leder till stora uttag av jungfruliga och ändliga resurser. Att utvinna och bearbeta sådana material leder till stora mängder växthusgasutsläpp och andra typer av miljöproblem (Göteborgs Stad, 2020). Återbruk av material i nybyggnation kan bidra till att minska avfall och energiförbrukning, minska utsläppen av växthusgaser och bevara naturresurser. Förändringar och åtgärder behövs inom byggbranschen för att minska utsläppen och dess enorma påverkan på miljön. Därför står byggbranschen inför en stor utmaning när det gäller att göra ett skifte från linjära till cirkulära materialflöden. Det finns olika incitament från EU och kommuner i Sverige att hantera sådana utmaningar och initiera ett mer hållbart förhållningssätt till den byggda miljön. Som en del av denna övergång är det avgörande att byta från traditionella linjära materialflöden till cirkulära flöden. En stor komponent i cirkulärt byggande är att återbruka material i nya byggprojekt för att stänga flöden och minska utsläpp och utvinning av jungfruliga material. Syftet med rapporten är att se över vad aktörer i branschen kan göra för att bättre möta kraven kring cirkularitet i byggbranschen. Mer specifikt analyserar rapporten förbättringsmöjligheter för återbruk inom projekterings- och byggfaserna. Dessutom undersöks det aktuella läget för materialåterbruk i byggandet och beredskapen att ytterligare implementera återbruk i stor skala i nybyggnation. Den granskade litteraturen och genomförda intervjuer utformades för att få olika perspektiv på ämnet och för att identifiera potentiella förbättringsmöjligheter. Den här studien ger en översikt över fördelarna, utmaningarna och möjligheterna förknippade med materialåterbruk i nybyggnation, och belyser potentialen för denna praxis för att främja mer hållbara och miljömedvetna byggmetoder. Huvudfynden från studien var vikten av samarbete mellan intressenterna. Leverantörerna har en betydande roll då de besitter mest kunskap om materialen och kan rekonditionera, lagra och lämna garantier för de återanvända materialen. Ur ett entreprenörsperspektiv är det viktigt att stödja andra aktörer som är involverade i projektet och tillhandahålla rätt verktyg för att förbättra återanvändningen vid samordning av byggprojekten.

Nyckelord: cirkularitet, återbruk, cirkulär ekonomi, cirkulärt byggande

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Pontus Svensson, Filippa Tinmark, Gothenburg, June 2023

Central concepts

Below is the central concepts of the report described and explained.

Concepts

Circular economy	An economy where waste principally is not generated but resources are retained in society's cycle or in a sustainable way returned to nature's own cycle.
Circular construction	The circular economy in the construction industry is often called circular construction.
Sustainable construction	Building with renewable and recyclable resources and materials.
Reuse	A product that is used again, without major adjustments.
Recycling	Materials that are seen as waste are recycled and becomes a new material.
Stakeholder	A stakeholder is a person, group or organization with a vested interest, or stake, in the decision-making and activities of a business, organization or project.
Procurement	Procurement refers to the competitive process in which contractors participate to obtain a business contract with the client.

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1

Introduction

In this chapter an introduction to the study and the background as well as the motives are provided alongside the purpose and questions the report intends to answer. An introduction to the topic and the concepts of circular economy and reuse in construction are presented. Further, the challenges with circular construction and reuse are also stated. Based on the background and the current challenges of reuse, the research questions for the study have been formulated.

1.1 Background

The construction industry was responsible for 21 percent of the total greenhouse gas emissions in Sweden during 2020, consisting of 9.8 million tonnes of CO₂ equivalents (Boverket, 2023b). Construction and demolition processes lead to large withdrawals of virgin resources. Not only does the handling of these withdrawals reduce the quality and potential of the materials, but it also leads to large amounts of greenhouse gas emissions and other types of environmental problems (Göteborgs stad, 2020). In addition, the construction industry creates large amounts of waste every year, in 2020 the construction sector in Sweden generated over 14 million tons of waste. Studies also show a negative trend where waste has increased by about 2 million tons per year from 2018-2020. A lot of today's waste is materials that should not be seen as waste but as useful materials (Boverket, 2023a). Up until the year of 2021 the construction industry was accountable for 40 percent of the energy demand, half of the consumption of raw materials as well as responsible for 36 percent of greenhouse gas emissions in Europe. This leaves immense room for improvement in the decision making and early stages regarding the design and construction of the built environment (Carvalho et al., 2021).

Considering the severe environmental impact from new construction projects and the large amount of waste generated, the industry needs to transition from a linear to a circular approach. A circular model would decrease the environmental impact such as emissions, waste and other environmental damage. In doing so, the general climate impact would decrease significantly as the construction industry holds such a large share of the total environmental pollution.

1.1.1 Circular Economy

Circular economy refers to an economic system that discards the end-of-life stage and aims to constantly keep the materials in flow through minimization of waste, implementing reuse and recycling or recovering materials. The circular business

model builds on efficient and clever strategies that enhances reuse in production and distribution phases which decreases the extraction and use of virgin materials and thereby the climate footprint. By restoring, reusing and recycling materials products can be part of a circular flow rather than a linear timeline where the life cycle of a material comes to an end (Ghaffar et al., 2020).

By reusing and recycling products and materials over several life cycles, the extraction of virgin and finite natural resources can be reduced and already produced materials and products can be used more efficiently. The construction sector's large consumption of materials and products creates an opportunity to significantly reduce the environmental impact by moving from linear to circular flows. As a part of this transition, the implementation of reuse in the construction industry is one efficient method of achieving a more sustainable approach to new construction (Göteborgs stad, 2020).

1.1.2 Circular Initiatives

There are several different initiatives that enhance and drive sustainable and circular solutions in the construction industry. One of the most driving forces are the EU Green Taxonomy Regulation, which was adopted in mid-2020 (Regeringskansliet, 2020). For the construction industry, the EU taxonomy provides a framework of conditions that construction activities must meet in order to be considered sustainable and eligible for sustainable investment. One of the sub-goals of the EU taxonomy is that 70 percent of construction and demolition waste should be reused or recycled. Furthermore, the EU taxonomy also has a framework for green financing of construction projects and for the real estate owners which refers to requirements that have to be fulfilled in order to receive loans with better conditions for instance in terms of interest rates (Sweden Green Building Council, n.d.).

In addition to the EU taxonomy, the City of Gothenburg has created its own guidelines for sustainability and reuse of materials in the construction industry to drive the transition to sustainable construction processes. Sustainability and circularity in construction are often compromised due to the complex public procurement process that tends to make decisions based on financial incentives (Göteborgs stad, 2020). The challenge for contractors is to have a competitive price in the bidding process while implementing circularity as costs often increase with recycled materials. The guide *"Dags att bygga och riva cirkulärt"* refers to what contractors can do in the different stages of a building's life cycle. Examples include, but are not limited to, creating a demolition plan when planning the building, changing structures and inventory for materials, performing life cycle analysis and hiring sustainability consultants. Further the guidelines entail that the use of reused and recycled materials should be the standard and using virgin materials should be the exception (Göteborgs stad, 2020).

1.1.3 Challenges

For circular construction to be implemented sufficiently, there are numerous challenges the industry needs to overcome. For instance, the lack of knowledge about circular construction methods and reuse is one commonly occurring obstacle. It is difficult and demanding with change as many are reluctant to change if they do not understand the context and the reason for it. Therefore, it is necessary to clearly present why the change should take place in order to get everyone involved to understand and work towards the same new goal. In order to successfully adopt and implement circularity, habits and attitudes need to change. Further, work processes need to change throughout the entire construction process in order to adapt to a more sustainable approach that enhances material reuse and circular construction. Processes that need to be considered especially involve dismantling of buildings, the early stages such as planning and design but also during the construction phase (Fastighetsägarna, 2021).

There are however many things that speak positively for and indicate a promising future for circularity within construction. To mention a few examples, laws and regulations regarding procurement and certifications are reformulated to favour and increase circularity in the construction industry. Furthermore, companies who are committed to work with sustainability and environmental issues are considered attractive employers amongst newly graduates (Fastighetsägarna, 2021).

1.1.4 Problem Statement

With the limited experience of implementation of material reuse in new construction projects, there are many challenges to face in order to transition from linear to circular construction. Currently, the industry has seen few successful examples that are often associated with high risk, uncertainty and costly processes which makes it difficult to drive initiatives for the enhancement of reuse. Thus, the problem is to bridge the gap between the theoretical visions and practical implementations for reuse at a larger scale.

1.2 Reuse

As mentioned above, circular construction aims to reduce the climate impact from the industry which can be done through reducing waste materials and energy demanding processes in the material production (Göteborgs stad, 2020). Material reuse in new construction refers to reusing construction materials from demolished construction projects for the same, or an alternate, purpose again in a new building. This requires careful dismantling processes that allow the materials to remain intact for future reuse of the product. Thereafter, the materials can then be restored and reconditioned to be able to be used for similar purposes in the future. Worth to mention, is that recycling does not fall under the same category as reuse due to the extensive processes that recycled materials go through prior to being reused again. Examples of materials that are reused today are bricks, steel beams, isolation materials or interior surface materials (EkobyggGuiden, n.d.).

1.3 Target Group

This report was aimed toward a major contractor in the construction industry, Skanska Sverige AB. As mentioned in the problem statement, the implementation of material reuse is one of the challenges the construction industry is facing today, especially in the average project. Therefore, this study have been carried out alongside Skanska to investigate the opportunities for implementing reuse at a larger scale, hence the report is written with consideration of the contractor's perspective. However, other stakeholders in the construction industry might find the results in this study relevant or helpful as it looks into the interplay necessary between actors including clients, suppliers and the contractor.

1.4 Purpose

The purpose of this study was to investigate the current state of reuse in the construction industry and further look into methods of implementing reuse at a larger scale. The study was aimed to find potential improvement opportunities, along the planning and construction phases of projects, that could enhance the implementation of reuse for Skanska as a major contractor and the construction industry in general. In doing so, tangible improvements for a more widespread implementation of reuse in construction could be identified. Further, the stakeholder responsibilities and interplay between the various actors in the construction projects and industry were also considered as this plays a significant part in moving from linear to circular material flows.

1.4.1 Research Questions

To investigate the current state of implementation of material reuse in construction and to find opportunities for future implementation of reuse, a number of research questions were created. The research questions have been posed with the intent of the study in consideration. These questions have been central to the literature study and empirical findings. Following questions have been examined:

- *What responsibilities should different stakeholders take in order to implement reuse at a greater scale?*
- *How can stakeholders interact during the planning and construction phases in order to enhance reuse of materials in projects?*
- *What can contractors do in project planning and in the production phase of projects in order to better implement reuse of construction materials?*

1.4.2 Delimitations

The focus of the study was how to better implement reuse in construction projects. A circular construction process is infinite and covers a lot of different processes. Therefore, the report is limited to the study of the project planning phase and the production process of new construction. Demolition and property management,

which are also a part of the building life cycle, will not be significantly considered in this study. As a part of the study on how to transition into circular material flows, the supply chain for reused materials and the driving forces behind are investigated. Geographically, the study is limited to what is applicable in the Swedish construction industry in terms of accessible materials and legal processes. Reference projects and examples from the industry are also limited to this geographic area.



Figure 1.1: Gothenburgs city's model for circular construction (Göteborgs stad, 2020).

The figure above demonstrates the different stages of circular construction. Like previously mentioned, the report was limited to investigating reuse in the project planning phase and the production phase, which are outlined in the lower half of the figure above. These stages correspond to when clients, contractors, suppliers and municipalities are involved and therefore the take on the study has been from these perspectives in regards to stakeholders.

2

Methods

The following chapter describes the work process and methodology of the study and the report. The study was outlined by two parts, a literature study and an empirical study. The empirical study was further divided into an interview study and a case study which included projects in which reuse was implemented. The interviews were conducted with various roles from different stakeholders in the industry. Below, methods of how the information was gathered and processed is also presented.

2.1 Work Process

The study was carried out as a qualitative method which can be described as an interpretive research approach where the aim is to create understanding of a subject rather than measuring it (Alvehus, 2019). This methodology was selected as the aim of the study was to investigate challenges and possibilities of reuse at a large scale which is complex and difficult to quantify through statistical measures.

Initially, the literature study was conducted in order to gain knowledge and understanding for the central concepts of the study. Following the theoretical study, a number of interviews were held in order to gain insight from the industry and a practical perspective. During the interviews, numerous reference projects were included in the study in order to identify the main challenges, but also future opportunities, for reuse at a large scale.

2.2 Literature Study

The literature study provides the results from the literature processed in the report. The content is crucial to provide relevant information, a background and context to answer the research questions of the report. Further, the results from the literature study are used as a foundation for the empirical study. The literature consists partly of scientific articles on the topic of reuse, circular economy, and circular construction. The study also included reports and studies carried out by various institutions on climate change, climate goals and waste management.

The literature was retrieved through Chalmers Library, resources at Skanska, Google Scholar and other relevant actors or forums in the industry. Important keywords were reuse, construction waste and circular construction. The search words were combined to get more search hits, while searches with equivalents in Swedish have been done in some cases to broaden the perspective. The literature processed for

the study included Swedish publications and/or studies but also international articles on the subject to provide a nuanced perspective. Literature published in recent years was prioritized because improvements in sustainability have developed over time and laws and regulations are continuously revised. The literature study also contributed to designing relevant interview questions.

2.2.1 Credibility of Sources

As the literature study was the foundation of the interviews as well as the report, it was important to use credible and reliable sources for the information gathered in the study. Sources include, but were not limited to, scientific articles, articles from industry journals and literature. The sources were considered according to the CRAAP test which was created at the University of California by Sarah Blakeslee (Bartee et al., 2017). The parameters pondered when selecting sources of information for the study were currency, reliable source, author, accuracy and purpose conforming with the above mentioned test. The CRAAP test is presented in the figure below.

Credibility Table

<i>Factors to consider</i>	<i>Least reliable</i> (0 points)	<i>Possibly reliable</i> (1 point)	<i>Most reliable</i> (2 points)
Currency	No date of publication or revision given	Outdated for this particular topic	Recently published or revised
Reliable source	Unreliable website, no additional info available	Possibly reliable	Official government or organization, institutional sites, academic journals
Author	No author is given / the author is not qualified to write about this topic	Author is educated on topic or is staff of an organization assumed to be knowledgeable on this specific topic	Specifically identified expert in this field with degrees / credentials in this subject
Accuracy	No review process and information is not supported by evidence from cited sources	The information may have been reviewed or edited by someone knowledgeable in the field. It mentions but does not directly cite other sources	The information has been peer reviewed and is supported by evidence from cited credible sources
Purpose	Obviously biased or trying to sell you something	Sponsored source; may present unbalanced information	Balanced, neutral, presents all sides of the issue fully

Figure 2.1: Credibility table that illustrates the CRAAP test (Bartee et al., 2017).

2.3 Empirical Study

The empirical study mainly consisted of two parts, the conducted interviews with various people from the industry and the case study which was a compilation of construction projects in which reuse had been implemented. The empirical study was carried out in order to get the industry's perspective regarding the implementation of reuse. In doing so, insight was gained on the obstacles of transitioning to circular material flows and possibilities for improvement were identified.

2.3.1 Interviews

As a part of the empirical study, several interviews have been conducted with stakeholders from the industry. The interviews were in a semi-structured format to allow space for the respondents to affect the content of the interviews. Semi-structured interviews build on a form which consist of open questions or topics (Alvehus, 2019). The questions followed a framework that was the foundation for all interviews but the questions were slightly customized to each interview respondent. The interview framework is presented in its entirety as an appendix, see appendix A.

The respondents for the interviews were selected to provide a broad perspective on the topic. Despite the wide range of respondents, not all perspectives were covered as some actors or roles were not available or could participate in the interview study. The interviews have been held with people in various roles across the planning and production processes in projects. Moreover, interviews with stakeholders who represent other parts of the industry have also been held in order to grasp the interplay between different actors. This in order to get a broad view of how different actors in the industry view the subject of reuse and how they each work to overcome the challenges that comes with it. The different perspectives provided insight into the responsibilities and what role each stakeholder has in the process of implementing reuse in construction projects. To succeed, all stakeholders need to be engaged and work together, and therefore representatives from various parts of the industry were selected.

Designation	Role	Company
Respondent 1	Processleader	Gothenburg Business Region
Respondent 2	Sustainability expert	IVL, Svenska miljöinstitutet
Respondent 3	Business developer - reuse	Stena Stål
Respondent 4	CEO	Brukspecialisten
Respondent 5	Sustainability specialist	Skanska Sverige
Respondent 6	Business project manager	Skanska Sverige
Respondent 7	Project manager	Skanska Sverige
Respondent 8	Project manager	Skanska Sverige
Respondent 9	Project engineer	Skanska Sverige
Respondent 10	Production engineer	Skanska Sverige
Respondent 11	Production engineer	Skanska Sverige

Table 2.1: Table of interview respondents describing their work title and company.

2.3.2 Thematic Analysis

The results from the interviews was transcribed in order to reassure that the interviewees' perspectives remain unbiased from the authors. When processing the interviews, no opinions or assumptions from the authors was made to make sure that the information remains uninfluenced. The results were compiled and are presented in chapter 5. The results from the theory, the case study and the interviews

were analyzed against each other to find similarities and differences and outstanding facts. This analysis is discussed under chapter 6 and results in conclusion under section 7.

2.4 Case Study

Aside from the interviews, the empirical study also consists of a case study where Skanska's way of building today is described and previous construction projects that implemented reuse were observed. The purpose of the case study was partly to investigate the current state of the implementation of reuse as well as investigating future opportunities for reuse at a large scale in new construction.

2.5 Writing of the Report

The writing of the report was carried out in parallel and as all interviews and literature studies were carried out. Quotes, tables, pictures, graphs, etc. have been used to support the text and give a more comprehensive idea where the text is not enough. In order to optimize the writing of the method/implementation, this was written during the work process, in order to produce while the content was fresh in mind. While writing the report, the idea was also to produce a model in which circularity can be assessed. The model provided a method to measure circularity and reuse in construction projects. In the model, methods of increasing reuse in projects are suggested at different levels in order to improve the environmental performance of construction projects.

2.5.1 Credibility and Reliability

The interviewees work directly or indirectly with the construction industry, sustainability matters or reuse in construction. Therefore, the candidates were considered reliable sources in terms of the practical perspective. However, respondents are individuals and have their own biased opinion on the matter and therefore a large number of respondents were interviewed in order to gain an objective perspective.

2.5.2 Social and Ethical Aspects

The report was conducted with the purpose of contributing from a societal perspective and to positively benefit the development of society. The construction industry needs to transition into circular patterns regarding construction and demolition, which was supported by the content in the report. Municipalities and actors in the construction industry have great ambitions for circularity in construction but in the report, a gap between ambitions and reality was discovered. The report aimed to investigate and clarify how to implement the visions and make tangible improvements in order to achieve these goals in practice. Given this background, the report contributes to providing research on reuse and circular construction at its current

state while also investigating future research on the subject.

The report has followed and taken the ethical aspects into account out of respect to the interviewees. All interviewees have been informed about the intent of the study, how the information will be managed and the interviews recorded were so with the approval of the interviewees. To comply with GDPR the information about the respondents is hidden and will be deleted after the end of the study. All information or quotes from the respondents was approved before publication.

2.6 Research Limitations

The study was based on a literature study, interviews and a case study. The results from the literature study and the the interview study were immensely in alignment and highlighted similar views and perceptions about what reuse means and the existing challenges. The literature provided a deeper and broader insight into the subject while the interviews pointed out more the critical parts as well as being able to provide real-life examples from their experience in the industry.

In the research process it was difficult to find successful examples of reuse at a large scale from the contractor point of view as the number of such projects are limited. A few of the examples included in the study were great examples of circular construction in terms of using recycled materials and reducing material spill but the implementation of reused materials, specifically, was limited. Other examples that occurred throughout the study were examples where the client was the driving initiator for the implementation of reuse which at times was difficult to translate into useful insights from a contractor perspective.

Further, there was a significant amount of literature available on circular construction with various definitions and theories on the topic. Lots of research has been done on recycled materials and reduction of waste products in construction as an approach to transitioning to circular construction. Further there were some literature and studies on material reuse and such theories. However, research on the specified topic of reuse was limited in comparison to recycled materials as it is not as broadly implemented as recycling.

2.7 Data Gaps

While writing the report, a few data gaps were encountered revolving accessible information on the topic. Further, it was difficult to get a hold of respondents for the interviews. Therefore, the desired outcome of gaining as much insight as possible from different roles and actors throughout the construction process was not completely feasible. In order to get a more objective result with more insight from all key people involved in the construction planning processes, more respondents from the municipality and client perspective would have been helpful. Including interviews from more clients and case managers from the municipality might have contributed to a more objective point of view on the matter. From a client perspective, the monetary incentives would probably be stronger and from the municipal point of

view, opinions might differ in regard to procurement and permitting processes as well as the detailed development plan.

Moreover, the report was written in collaboration with a contractor which may have subconsciously contributed to a contractor biased perspective. A lot of the data utilized in the study has been accessed through the company's data base which also may have influenced or provided a tinted perspective in regard to the company's views and structures. Including more of a client or municipal perspective might given a different perspective of the reasoning behind flaws in collaboration between the actors in construction processes.

3

Literature Review

In this chapter, findings from the literature study is presented. The theoretical background of the report covers the topic of reuse in the construction industry. In order to provide contextual information, brief explanations of the concepts of circular economy and reuse have been provided. The construction process, theories of construction and other relevant background is also covered. Data gathered from reports and studies of the construction industry as well as environmental initiatives by different governments are also provided in this chapter. Challenges regarding reuse in construction as well as successful, previous implementations of reuse are also presented in the chapter below.

3.1 Construction Process

The construction process is complex and consists of a line of activities with multiple stakeholders involved at the different stages of the process. Looking at the timeline from a contractor's perspective, the beginning of a new construction project varies from project to project depending on the client and the contract form. Generally though, it can be said that the earlier on in the planning process the contractor is involved, the more the contractor can influence the selected methods and the product (Jonas Celander, personal Communication, March). One could say that the client is the core of the construction process as they initiate and finance the construction projects and activities associated with them. Therefore, the client requirements are the driving forces and primary source of information for the construction process and finally the end product (Kamara et al., 2000).

3.1.1 Partnering

Partnering is a collaborative procurement approach in which the contractor engages early on in the project in order to facilitate long term relationships and ensure the best outcome for the client. In this type of partnering arrangement, designer and contractor collaborate in a contractual relationship with the customer. Firstly the scope and price for the project is determined and then project can be designed and constructed. (Rahmani, 2021).

A partnering approach, where the contractor is involved early in the planning stages, is beneficial to the design process as it utilizes the knowledge and expertise from contractors. Other perks associated with partnering contracts also involve effectiveness of the contractor's input to design, efficient resource utilization and an overall improved project delivery (Rahman & Alhassan, 2012). Due to contractor's generally

high level of construction expertise, their input in the early stages will contribute positively to the outcome of the performance of projects. It also contributes to a higher level of efficiency in regard to costs, safety and time schedule due to the contractor's significant knowledge of construction materials and methods as well as local practices (Rahmani, 2021).

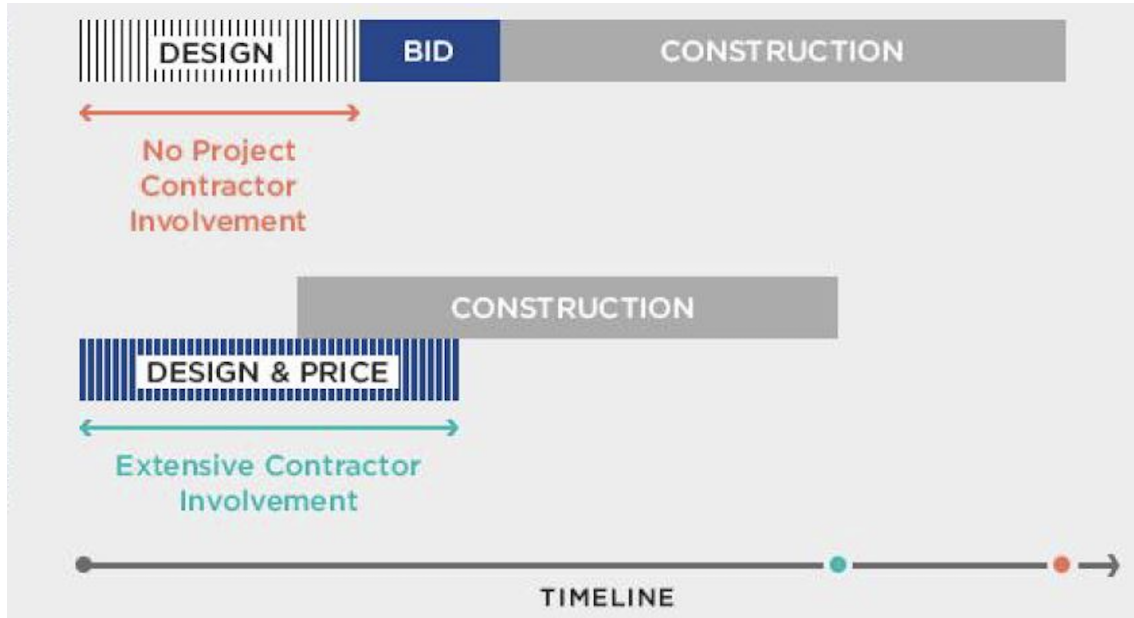


Figure 3.1: An overview of the traditional method in comparison to partnering contracts where the contractor is involved from the early stages (Simmons, 2021).

3.1.2 Environmental Impact of Construction

The construction industry has a huge negative impact on the environment and in 2020 they accounted for 9.8 million tons of carbon dioxide equivalents, which corresponds to approximately 21 percent of Sweden's total annual emissions of greenhouse gases (Boverket, 2023b). In addition to greenhouse gases, the construction industry generates large amounts of waste which today accounts for approximately 40 percent of the gross waste in Sweden. The 40 percent corresponds to over 14 million tons of waste and studies also show a negative trend where waste has increased by about 2 million tons per year from 2018-2020 (Boverket, 2023a), see figure 3.2.

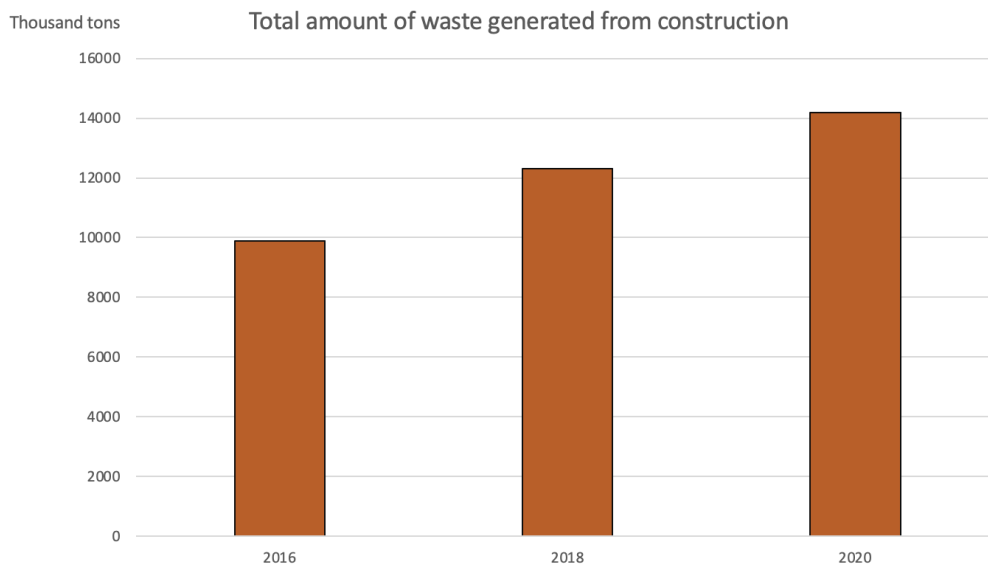


Figure 3.2: A reconstruction of the National Board of Housing, Building and Planning's figure of the construction and real estate sector's generated amounts of waste in Sweden 2016-2020 (Boverket, 2023a).

The City of Gothenburg has set an ambitious goal for Gothenburg to be a climate-neutral and ecologically sustainable city by 2030. They have developed a new environmental and climate program that, together with a common environmental management system and a challenge-driven approach, will ensure that the city succeeds in achieving this environmental goal (Göteborgs Stad, 2022). This program has been developed to increase the pace of transition to an ecologically sustainable city and the three subgoals is to have a city with high biodiversity, a climate footprint close to zero and a healthy living environment for the city's inhabitants (Göteborgs stad, n.d.-c). The sub-goal of having a city with a climate footprint close to zero is about reducing the city's emissions of greenhouse gases and to make the reductions with higher pace. Under the goal climate goal there are another four subgoals and one of these goals are to reduce the climate impact from purchases as the city's operations cause 500 million tons of waste annually, with the construction industry accounting for half of this. The City of Gothenburg wants, through a life cycle perspective, to reduce emissions from the purchase of construction industry materials by 90 percent (Göteborgs stad, n.d.-b).

3.2 Circular Economy

In order to reduce the amount of waste and increase the utilization rate of recovered materials, the theory of "circular economy" has often been mentioned in the construction industry. Circular economy means moving away from traditional linear strategies and switching to circular closed loops (Geissdoerfer et al., 2017). This means that you place greater value in products by seeing them as a material bank rather than waste and therefore recycle and reuse rather than throw away (Natuskyddsföreningen, 2022). The aim of the circular economy is by reusing and recycling products and materials in multiple life cycles, the use of virgin and finite natural resources can be reduced, and already produced materials can be utilized more effectively (Göteborgs stad, 2020). The circular economy are tightly connected to the waste hierarchy which describes how waste should be prioritized. In a perfect circular economy, no waste exists, but instead is defined as usable material banks (Stockholms stad, 2021).

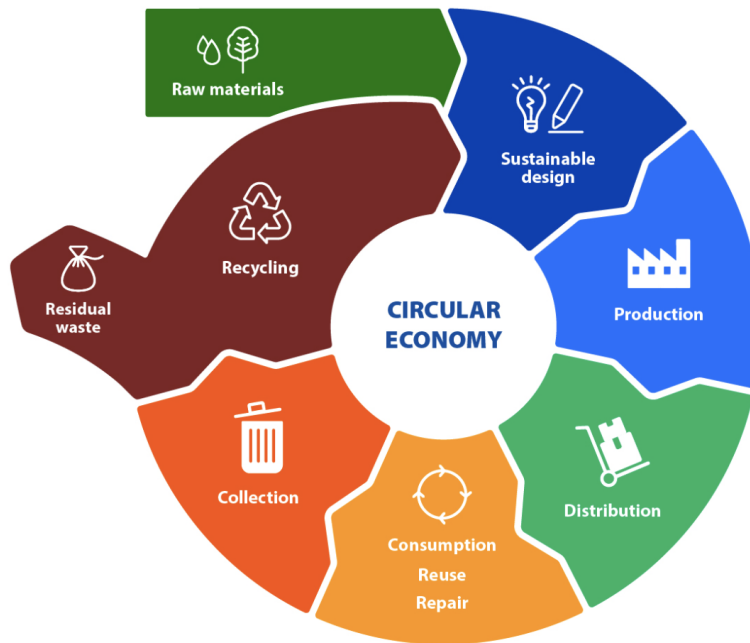


Figure 3.3: Circular economy model (European Parliament, 2022).

3.2.1 Waste Hierarchy

The EU has initiated a waste framework directive that presents fundamental waste management principles that are based on the waste hierarchy which is presented in the figure below. The directive aims to transform management of consumption products and materials from a linear economy into a circular economy with minimal waste (European commission, n.d.). As seen in the waste hierarchy, prevention of waste should be the first and foremost method of reducing waste. The most efficient method of preventing waste is to decrease consumption. In the construction industry, this would translate into a significant reduction in new construction. The second-best option is to plan for and perform reuse of the materials that are in-

tended to discard (European commission, n.d.). The third best option according to the ladder is to recycle materials and make them in to something new. If this is not possible the fourth best option is the recover the energy that's created when destroying the materials. It can be hard to define the lines between the different steps in the ladder, especially between reuse and recycling. However its not the biggest of thing, the most important thing is to reduce the negative climate impact.

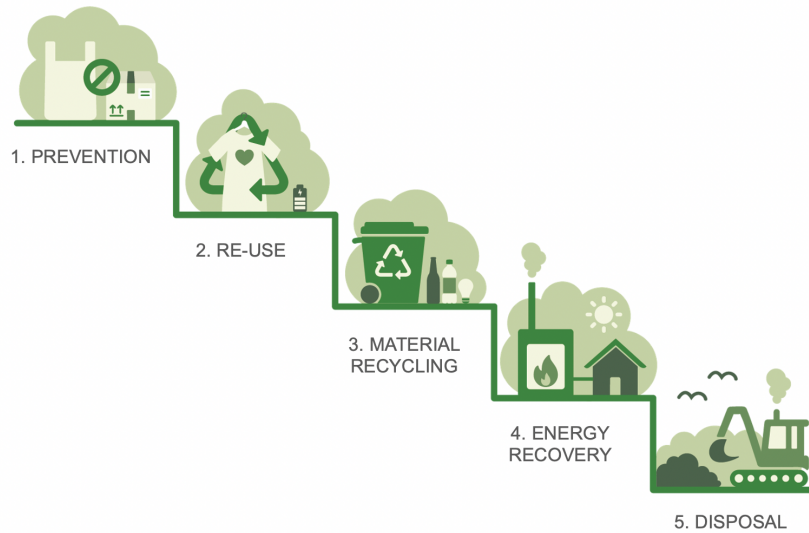


Figure 3.4: Waste Hierarchy, recreation inspired by the EU waste hierarchy (European commission, n.d.).

For the construction industry this would mean significant change in handling of materials throughout the lifecycle of buildings, from the design process to the demolition processes and everything in between (Göteborgs stad, 2020). If materials cannot be prepared for reuse, they should be recycled and re-produced into new materials. Further, if recycling is not possible, the waste can be recovered and used to produce energy. According to the Waste Framework Directive (European commission, n.d.), disposal and landfill should be considered a last resort.

Transitioning from linear to circular material flows in the construction industry is a significant change that is complex and at times difficult. There are regulations that regulate the performance and certification of construction materials (EU Regulation No 305/2011) which is one of the obstructions in regard to reuse of materials (Ghafar et al., 2020).

3.2.2 Circular Construction

The theory of “circular economy” was first introduced in 1989 but without a uniform definition. Further, there is a gap between circular economy and what it means to the construction business (Ejlertsson et al., 2018). The construction industry’s implementation of the circular economy is often referred to as circular construction and is today a widely adopted expression and ideology. Circular construction is based on the circular economy model and the waste hierarchy where the aim is to reduce the extraction of virgin materials and make use of the already existing materials and products (Stockholms stad, 2021).

Circular construction often refers to designing the building in a manner of which it supports flexibility in design in regard to the use of the building. Other important parameters include enhancing possibilities to incorporate reused and recycled materials to minimize extraction of virgin materials (Mangialardo & Micelli, 2018). Further, it also includes designing the building in a way so that the materials in the building can be reused again, either with the same or a different purpose, in the future. Fundamentally, this means that the planning and construction phases involve circular design, flexibility in design and use of the product as well as possibilities to dismantle the building in a way where the materials can be used again (Lisa Lundin, personal communication, April) (Gorgolewski et al., 2008).

In order for circular construction to become a reality, development and a changed approach on the part of all actors is required. There are many obstacles and challenges that need to be overcome for circular construction to become a reality in its entirety. Some obstacles that stand in the way of circular construction being implemented in its entirety are laws and standards, product and material quality, costs and logistics (Strand Nyhlin & Åfreds, 2022). In addition to having to comply with laws and regulations, you need to be able to ensure the quality of the products and solve the logistics of how it should be stored and shipped. In addition to this, it is usually always the economy that determines whether reuse is worthwhile. A completely circular construction is currently a vision, but gradually the city needs to move in that direction.

The City of Gothenburg has identified circular economy as an effective approach to succeed in achieving the city’s vision of being a sustainable and climate-neutral city by 2030. They have therefore started the initiative that they call Circular Gothenburg where the purpose is to drive the construction industry’s transition from a linear to a circular economy (Göteborgs stad, n.d.-a). Society needs to change and find a way to design, produce and use resources smarter. The City of Gothenburg therefore wants to make it easier to return, repair and share instead of buying new materials and thereby increasing the production of waste materials.

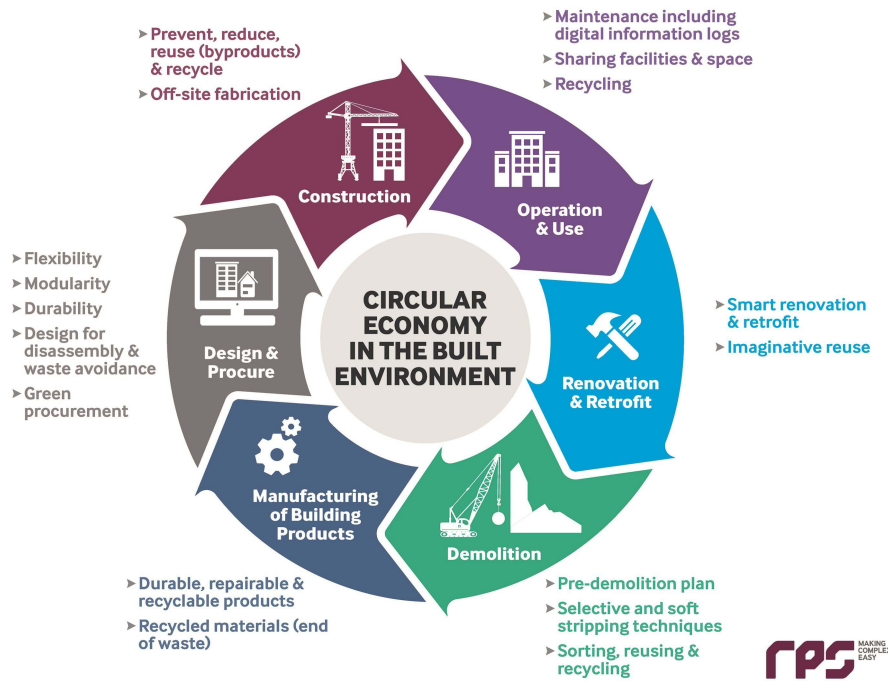


Figure 3.5: A model of circular construction (RPS, n.d.)

The goal of circular construction is to reduce the use of virgin materials and take advantage of the materials and products that already exist today. Circular construction is therefore closely linked to the EU's waste hierarchy, most often called the waste ladder in Sweden. The waste ladder describes how waste should be prioritized and as seen in the waste hierarchy, see figure 3.4, prevention of waste should be the first and foremost method of reducing waste (European commission, n.d.).

In figure 3.5, which describes the circular economy in the built environment, the different stages of circular construction are illustrated. In the transition from linear to circular processes in construction, extraction of new raw materials can be significantly reduced (RPS, n.d.). Moreover, a circular construction process also results in decreased construction material waste and spill which in turn decreases disposal. Through reuse, a reduction in the extraction of raw materials as well as minimization of waste disposal is made possible which completes the circle and can contribute to significantly reducing the climate impact from new construction (Göteborgs Stad, 2022).

3.3 Definition of Reuse

Reuse can be defined as using a product or material in construction more than once which includes making use of the materials again but for a different function than the original use (Park & Tucker, 2017). The point is that reused products replace newly produced ones and thereby the climate impact is reduced. In doing so there is a reduction in the extraction of raw materials, energy-intensive processes, and long transports, which leads to less emissions. In addition to climate benefit, reuse can also be beneficial in terms of economy and social aspects (Fastighetsägarna, 2021).

In order to successfully build with reuse, a completely different construction process is required compared to when building with new materials. One of the major differences is that the building design must be based on the materials that can be reused and based on these create the new design (Strand Nyhlin & Åfreds, 2022). It is also necessary for products to be designed so that they can be easily dismantled and then reused. In this way, buildings in the future will instead be seen as valuable material banks instead of objects to be demolished (Göteborgs Stad, 2021).

3.3.1 Life Cycle Assessment Analysis

As a method of measuring the specific environmental pollution from each individual construction material, life cycle assessment calculations can be performed. Life cycle assessment calculations takes in to account different parameters such as energy usage, transports, extraction of raw materials etc to calculate the climate impact from a product or process. This allows for quantitative comparison between different materials in order to analyze the emissions of each product. Also, it allows designers to simulate realized environmental impact of different scenarios in a construction project with different materials and processes (Carvalho et al., 2021).

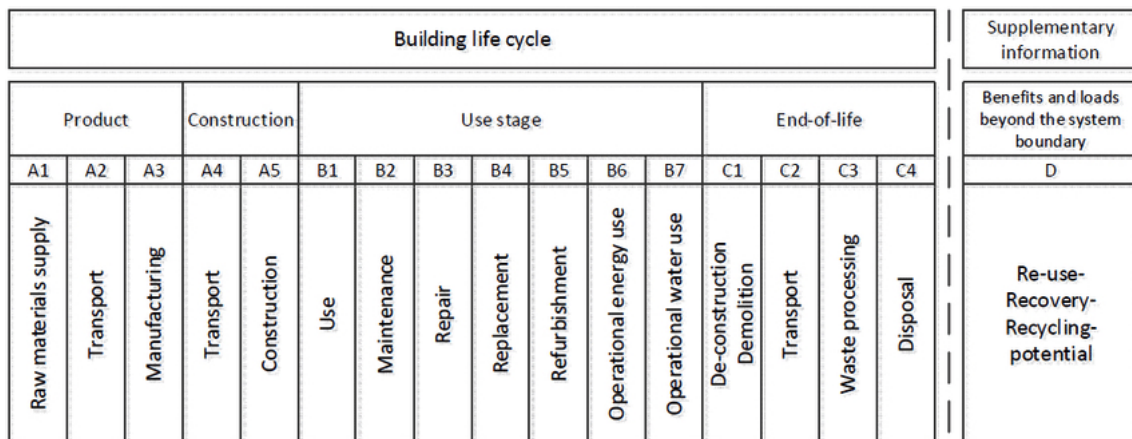


Figure 3.6: A model of the different stages of a building's life cycle (RPS, n.d.).

As shown in the figure above, the life cycle of a building can be divided into cycles which correspond to the product, construction, use stage and the end-of-life cycle (RPS, n.d.). Beyond the boundaries of the system, as referred to in the figure, reuse and recovery potential are mentioned as beneficial potential. Looking into the opportunities for the impact reuse would have on a building's life cycle, it corresponds to multiple categories and not only beyond the system. For instance, reusing materials in new construction would reduce emissions in stages A1 through A3 through the significant reduction in extraction of virgin materials. Depending on the geographical proximity in which the construction materials will be reused it is also possible to reduce the climate impact in construction transport, A4. In the end-of-life stage, the climate impact will be reduced because materials that are reused will not be disposed as waste. This corresponds to the categories C3 and C4. The significance of the reduced climate impact will depend on how much reconditioning is required for the materials to be fit for reuse. Moreover, if buildings are refurbished rather than demolished extraction of new construction materials can

be reduced through replacing and renovating components in a building with reused materials (Lisa Lundin, personal communication, May).

3.4 Challenges of Reuse

There are several challenges that needs to be overcome to be able to implement full-scale reuse, the biggest challenges are traditions and ignorance, supply, inventory and logistics, quality and guarantees, financially, measurable, rules and requirements (Strand Nyhlin & Åfreds, 2022). Further challenges involve the time gap regarding the project planning and the actual construction. The reused material supply at the time of the planning rarely corresponds to the available materials at the time of construction which often occurs years after the project planning (Strand Nyhlin & Åfreds, 2022).

3.4.1 Traditions and Ignorance

New products and materials are often seen as having a greater value than old ones. Reuse is often associated with less quality and poverty, even though the products are only a few years old and have the same quality as new (Strand Nyhlin & Åfreds, 2022). The useful functions of the products are usually good, while the aesthetics are usually lacking. On the other hand, incorporating reused materials a new project might add value to the building in terms of social and historical value corresponding to sentimentality. The attitude to reuse is a lot about feelings and attitude, but there are studies showing that more and more customers and/or tenants are willing to implement reused products in their everyday life and household (Simonsson, 2021).

More and more companies in the construction industry are working with resource efficiency and sustainable construction, but it is still very difficult to get everyone to work in the same direction. It is difficult to break traditions and change working methods that have been in place for a long time, and by continuing to work as always done it's hard to succeed with reuse (Strand Nyhlin & Åfreds, 2022). It takes time and energy to persistently implement what is required to change the way of working adapted to reuse. In order to succeed in switching to circular models, it is required that all actors are involved and work towards the same goal (Björkman & Kardell, 2021). Because if there is any actor who loses the will for reuse, the whole thing often falls short.

3.4.2 Supply

Supply and demand are not usually a problem on the market, but in reuse it is problematic for buyers and sellers to find each other. The reuse market is immature and there is no balance between supply and demand (Fastighetsägarna, 2021). There are only a few actors who operate a large-scale market for reused products, but construction companies often operate small-scale reuse within their own projects.

It is important to make reuse inventories to know which materials and products can be reused, but this is done far too rarely and not extensively. This means that very few products reach the market and that the quantities that reach the market are usually small-scale. There is a demand of large amount of the same products but usually there are only small amount of each product on the reuse market (Miliute-Plepiene et al., 2020). In order to enable large-scale reuse, large volumes of the same type of material are needed, as in a project there is often a need for 100 doors of the same make and 300 windows with the same dimensions (Strand Nyhlin & Åfreds, 2022). As this is almost never available on the market, construction companies chooses the easier way of ordering new products that they can tailor to their needs.

One way to the access problem of supply would be if several companies had started using a kind of "take-back system" (Strand Nyhlin & Åfreds, 2022). Where leftover waste from the construction projects goes back to the producer and is reused or recycled. There is no established take-back system in the industry today, but individual companies that have taken their own initiative. By taking back their own products and restore their quality, less material would go to waste. It is also the producers of the materials who have the most knowledge about their products and can carry out tests and take responsibility for their quality through the entire lifespan (Strand Nyhlin & Åfreds, 2022). If companies were to complement their new products with restored and approved recycled ones, it would increase the supply and availability of the recycled market.

3.4.3 Inventory and Logistics

The planning phase for a project is often several years long and makes it difficult to plan for reuse. It is impossible to know in the design phase which materials and products will be available on the market at the time of construction, which is often several years later. It is costly to keep an inventory for several years and from a business perspective it is not beneficial to have products on the shelves that cost money (Strand Nyhlin & Åfreds, 2022). As it is not possible to rely on finding the right product at the right time, most projects working with reuse uses some form of intermediate storage.

The way of working that is used today, where you draw first and buy later, does not work for reuse (Strand Nyhlin & Åfreds, 2022). The purchasing processes need to be changed so that products are purchased and reserved already during the planning process in order to know which materials and products to use in the design. Interim storage often takes place over long periods of time, and it needs to be clarified whether the products should be stored with the selling company or the company that will reuse the product. The construction industry lacks the infrastructure and routines to able to take care of it themselves (Miliute-Plepiene et al., 2020). Most construction projects lack space and storage facilities, so some form of storage facility is needed where you can temporarily store and recondition products (Ding et al., 2023). Such a facility should also be close to the building products it distributes in order to reduce transport and its emissions (Strand Nyhlin & Åfreds, 2022).

3.4.4 Quality and Guarantees

When building, you want to use reliable products and to know how they work and behave, so as not to take any unnecessary risks that could result in damage or unforeseen expenses. It is difficult for clients and contractors to know how the performance of the reused products is and it is unclear about its functionality and if the material contains any dangerous substances (Yeung et al., 2015). They feel a concern about building in materials that do not measure up or are harmful to health (Strand Nyhlin & Åfreds, 2022).

Actors are needed who can control and guarantee the quality of the products so that you know they are acceptable to build with. It is the origin suppliers who know the most about its products and are therefore seen as the most reasonable actor to undertake to control and guarantee the quality of products (Strand Nyhlin & Åfreds, 2022). It is costly to test the material quality and there is often a lack of information about the history of the material and its stress throughout its lifetime (Johansson et al., 2017). When the construction industry further implements topics of reuse and recycling, new professions will be created such as material inspectors and professionals who hand out material certifications. With this, yet another question arises: who will be responsible to fill these roles?

3.4.5 Financial Obstacles

Construction projects' finances are often strained, and profitability is crucial, this results in that only few actors dare to take a chance. As material prices have been so low for many years, it has been cheaper to build with new materials than recycled ones (Holmqvist & Älvegran, 2020). Working time is more expensive than material costs, and therefore you would rather buy new than spend time on reuse (Gorgolewski et al., 2008). Reuse is not seen as economically beneficial as there are additional costs for the demolition process, storage and refurbishing of materials, which makes it cheaper to throw away and buy new (Strand Nyhlin & Åfreds, 2022). However, this is believed to change with the current recession and the rampant material prices.

Most reuse projects have so far only been on a smaller scale and therefore have not affected the project's finances perceptibly. It is mainly large companies that have worked with large-scale reuse as they have the financial muscles to take the risks and extra costs that may arise. There are no established work routines for reuse and this means that the economy around it increases, when routines and working methods around reuse are established, the costs of reuse will decrease and make it economically favorable compared to new materials (Holmqvist & Älvegran, 2020).

3.4.6 Measurability

In order to be able to measure and know how sustainable reuse is, new ways of measuring are needed. Today there are lots of different ways to measure circularity and some of these are waste amounts, carbon dioxide emissions, economics, or the percentage of reused materials. A standard needs to be set for how to measure circularity and reuse and in which units in order to be able to objectively assess case

by case (Strand Nyhlin & Åfreds, 2022). It is based on measurable values that you can set requirements/limits and based on that see improvement.

IVL has developed a guide for how to measure and value recycling linked to a building's life cycle, and this is important to be able to lift recycling within the industry (Gerhardsson et al., 2020). Even the climate declaration requirement for new buildings will require that you calculate the climate impact, which in turn can show the climate benefits of reuse.

3.4.7 Laws and Regulations

Another challenge regarding the implementation of reuse in construction are the regulations and requirements that projects need to abide to. Receiving building permits and following the detail plans from the city are complex processes of considerable length which sometimes makes it difficult for alterations to be made to the project while under construction. Since reused materials can vary in technical and visual specifications the design and permits need to be more flexible and accept these uncertainties (Gorgolewski et al., 2008).

3.5 Stakeholders Responsibilities to Reuse

In order for reuse to be applicable at a larger scale, all stakeholders need to contribute to the implementation of reuse to achieve this. As stakeholders are involved at different stages of construction it is important that they collaborate throughout the entire project and that each actor does their part.

3.5.1 The Client

The client is the one who owns the project and the land it is to be built on, and therefore it is the client who sets the tone for the project (Strand Nyhlin & Åfreds, 2022). The client formulates the vision and requirements for the project as well as being the initiating and financing force. Therefore, it is crucial that the client is onboard with the implementation of reuse in order for them to include this in their vision that the contractor must follow. On the other hand, clients are driven by economical forces and due to the fact that reused or recycled materials often are more expensive than new materials this is not always a main priority for the client (Gorgolewski et al., 2008). At the end of the day, it is often a matter of cost and if it is not financially feasible to select reused materials, the client is more likely to choose the cheaper option (Strand Nyhlin & Åfreds, 2022). Due to the above mentioned, the final decision on whether to use reused materials or not is a choice the client has to make, weighing environmental aspects versus the economical incentives.

3.5.2 The Municipality

The municipality or the city is involved in all construction projects in one way or another. If the municipality is not the client themselves, they are involved in the

permitting process for the projects and the municipality is also responsible for the detailed development plan. In their significant involvement when it comes to the development of new construction, lies heavy responsibilities to adapt to circular construction and enhance the possibilities for contractors and clients to reuse (Circle Economy, 2019).

Further, in cases where the municipality is the client, the procurement process is more intricate as the municipality is funded by tax money. The public procurement process is different from private procurement processes and there are laws and regulations for how such procurement processes should look like. This often results in the municipality proceeding with the contractor which offers the lowest price which leads to little room for innovation regarding environmental initiatives on behalf of the contractor (Personal Communication, Lisa Lundin and).

However, the environmental agenda is of great importance for the Swedish government and both private and public clients often include environmental requirements in the documents for procurement. Although, to what extent these environmental requirements are set varies. Procurement processes that include or prioritize environmental aspects are referred to as green procurement processes. Examples of parameters that can be considered in a green procurement processes involve building and demolition waste, construction waste, energy efficiency, the contractor's environmental work etc (Sterner, 2002).

Green procurement can be used as policy instruments for public authorities in public procurement in order to influence the market to become more environmentally sustainable. In green procurement, environmental performance is included as a decisive factor in the choice of supplier in addition to the usual factors in who offers the best product and service at the best prices (Konkurrensverket, n.d.). Green procurement processes set environmental requirements that stakeholders in the market must meet in order to submit tenders in the procurement. As a result, market stakeholders are forced to become more environmentally friendly in order to be able to participate in tenders and find jobs (Edlund, 2019).

3.5.3 The Contractor

The contractor is selected by the client through a procurement process in which the interested contractors submit their tenders. The client selects which contractor they want to proceed with based on numerous factors that outline the performance of the project. This means that the contractor theoretically could suggest the implementation of reused materials in their tender, but in order to win the tendering process they would still have to stay at a competitive price as the client is most likely to choose the cheapest option, which is more difficult due to the uncertainty and higher prices involved with reused materials. (Kamara et al., 2000)

Working with reuse requires new work routines and knowledge of how to handle materials and products to maintain their quality and function as best as possible (Park & Tucker, 2016). Therefore, it is required that the contractors are knowledgeable in reuse and be ready to offer a way of working that enables smarter waste management, dismantling and reuse. The contractor need to have a flexible business

model and not get stuck in the documents from an early stage, but work flexibly as reuse is not always what's expected (Waern, 2021).

3.5.4 The Architect

The architects have great importance for reuse projects where they through their visions and possible interest in reuse have the opportunity to enable and initiate reuse. In order to succeed with reuse in projects, the architect needs to be involved early on and distinct ambitions for reuse needs to be established prior to any demolition of buildings on site (Park & Tucker, 2016). The design of the building should thereafter be created based on the materials available after creating the reuse inventory. In projects such as these, the architect needs to be involved throughout the entire project as reused materials places greater demands on flexibility in design. In practice this means that decisions about the appearance and design of the building will have to be made continuously during the course of the project (Strand Nyhlin & Åfreds, 2022).

Even in new construction projects that do not involve demolition processes prior to the construction, it is wise to include the architect at an early stage as the design process will be iterative in these projects as well. Allowing flexibility in design will make it easier to adapt the finished product based on what reused materials supply is available at the time of construction (Gorgolewski et al., 2008).

4

Case Study

The following chapter presents a case study of the work processes in construction projects and looks into the current state of circular construction and reuse in general construction project. Further, the case study also looks into a few examples where material reuse has been implemented. The examples studied are projects in which Skanska has been involved and thorough research has been conducted with the help and input from resources at the company. The resources accessed revolving these projects mainly involve interviews with project managers and information available about the projects on the company's website. The idea of studying these projects were to gain insight on the current state and readiness for reuse in the industry as well as finding the learning outcomes in regard to the planning and construction processes when implementing reuse.

4.1 The General Construction Process

Skanska, which is one of Sweden's largest contractors, builds everything from roads and streets to high-rise buildings and bathhouses. Through the organization, there are clear routines for how to work and build in order to be able to lead the business towards satisfied customers, engaged employees and financial profitability. The common tool VSAA ("Our Way of Working") may differ slightly between the departments but generally it can be described according to the figure below.



Figure 4.1: The stages in a construction process. The processes highlighted in green are the ones taken in to consideration in this study.

4.1.1 Tendering Process

Skanska works with several different types of customers, such as municipalities, private companies and their internal property and housing companies. This means that the tendering process varies depending on the customer. For procurement processes with municipalities and state-owned companies, the Public Procurement Act applies which is not the case for private customers. A tendering process is competitive meaning other contractors also submit tenders and the contractors are pressured against each other to provide products with the highest quality for the best price. The requirements for the project are decided by the client and the contractors create

their tender based on these demands.

The most critical obstacle regarding reuse in this stage of the construction process is that generally the client chooses whichever contractor has the lowest price. In order to solve this issue, the client has to prioritize environmental aspects over the financial aspects, looking at all three parameters of sustainability (environment, social, economy) and not just financial sustainability. Furthermore, the exact cost of reused materials is not always known at this stage of the process which makes it difficult to take account for such costs. One way of approaching this problem is to use partnering contracts in which operating expenditure is applied (Personal communication, Lisa Lundin, March 2023).

4.1.2 Design Process

If you win the tender and get the job, the planning of the project begins. Skanska holds a start-up meeting with the customer where vision and goals are agreed so that Skanska can later meet expectations and satisfy the customer. It is in this phase that the customer can set environmental requirements or requirements for circularity.

After this, planning managers from different disciplines gather to set routines, riding plans, quality levels and project goals. Drawings and action plans for the implementation of the project are created here. In this phase, it is decided which materials are to be purchased and how they are to be built into the project. In this phase, Skanska can be involved in providing suggestions for construction methods and possible circular solutions. But it is far from every project that Skanska proposes reuse and other circular solutions, and this is largely due to the fact that they do not have clear examples and experiences for which circular solutions they could introduce. The client is often difficult to persuade to change, and therefore it is important that Skanska is clear about the implementation and goal of the proposed circular solutions. Skanska needs to develop a model with clear examples anchored in reality that they can use as a basis for this process.

The major obstacle and problem when it comes to the design phase for the implementation of reuse is the time aspect. From design to finished construction, there are often several years in between, which makes it very difficult to design reused products and materials. If you don't demolish a building in connection with the new construction, you don't know which materials are available for the need and when you need them. Therefore, the design process needs to be made more flexible for change over time. In addition, the buildings need to be designed so that they can easily be dismantled and recovered when the materials have reached their end point in the future. A further problem with the consumption of reused materials is that more is being built than is being demolished today. Which means that there is not enough reclaimed material to be able to fulfill the need for new buildings.

4.1.3 Production Process

In the production phase, they must go to reality and the visions and goals previously created must be fulfilled. During production, the contractor, usually together with subcontractors, builds the project and ensures that the finished product is ready by

the appointed time.

During the production phase there are clear routines for exactly how Skanska builds and this is compiled under their tool VSAB (our way of building). This is a standard for how Skanska as a contractor builds its houses etc.

The problem for implementing reuse in the production phase is that laws and regulations set high standards for which certifications and qualities the building materials need to have. The quality of new products is constantly evolving and it is also difficult to determine the quality of a recycled product that has endured some force or strain during its previous lifestyle.

Skanska has a desire to build with reused materials and in a circular way, but is still in the initial phase of working with reuse. They lack work routines and practical knowledge of how to work with recycling, but there are constant educations and lectures about reuse and circular construction to promote knowledge and train their employees. They have only built a few projects with reuse and these have been innovation projects to test and learn from experience.

4.2 Projects with Experience in Material Reuse

The following section provides examples of construction projects in which reuse has been implemented to different extents, followed by initiatives that were not successful. Most of the examples provided are so called innovation projects and differ from the usual projects. The driving forces behind projects as such are usually the client. These examples have provided experience and more further knowledge about circular construction and material reuse to Skanska.

4.2.1 Epic

In 2020, Skanska built the office building named Epic which is located on Universitetsholmen in Malmö. Epic is a six-story building with 12,000 square meters of office space divided in to two building bodies connected by a verdant atrium (Skanska Sverige, n.d.). Epic was an innovation project where Skanska wanted to use recycled and reused products to see how it works in practice and to create a talked about and attractive office building. There were no precise calculations made on behalf of Skanska in regard to savings of carbon dioxide emissions thanks to the implementation of reuse and recycling in the project. However, estimations entail that Epic emitted 100 tonnes less carbon dioxide compared to if traditional building methods and materials were used. (Strand Nyhlin & Åfreds, 2022).

Skanska refers to Epic as "the office of the future" and this is due to the fact that Epic was one of the first projects in Sweden to clearly implement reuse and recycling with intent. In the project, Skanska managed to reduce the climate impact significantly through reuse and recycling old building with the help of the Danish architect Anders Lendager (Strand Nyhlin, 2021). The Danish architect firm Lendager has a sustainable approach to the built environment and design buildings only using reused and recycled materials (Strand Nyhlin, 2020).

The walls of the atrium are made of wooden panels where the wood material has been reused from window frames and wooden beams from a demolition project in Nyhamnen. They have also used a sound-absorbing cloth made from recycled PET bottles and mixed in waste material from Epic's old facade in to the floor tiles (Skanska Sverige, 2019).



Figure 4.2: The green atrium of Epic, with reused wood as the wooden panels (Skanska Sverige, n.d.).

The learning outcomes from the construction of Epic was that reuse needs to be implemented from the start of the planning and design phase. And at the same time, you need to be able to be flexible during the course of the work, as there is a risk that it will not always turn out as planned (Strand Nyhlin & Åfreds, 2022). Therefore, it is important that the cooperation between the client and the contractor works well and that both take responsibility for the project (Strand Nyhlin & Åfreds, 2022). Good cooperation and mutual understanding is required to effectively solve the obstacles and problems that may arise during construction with reuse.

4.2.2 Nya Konst

Nya konst is a project that Skanska is building for Akademiska Hus and the faculty of arts at Gothenburg University. Akademiska Hus is an example of an innovative client which prioritizes reuse and considers circularity in their projects due to their sustainability goals. The project consists of two new buildings with 35 thousand square meters as well as the reconstruction of the previous building Artisten that

will be transformed to meet the future needs of the (Skanska Sverige, 2022). The construction started in January 2023 and the project is expected to be finished in stages over the course of the years 2025-2027.

As a part of the project the previous building *Artisten* will be renovated in order to create new spaces that better meet the needs of the university. During the dismantling processes of *Artisten*, various materials were found suitable for reuse (Skanska Sverige, 2022), and these will be used and replace new materials and therefore reduce the project's climate footprint. According to Respondent 6, there were initial difficulties finding suppliers who would recover or restore the materials. However, after significant efforts from the project manager the materials could be refurbished and thereby used again.



Figure 4.3: Vision picture of the project *Nya konst* (Skanska Sverige, 2022).

4.2.3 Varvstaden

Many industrial environments around Sweden have previously been converted into offices and homes, but in Kockum's old area, in the middle of Malmö city, this conversion is done in a unique way (Strand Nyhlin & Åfreds, 2022). Shipyards and industrial environments from the beginning of the 20th century are to be transformed by the year 2035 into 182,000 square meters of offices, hotels and other businesses, as well as 2,500 apartments. The project is run by Varvstaden AB, which is owned by Peab and Balder, and before the transformation, Lendager group presented a sustainability strategy for the reuse of the buildings that would not remain.

Existing material from the site will be used in the new projects and this reduces the environmental impact significantly (PEAB, 2021). For Varvstaden, materials such as concrete, steel, glass and brick will be reused or recycled to the greatest extent possible, where preliminary calculations showed that over 80 percent of all existing materials could be reused. Up to 2 million bricks will be reused and used in various facades in the area. These recycled bricks save carbon dioxide emissions equivalent to the annual emissions of 810 Swedes. If Varvstaden succeeds in its goal of reusing 80 percent of all existing material, the CO₂ saving will be 30,000 tons compared building with new materials, which corresponds to the annual emissions of 6,666

Swedes(PEAB, 2021).



Figure 4.4: The brick facades of the old building will be kept or reused in the new projects.

A lesson that Varvstaden AB has learned is that it is more difficult to implement recycling in new housing projects(Strand Nyhlin & Åfreds, 2022). Initially, they had ambitions to reuse bricks, steel and windows, but this was not possible as the homes must be Svanen-labelled and the reused materials were not CE-marked. The reused products will instead be more interior design products such as fixtures, benches and hooks that create a nostalgic feeling in the homes. It has also emerged during the course of the project that reuse is usually not cheaper than new materials and therefore you need to be aware of this and set a risk fee for reuse(Strand Nyhlin & Åfreds, 2022). The environmental benefits needs to be put in perspective to the financial risks.

4.3 Obstacles in the Implementation of Material Reuse

Further, the contractor Skanska has experience of projects where material reuse was not approved due to the detailed development plan for the municipality. Specifically, the bricks that were going to be reused were not in alignment with the detailed development plan due to the fact that they had a different color compared to what was specified in the plans (Åfreds, 2023).

When developing and rebuilding the St. Erik area in central Stockholm, Skanska as the developer wanted to use the frame and foundations of existing buildings. But this was not approved as this did not correspond to the principles that were determined in the detailed plan. The aim from Skanska's side was to reduce the climate impact from the construction stage through recycling and to be resource efficient (Åfreds, 2023). The group manager for sustainable business development said: "Unfortunately, there was no review of the detailed plan, but the City of Stockholm still appreciated the proposal for reduced environmental impact and recycling and will

consider this aspect for future work with other detailed plans" (Åfreds, 2023).

4.4 Learning Outcomes

The gathered experiences from the above mentioned projects gave insights in the commonly occurring obstacles regarding material reuse. To mention a few, the challenges include the end users mindset toward reused products, late changes in design due to changes in supply and the logistics regarding the reconditioning and storage of the dismantled construction materials. Solutions to such problems involve a flexible design process that is more forgiving to changes later on in the process and a strong collaboration with the suppliers who are the most knowledgeable and have the best capacity to recondition, store and resell reused materials. Further realizations involved the contractor's role in reuse and the fact that contractors have a limited amount of impact on the project as the final decisions generally are up to the client. Contributions from the contractor involve the coordination of the actors (e.g. suppliers, subcontractors, the client etc) and construction activities. Therefore, the contractor's main tools to enhance reuse are through knowledge and successful collaboration with other stakeholders.

5

Results

In this chapter, results from the interviews conducted will be presented. The interview results have been processed accordingly to what is described in the methods chapter. The general format for the interviews, questions and talking points are presented in appendix A. Furthermore, findings and the results from the case study conducted in the report will also be presented in this chapter.

The semi-structured interviews were conducted with key roles in the construction industry as well as with different sustainability experts and specialists working in the segment. A total of eleven interviews were held with the various respondents. The idea was to gain perspectives and insight from people in different roles throughout the entire construction process and the various stages. Given the variation of respondents, a larger range of construction projects and clients were covered which contributed to obtaining a more objective point of view on the subject.

5.1 Current Implementation of Reuse

As previously mentioned, the topic of reuse and circular construction is relatively widespread within the industry, but that there is a lack of knowledge and routines about how to actually work with reuse in practice. This is something that our respondents have confirmed with the fact that there are very few projects where reuse is requested and even fewer where it is actually implemented. Respondent 6 said that reuse has previously been more widespread in the industry, but as quality requirements have increased and material prices have fallen, it is now cheaper and easier to build with new materials.

Skanska is one of the leaders in the industry and does a lot that is good from an environmentally sustainable perspective, but with their size, resources and knowledge they can do even more. They have so much knowledge in-house that could have been put to good use and used more in every construction project. Skanska has only implemented reuse in a few so-called innovation projects, but it is reuse in each project that makes the big difference for the climate and the transition to circular construction. As Respondent 2 says, Skanska needs to raise its lowest level in each project to make a bigger difference.

”Skanska works very well with sustainability and has decided to try to be at the top of the industry at all times. However, they need to raise their minimum level, it is good with cutting-edge projects, but the big difference is by raising the minimum level.”

-Respondent 2

5.2 Knowledge

According to multiple respondents, the first important step in the transition to circular construction is to acquire knowledge about the topic and set goals for circularity. It has been clear from the interviews that the level of knowledge in reuse varies alot. Skanska, as one of the leaders in the industry, wants to be at the forefront when it comes to circular construction and therefore holds lectures and seminars on Fridays to educate its employees in the subject. These lectures are called "circular Fridays" where driven and knowledgeable people in circularity are invited to lecture the employees. These meetings are then recorded and posted on the Skanska intranet for all employees to take part in afterwards. These lectures can educate the employees and contribute to eradicating the current situation where there are many who understand the meaning of why we need to switch to circular flows instead of linear ones, but there are few who know how to proceed with this and how it actually should be done in practice. It is one thing to set goals and visions but quite another to actually work for and fulfill these. There is today a gap between idea and action in the industry where routines and attitudes are obstacles are the reason for these gaps.

This gap may also be due to the fact that the level of coordination in circular construction and reuse becomes smaller the closer the people work to the construction site. The knowledge of circular economy specialists is quite large and understanding while those who actively build and plan on site have little understanding of the subject that creates an unwillingness to change the way of building. The lack of knowledge is the main hindering factor and the threshold for implementing circular construction methods seems to be bigger in reality.

5.2.1 The Reuse Initiative: Handslaget

As a part of making the transition from linear to circular material flows in the industry, the initiative Handslaget was created by Business Region Gothenburg. Handslaget acts as a networking arena and community for actors who have signed the initiative. The main purpose with the initiative, according to Respondent 1, is to help property owners in the region to achieve goals of circular construction through setting demands on the different stakeholders in the industry. To give an example, the project Nya Konst which was mentioned in the literature study is initiated by Akademiska Hus who is a part of Handslaget.

Providing a platform where the stakeholders can share information and experiences on the matter can hopefully inspire and help other stakeholders who strive to improve their work in circular construction. Respondent 1 also mentioned that they aim to act as a match making service between companies in the industry and com-

panies who provide services or tools that can facilitate circular construction. There are almost 40 property owners, public and private, who have signed Handslaget and thus taken responsibility of working to succeed with circular construction. The initiative will serve to establish a developed market for reuse in Gothenburg at a rapid pace and on a larger scale. For municipal property owners, reuse and other circular solutions will be the first choice for new construction and renovation.

According to Respondent 1, the municipality has limited means and tools to influence the laws and regulations for construction and therefore, they mean it is hard to set demands on the actors of the industry. Respondent 1 means that it is mainly up to the Swedish planning and building act to regulate and set such requirements on the municipalities. However, they still want to play their part in making the transition from linear to circular construction and that is part of the reason Handslaget was initiated. Handslaget can be considered as one of the municipalities incentives or contributions to the transition of circular construction and reuse.

5.3 Identified Challenges for Reuse

The results regarding obstacles for reuse in construction are in alignment with what was found in the literature study. During the interviews there were two recurring obstacles that many respondents meant were the reasons as to why it is difficult to implement reuse in construction projects at a larger scale. According to both respondent 2 and 5, who both have a significant background from the contractor's perspective, the lack of suppliers who can provide reused products was one of the obstacles. This obstacle correlates to the other commonly mentioned obstacle which referred to the uncertainty of supply in reused materials. Not knowing what materials will be available at the time of construction creates challenges in the planning stages.

Further, material reuse requires a lot of commitment from project managers in terms of the logistics and administration. Respondents from the interviews share that the current state of the market for used and restored construction materials is too uncertain and small. The lack of a marketplace for such products leads to the project manager having to spend significant amount of time to find or sell such materials on the second hand market. Respondent 11, who was dedicated to reduce material spill and waste through posting and selling materials said she had to do so in her own spare time. This was partly due to a tight schedule but also due to the lack of routines for how such processes should work.

5.3.1 Successful Reuse Market

In order to succeed in implementing and build in more reused products into new buildings, it is necessary that there are materials available on a market or from one's own previous demolition. The majority of the respondents see today's market for reused materials as immature, sprawling and difficult to match supply and demand. The range of reused materials is small and the materials that are actually on the market are sold on various sales sites that make it difficult to find what you are looking for and in the quantities you need. Respondent 1 thinks it would

be a good idea if a buy and sell page was created where all materials, products, buyers, and sellers could be gathered instead of having it spread out over several different ones. Respondent 1 thinks that if the market for reused products is too unsure and complicated others will go with new and easily accessible materials instead.

There are somewhat divided opinions between who should take responsibility for creating a functioning market for reused materials. Some respondents think it would be best if the material suppliers took back their products and reused them as they know the most and best about their products. While some respondents had rather seen a common market created by, for example, the municipality. It is difficult to decide which option would be best as there are examples of both working well. But it is clear from the respondents that it needs to be sorted out who can put guarantees on the materials and who should bear the possible risks that exist with reused products. Entrepreneurs are rarely willing to take chances and take risks as they are controlled by the economy and, as respondent 8 described it, have tight margins already as they are.

5.3.2 Laws and Regulations

In order to be able to implement reuse on a larger scale, the respondents believe that laws and regulations need to be changed in order to benefit reused construction materials rather than prevent it. The actor with most influence in these processes is governmental instances who are responsible for the planning and building act but also the municipality, which handles building permits.

Respondents 1 and 2 believe that laws need to be stricter and that more demanding requirements should be placed on construction projects for emissions and environmental standards. By setting requirements or rewarding successful projects, you motivate and drive companies to constantly work to become better in sustainability, where reuse is a major issue. Respondent 2 emphasized that laws and requirements need to be changed to suit reuse where the materials may vary a little bit from what was planned from the beginning. There are examples of a project where Skanska wanted to build with reused bricks, but the initiative was stopped because the reused bricks had the "wrong" color compared to what was specified in the building permit. It needs to be more flexible in building permits and other legal requirements if you want to promote reuse in construction projects.

5.4 The Different Roles in Reuse

The interplay between the different stakeholders involved in construction projects is a key aspect in the implementation of large scale reuse in new construction. To succeed with the implementation of reuse on a large scale, it is required that all actors involved work together and strive towards the same goal. In order to enhance good collaboration, it is required that the actors take specific responsibilities and initiatives which are further specified below. From the interviews, it is evident that the implementation of material reuse in construction is still in the development process and generally actors do not have structured processes for reuse. Because of this it is not obvious who is responsible for each part of the processes needed for the

implementation of reuse.

5.4.1 The Client

From the interviews carried out in the study, it was often mentioned that the client beholds the largest opportunity to decide whether or not the project should use reused construction materials. Project managers also mentioned the contract form as one important parameter for the possibilities to implement reuse. Ultimately, the client decides what the end product will and they are the ones who set demands on the design and functions of the building. Further, the client is the financier of the project and in the end, the one who pays for any extra work or added material costs.

Some clients have good internal knowledge of reuse and work in several projects with reused materials, while others do not have that knowledge and does not work in that way. It has emerged through the interviews that clients who lack knowledge in reuse find it difficult to switch to circular processes and tend to consider implementations of reuse a liability, financially and in terms of time and warranty. Therefore, it is commonly occurring that clients take the easy way out and leave ready-made documents to the contractors on what to build as it gives more control of the project in terms of time and money. According to respondent 9, one of the main reason the clients do not want partnering contracts for the construction projects is that there is no predetermined price but a running bill which is frightening for some clients as they assume it will be more expensive.

Also highlighted during the interviews was the fact that sometimes, the client is actually the driving factor in initiating reuse and setting demands on the contractor. According to respondent 7, there are numerous clients who are innovative and open for reuse and try to implement reuse whenever possible. This also gives the contractor an opportunity to gain experience on material reuse in construction projects which can help the future implementation of reuse at a large scale. If the client is the driving force behind the implementation of reuse in the project, it is also more likely that they are aware and willing to take the risks associated with reuse. Respondent 7 mentioned that the risks clients are worried about mostly revolve the financial aspect as well as aesthetics.

5.4.2 The Contractor

The contractor plays an important part in the implementation of large scale reuse in new construction projects. It is the contractor who in practice carries out the construction of the reused materials and therefore it is important that the contractor has good knowledge in reuse and how different materials must be handled and installed. Respondents state that Skanska is knowledgeable in reuse and have the right competence to construct with reused materials. However, respondents also mean it is difficult to influence the client or the project in that direction when the client has a predetermined vision for the project. Methods for better implementation of reuse at larger scale in such scenarios could include the contractor presenting concrete suggestions and methods for the implementation of reuse.

Respondents at Skanska believe that being involved in early stages would be beneficial for the implementation of reuse as the contractor can share their knowledge and experience to influence the project towards the better. However, it is commonly occurring that contractors receive projects where the client has already prepared for and planned the design of the building. Representatives from the contractor side often experience that it is difficult to propose changes about the design or materials in hindsight. There is a lot to be gained for the client in utilizing partnering contracts and the knowledge and experience from the contractor. In doing so, the client has the potential to become more knowledgeable about building in a circular manner and implementing reuse in their projects.

The production engineers stated that the individuals' knowledge in reuse decreases the closer they are to the construction site. The level of knowledge about reuse and circular construction is generally higher amongst the sustainability experts and specialists in the organization. However, respondents experience a communication gap between the specialists and the employees who work on site. The goals and visions presented by the sustainability experts seem to have a hard time reaching the construction sites and project managers. Therefore, the goals are not always achieved nor prioritized as they are general and not custom for their specific project. In order to bridge this gap, it is important to keep educating all employees through initiatives such as Circular Fridays to inspire and motivate people throughout the organization and not just the specialists. This way, employees who work with reused construction materials in practice also gain a better understanding for how important their individual contribution is for the bigger picture.

Other challenges from the contractor's perspective with today's methods of construction involve the highly set requirements and strict routines and behavioral patterns that are difficult to change. Respondent 2 described that routines for construction processes need to adapt to a more circular approach in order to facilitate and favor reuse. According to multiple respondents, the current state of the construction industry even discourages reuse and the use of reused materials as it is economically unsustainable due to the fact that reconditioned and restored construction materials generally are more expensive. However, there are also cases where reuse happens out of coincidence. Respondent 8 highlighted that some of the reuse already takes place on construction sites without the initial intent to reuse. For example, temporary constructions such as temporary doors and temporary guardrails are used in several different constructions. Leftover waste is often used as temporary construction or for surrounding buildings such as a bicycle storage or a garbage station. This reduces the climate impact somewhat, but not excessively, but every step towards a more circular mindset regarding construction is a step in the right direction.

5.4.3 The Material Suppliers

Respondent 6 and respondent 2 both highlighted that the material suppliers play a key role in enhancing and making reuse at a larger scale possible. This is because it is the material suppliers who are most knowledgeable about their products and therefore have the right competencies to perform tests and guarantee the quality of the reused products. In doing so, the supply would be more consistent and reliable which would make it easier for contractors and clients to design and plan for reused

materials in their construction projects.

Stena Stål is one example where the supplier succeeds in doing so, their concept is to take back steel beams and locate where they have previously been in a former building, to see how old the product is or at what capacity the beam possesses. Through the establishment of this information about the beam, the amount of testing and samples needed for the beams are decided and then conducted. After the sampling and testing process, Stena Stål can see if the beam is fit for reuse and if so, resell the beam to customers with quality certificates and guarantees. Another reliable supplier that delivers reused materials is Bruksspecialisten who specializes in reused brick. Respondent 4 who works at Bruksspecialisten looks positively at the possibilities for large scale reuse in the near future. However, they mentioned that there are yet a few obstacles that need to be overcome before the supply chain can be complete and reliable. One of these challenges involve the mindset from the customers, they have to be more flexible in regards to design and more accepting towards various bricks as the wanted volume might not be available in one specific color. Further, customers who send their bricks for restoration with Bruksspecialisten often want or expect that their exact bricks will be sent back to them which causes logistical problems. Respondent 4 says that the best way to scale up the reuse would be if a customer submitted their brick and then received a check for a corresponding amount of brick, but not necessarily the specific bricks they turned in.

Respondent 6 and 3 told us that Stena Stål is actively searching among demolition projects to find its old beams that can be restored, and quality tested, and then get a new life in another project. This business model also simplifies the market for reused products as the reused products are found on the same market as new products. It is often complicated and difficult to find reused products, but if they are in the same product sheet as new ones, it greatly facilitates the reuse. Since the market for reused products is limited and often cannot meet the quantities needed in new construction projects, Stena Stål's business concept is creative as they complement orders for new products with quality-assured and reused products. Respondent 3 gave an example where if you for instance need 100 beams for a project, you can order 97 new beams and 3 reused beams. In doing so, the carbon dioxide emissions can be decreased significantly as steel production has a very high environmental impact. Therefore, suppliers have a significant role in restoring and delivering qualitative, restored products as it is more difficult and demanding, both in regards of time and logistics, for the contractors to do so themselves.

5.5 Interplay Between the Different Actors

During the interviews the importance of strong collaboration between all actors was also mentioned as one of the main factors for reuse to be implemented in more projects. The client needs to be interested in implementing reuse, the contractor needs to contribute with their knowledge and know-how on the topic and the suppliers need to provide the products and materials. Respondent 8 especially highlighted the importance of the collaboration between the client and the contractor but the respondent also mentioned that other actors such as the municipality and the suppliers play an important part as well.

”Collaboration is necessary, someone must want to build sustainably and someone must be able to deliver. One can’t exist without the other, there has to be a synergy.”

-Respondent 8

If the client and contractor are in a partnering agreement or use early contractor involvement, the contractor is more likely to influence the design process and suggest sustainable ways of production including implementation of material reuse. According to respondent 8 the interplay between all the actors involved is the most crucial step in order to make the transition to a more circular building industry. However, the client has the most significant role as they are the ones who set demands and at the end of the day the one who finances the project. Therefore, according to respondent 8, it is important that reuse is financially beneficial in order to justify it for the client. This way, the client can take advantage of the contractor’s knowledge and experience and the most sustainable, both environmentally and financially, outcome can be achieved.

6

Discussion

The gathered results from the literature study and the empirical study give a multitude of different perspectives and insight to the topic of material reuse in new construction. The results and answers are summarized and discussed in this chapter. The research findings from the study were assessed and elaborated and further the relevance and implications of the results were discussed. Also covered in this chapter are the limitations of the study as well as ideas for further research on the topic. Moreover, a reflection upon the study is made which covers data gaps, potential sources of errors and confounding factors.

Key findings from the study include realizations about an unsustainable approach to the built environment and new construction. The construction industry holds such a large share of environmental pollution and needs to change its attitude towards demolition and new construction. There are many examples of fully functional buildings that have been tore down to be rebuilt again. In such cases, the client should firstly consider if it is truly necessary to tear down the building at all or if the building could be refitted for its new purpose. If that is not possible it is crucial that the building is dismantled in a way where the materials keep its value and function in order to be able to be used again and again.

6.1 Current Implementation of Reuse

The current state of reuse in the construction industry is limited. From the conducted study in this report, it is evident that there are driving forces in order to understand how to better implement reuse. In reality however, the actual use of reused materials is quite low as the stakeholders consider the process difficult and complicated. There are a few good examples of projects where they have succeeded with material reuse, but these are innovation projects. Reuse should be implemented in the general project in order to raise the minimum level and thus do better for the climate. Because raising the minimum level for all projects would mean much more for the climate than the innovative key projects. Our study has shown that reuse is usually only implemented for projects that are seen as innovative projects or where eager and driven individuals themselves take the initiative. Since there are no clear work routines for reuse, enthusiasts are required who have the energy to take the time and energy to create their own working methods to succeed in implementing reuse.

From the interviews and the literature processed in the study it is evident that there is a strive and will to implement reused materials in construction projects. The industry in broad is aware of the climate challenges they are facing and there are

numerous creative and innovative actors in the industry who set great examples for circular construction and reuse in the construction industry. The gathered results from the interviews also show that there are notable incentives to get better at implementing reuse and reducing material waste from the significant majority of actors and stakeholders that were interviewed. But there is still a gap between idea and reality where actors are afraid of failure and there are no routines for how to work with reuse. The interviews have shown that there is too much uncertainty about guarantees, logistics and the market, and this creates too great risks in construction projects that already have small economic margins. The desire to work with reuse and previous good examples of projects with reuse show that it is possible to implement more reuse in the projects. What seems to be the common denominator is that there is no routine or general process for the implementation of reuse in projects. These uncertainties make companies hesitant and reserved to implement reuse as the risks are currently considered too great.

6.2 Discussion of Research Questions

In the coming paragraphs, the results of the study will be discussed based on the research questions on which the study was based on. These research questions will also be answered built on the findings of the study.

6.2.1 Actors Responsibilities in Reuse

Findings from the report show that the client's have a crucial role in the implementation of reuse. Even though material reuse in construction requires extensive collaboration between all stakeholders, it is evident that the client plays the most significant role as they are the one actor who finances and initiates the project in its entirety. Therefore it is often the client who has to initiate reuse or environmentally conscious construction projects. Still, this requires that the client is open minded and susceptible for such initiatives. From the interviews, it is evident that the clients generally are susceptible for these types of initiatives as long as it does not majorly impact the timeline or finances of the project.

There is a need for more direct demands and regulations from the government and municipalities to drive construction companies to raise their minimum level and build more sustainably. Based on the case study, there are clear examples of where laws and regulations have prevented proposals to implement reuse in projects. It is easy for contractors to lose motivation for reuse if they are constantly refused building permits based on little things as like color of reuse materials and such.

The contractor also plays an important role on setting realistic expectations on clients based on their given circumstances because they vary from case to case. Most clients can probably afford implementing reuse to a certain extent but as the costs of reused materials are slightly higher it might not be achievable for all customers to reach the same goals. One idea could be for the contractor to have a business offering where reuse is included in some way in all their tendering offers but at different levels depending on how much effort the client is willing to put in. Although it sounds harsh, construction companies will not change their ways of working to

more sustainable ones just to be nice, but it is about having economically favorable business models. However, today's world situation with the war in Ukraine and increasing material prices can be a driving factor to implement more reuse in construction. New materials will become increasingly expensive, which will make the financial barrier for reuse smaller and could make reuse more economically beneficial.

6.2.2 Collaboration Between Actors

To start the journey of a more widespread implementation of reuse, the involved stakeholders need to collaborate and communicate what needs to be done. One of the main findings in the study, that also answers the second research question, was that the collaboration between client, contractor, suppliers and other involved actors is of utmost importance to be able to successfully implement material reuse in construction projects. As mentioned in the case study, partnering contracts between the client and contractor open up for the possibility to share knowledge and allow a more flexible design process. This in turn enhances the possibilities for applications of reused materials. Another obstacle in the implementation of reuse revolves the logistical aspect of reconditioning and storage of the reused materials. To approach this issue, the suppliers are most suitable to take on this responsibility as they have the right knowledge and capacity to do so. At this stage it is important for the suppliers and contractors to communicate the supply and demand for materials in order to solve the logistics.

6.2.3 How Contractors can Enhance Reuse

The contractor plays an important part in regard to the coordination of construction projects and communication between actors in the projects. However, as the contractor itself does not provide the materials or physical goods but only the service of construction, they have limited means to impact design and material selection as the client has the final say. Furthermore, if the contractor beholds relevant information and the right tools to offer the client material reuse in projects that could be one approach to further implement material reuse in new construction projects. Therefore it is crucial that it is a part of the contractors business offering to provide more sustainable options which includes more extensive circular construction methods, such as material reuse, as an option in order for the customers to make the right choice.

However, through enthusiasm and desire, the contractor can push the client to implement more reused materials. It would make it easier for the contractor if they could deliver a clear model for the client on which circular measures they can introduce, what the benefits are and what they cost. It is difficult for a client who is not familiar with the subject to grasp the scope of reuse and then a clear model would be beneficial to be able to understand how reuse will affect their project financially and the climate positively.

Lastly, it is important to set realistic and attainable goals regarding circularity for the projects. Aiming to high increases the risk of thinking it is unattainable to achieve the goals and could be demotivating rather than the opposite. Therefore, it is important to highlight that all reuse, no matter how little, is better than no reuse at all.

6.3 Improvement Potential for the Near Future

As mentioned previously, there are no obvious routines or structures for how to work with reuse which becomes a problem for the implementation of reuse. Highly set goals and ambitions become overwhelming and unattainable, especially when routines for reuse are lacking. To get the implementation of reuse started and thus see how it works and create new work routines, it would be smart to start a little smaller and more realistic. Review which building parts are most worth reusing in terms of benefit per effort and start with them and based on that take learnings and set new goals for the future. The most important step in getting the implementation of reuse started on a larger scale is to create new work routines and create a market where products move in circular flows. Therefore, we believe that the steps that today may feel small should be implemented and these will later get the ball rolling and lead the way for large-scale implementation of reused materials. For example, it would be an excellent first step to reuse bricks, where there are material suppliers who have routines for taking back the bricks, testing and quality assuring them, and then selling them again. As the transition for the industry will take time, the most important thing for the industry now is to get the ball rolling and the other will follow afterwards.

6.4 Proposals For Skanska and Other Major Contractors to Enhance Circular Construction

As a part of the study, and to answer the third research question, we have created the figure below with the purpose to suggest tangible ideas for the enhancement of reuse in construction projects. The parameters in the figure are examples of objectives to aim for in order to achieve higher levels of reuse as well as circularity in new construction projects. The parameters include goals for waste disposal per square meter, emissions per square meter, reusing a certain amount of products in projects, including demolition plans etc. These parameters have been developed through facts from the literature study and the results from the interviews. The goal of this figure is for it to serve as an embryo and a start for a useful model that Skanska can use to quantify its circular solutions at different levels. In the future, this model can be linked to practical examples and function as a sales model where Skanska can present its circular solutions and what they mean for the customer financially and what benefit it does for the environment. The figure is presented below.

	Level 1	Level 2	Level 3
Demolition plans	Demolition plans in the planning and design phase	Demolition plans in the planning and design phase, integrated with the BIM model	Demolition plans in the planning and design phase, integrated with the BIM model and published in a organizational database for inventory of materials
Reused materials	Reuse one material in the project	Reuse two materials in the project	Reuse three, or more, materials in the project
Waste management	Sort waste into correct fractions	Look over the opportunities for reusing waste materials in surrounding buildings such as storage units or bicycle garages	Selling the material spill through second hand platforms such as CC build or Klaravik
Waste per sqm, accouring to Upphandlingsmyndigheten	37 kg/sqm	30kg/sqm	20kg/sqm
CO2-emissions per sqm, during construction stages (A1-A5)	Follow the reference values and limits by Boverket	A reduction in 10 percent of the reference values and limits by Boverket	A reduction in 20 percent of the reference values and limits by Boverket

Figure 6.1: Our model with tangible suggestions for enhancement for circularity from a contractor perspective

Regarding the planning and design process it is evident that the structures in place today are not fully suitable for reuse as they do not respond well to changes in later stages of the construction process. Therefore, it is important to adapt the design stages into processes that allow changes later on, meaning the design process would be more iterative. For this to happen, not only the contractors and clients need to have an open mind in regards to later changes but also the municipality needs to have permitting processes that can allow for changes in design and appearance due to reused products. Another important aspect in a circular design process is to include demolition plans, meaning that the buildings are designed and constructed in a manner where they can be dismantled to preserve the materials. This makes reusing the materials in future projects less difficult. As a part of creating demolition plans, an inventory for what materials are included in the building can be added so there is an overview of what materials and at which quantity is available in the building.

The key to success might be to start small and maybe even find a niche of materials through a supplier. Another incentive to increase the reuse could be implementing some sort of bonus or reward system for the project managers who achieve the goals that are set for the projects. It is also important to build today in a way that makes it possible and easier to reuse in the future, and therefore every project should include demolition plans from the planning stage.

6.5 Confounding Factors

One major parameter which occurred during the study was the fact that in reality more buildings are being constructed in comparison to how much is being demolished. This makes it difficult to create a functioning market that is in balance regarding the supply and demand of reused construction materials. The demand for reused products will be significantly higher than the available supply of reused construction materials which makes it hard and unpredictable to rely on the supply of reused products. This raises questions about if reuse is truly a sustainable solution long term in the desired extent. The general ambition would be to reuse as much materials as possible, which is positive, but the supply of reused materials will not be enough to meet the demand for all projects in the industry. The reused materials will not be able to meet the demand that exists to be able to build everything that is being built in Sweden right now. New innovative solutions are therefore needed to make the products, that reused materials cannot replace, better and more sustainable. But as said, reuse is environmentally beneficial solutions that needs to be seen as a first solution before looking at others.

6.5.1 The Economy Limits Circular Innovations

Something that has arisen during the interviews, which is not mentioned much in the literature, is how much the industry is controlled and, in many cases, tied back by the economy. There are many good initiatives and goals for what wants to be achieved and implement in terms of building circular, but many of these do not happen as it is not financially sustainable. With the working routines and standards that exist today, contractors do not consider it economically beneficial to work with reuse on a larger scale and therefore decides to build in the traditional way. We believe they want to build sustainable, but it has to be economically justifiable. Although the industry is changing, it has historically been the case that project managers' previous projects function a bit like their resumé in any promotions, where they are evaluated based on how their projects have gone financially. This means that it is not only the project's finances that are affected but also individuals' careers, and therefore there is a lot of focus on economic benefit instead of building sustainably and circularly. As said, this is changing in the industry but there is still some way to go, the economy still has too much power over other soft values. It is necessary to equate and find a symbiosis where soft values such as environmental impact and sustainability are valued in the same way as the economical ones.

7

Conclusion

To summarize the results of the study, the construction industry is trying to adapt to the challenges regarding the significant negative climate impact the industry contributes to. Specifically, the extraction of finite raw materials is one major source to CO₂ emissions. If the construction industry in broad makes changes in work patterns and processes, material reuse will be commonly occurring in more construction projects even at a large scale. The transition from linear to circular material flows will take time as there is limited previous experiences and know how about such processes. Actors that are successful in providing or implementing material reuse in construction projects have been some of the first to do so meaning they have had to experiment and try different methods to see what works best. Because material reuse in construction is still in the early stages of evolving, a sort of learn as you go approach is necessary to start the implementation. For this transition to happen in the foreseeable future it is important to start making changes right away. Large scale reuse in the industry might seem far away today but through many small changes it will be possible. Setting small, attainable goals that can be achieved in all projects will help starting the journey to a more sustainable approach in the built environment.

7.1 Concluding Remarks

The industry is currently in the early stages of making a transition to circular material flows. To be able to achieve successful implementation of material reuse in new construction, structured processes for this needs to be put in place. Extensive collaboration between all stakeholders is crucial and the environmental aspect needs to be prioritized in order to implement patterns for reuse in new construction and change current construction and demolition methods.

In conclusion, the study highlights the urgent need for the construction industry to transition from a linear to a circular material flow in order to mitigate the significant negative climate impact it contributes to. Material reuse is identified as a crucial element in achieving this transition, but it is still in the early stages of evolving, and there is limited previous experience and know-how about such processes. Successful implementation of material reuse requires extensive collaboration between all stakeholders, but the client plays the most significant role in initiating and financing the project. Therefore, it is crucial that the contractor includes more extensive circular construction methods, such as material reuse, as an option in their business offering. This study has resulted in a model that can be used in its entirety or as an idea for what such a business model for reuse could look like. Suppliers also carry significant responsibility in regard to restoring and guaranteeing the quality of reused

materials. The planning and design process also needs to be adapted to allow for changes later on in regard changes in design and appearance due to reused products. This also requires a more iterative approach to the design and building permitting process. Finally, it is important to set realistic and attainable goals for the projects and to start small by implementing reuse of construction materials.

7.2 Future Research

Future research for the topic of large scale reuse could include information models that can communicate the supply and demand of construction materials. Further relevant studies would be on the logistics and supply chain of reused materials. Logistical issues also include matters of the design and reliability on the supply of reused products. To solve this, a more iterative design process could be researched.

There is still a gap between idea and reality for the implementation of reuse. To bridge the gap, a practical study could be of great benefit to make observations and gain practical experience. Efficient work structures for successful implementation of material reuse need to be put in place. This could be supported through a field study of several projects where reuse has been implemented. A practical framework for reuse may help the contractor in their working methods and could serve as a concrete example and selling point in procurement processes.

References

- Åfreds, J. (2023, 1). Detaljplan hindrade cirkulärt byggande - Skanska fick inte återbruka stomme. *Byggindustrin*. Retrieved from <https://www.byggindustrin.se/affarer-och-samhalle/hallbarhet/detaljplan-hindrade-cirkulart-byggande--skanska-fick-inte-aterbruka-stomme/>
- Alvehus, J. (2019). *Skriva uppsats med kvalitativ metod*. Stockholm: Liber AB.
- Bartee, L., Shriner, W., & Creech, C. (2017). Using Credible Sources. *Principles of Biology*. Retrieved from <https://openoregon.pressbooks.pub/mhccmajorsbio/chapter/using-credible-sources/>
- Björkman, K., & Kardell, I. (2021). *Drivkrafter och hinder med återbruk inom byggbranschen* (Tech. Rep.).
- Boverket. (2023a, 1). *Bygg- och fastighetssektorns uppkomna mängder av avfall*. Retrieved from <https://www.boverket.se/sv/byggande/hallbart-byggande-och-forvaltning/miljoindikatorer---aktuell-status/avfall/>
- Boverket. (2023b). *Utsläpp av växthusgaser från bygg- och fastighetssektorn*. Retrieved from <https://www.boverket.se/sv/byggande/hallbart-byggande-och-forvaltning/miljoindikatorer---aktuell-status/vaxthusgaser/>
- Carvalho, J. P., Villaschi, F. S., & Bragança, L. (2021). Assessing Life Cycle Environmental and Economic Impacts of Building Construction Solutions with BIM. *Sustainability*, 13(16). Retrieved from <https://www.mdpi.com/2071-1050/13/16/8914> doi: 10.3390/su13168914
- Circle Economy. (2019). *The role of municipal policy in the circular economy* (Tech. Rep.).
- CIRCuIT. (n.d.). What is circular construction? Retrieved from <https://www.circuit-project.eu/about-circular-construction>
- Ding, L., Wang, T., & Chan, P. W. (2023, 2). *Forward and reverse logistics for circular economy in construction: A systematic literature review* (Vol. 388). Elsevier Ltd. doi: 10.1016/j.jclepro.2023.135981
- Edlund, A. (2019). *Grön upphandling* (Tech. Rep.). Retrieved from <http://www.diva-portal.org/smash/get/diva2:1411604/FULLTEXT01.pdf>
- Ejlertsson, A., Loh Lindholm, C., Green, J., & Ahlm, M. (2018). *Cirkulär ekonomi i byggbranschen*. Retrieved from www.ivl.se
- EkobyggGuiden. (n.d.). *Återbruk*. Retrieved from <https://www.ekobyggguiden.se/aterbruk>

- European Parliament. (2022). *The circular economy model*. Retrieved from https://www.europarl.europa.eu/resources/library/images/20230222PHT76206/20230222PHT76206_original.jpg
- European Commission. (n.d.). *Waste Framework Directive*. Retrieved from https://environment.ec.europa.eu/topics/waste-and-recycling/waste-framework-directive_en
- Fastighetsägarna. (2021, 9). *Cirkulärt byggande gynnar såväl plånboken som klimatet*. Retrieved from <https://www.fastighetsagarna.se/aktuellt/nyheter/2021/cirkulart-byggande-gynnar-saval-planboken-som-klimatet/>
- Geissdoerfer, M., Savaget, P., Bocken, N. M., & Hultink, E. J. (2017, 2). *The Circular Economy – A new sustainability paradigm?* (Vol. 143). Elsevier Ltd. doi: 10.1016/j.jclepro.2016.12.048
- Gerhardsson, H., Andersson, J., & Thrysin, (2020). *Återbrukets klimateffekter vid byggnation -Handledning för klimatberäkningar i enlighet med EN 15978*. Retrieved from www.ivl.se
- Ghaffar, S. H., Burman, M., & Braimah, N. (2020). Pathways to circular construction: An integrated management of construction and demolition waste for resource recovery. *Journal of Cleaner Production*, 244, 118710. Retrieved from <https://www.sciencedirect.com/science/article/pii/S0959652619335802> doi: <https://doi.org/10.1016/j.jclepro.2019.118710>
- Gorgolewski, M., Straka, V., Edmonds, J., & Sergio-Dzoutzidis, C. (2008). Designing buildings using reclaimed steel components. *Journal of Green Building*, 3(3), 97–107.
- Göteborgs stad. (n.d.-a). *Cirkulära Göteborg*. Retrieved from <https://goteborg.se/wps/portal/start/miljo/det-gor-goteborgs-stad/cirkulara-goteborg->
- Göteborgs stad. (n.d.-b). *Klimatet - Göteborg ska ha ett klimatavtryck som är nära noll*. Retrieved from <https://goteborg.se/wps/portal/enhetssida/miljo-och-klimat-goteborg/miljo-och-klimatprogrammet/klimatet>
- Göteborgs stad. (n.d.-c). *Miljö- och klimatprogrammet*. Retrieved from <https://goteborg.se/wps/portal/enhetssida/miljo-och-klimat-goteborg/miljo-och-klimatprogrammet>
- Göteborgs stad. (2020). Göteborg stad - Dags att bygga och riva cirkulärt! Retrieved from <https://goteborg.se/wps/wcm/connect/d0600675-8e9c-4522-9984-4783c65d9a07/Slutrapport+Upphandlingskrav+fÅur+cirkulÅdra+flÅüden+i+bygg-+och+rivningsprocessen.pdf?MOD=AJPERES>
- Göteborgs Stad. (2021, 2). *Storstadsöverenskommelse för cirkulärt byggande 2030* (Tech. Rep.). Gothenburg. Retrieved from www.goteborg.se/cirkularagoteborg
- Göteborgs Stad. (2022, 2). *Göteborgs Stads miljö- och klimatprogram*. Retrieved from <https://goteborg.se/wps/portal/enhetssida/miljo-och-klimat-goteborg>

- Holmqvist, M., & Älvegran, A. (2020). *Återbruk i ett fastighetsutvecklingsprojekt* (Tech. Rep.).
- Johansson, P., Brander, L., Jansson, A., Karlsson, S., Landel, P., & Svennberg, K. (2017). *Kvalitet hos byggnadsmaterial i cirkulära flöden* (Tech. Rep.).
- Kamara, J. M., Anumba, C. J., & Evbuomwan, N. F. O. (2000). *Process model for client requirements Process model for client requirements processing in construction* (Vol. 6; Tech. Rep. No. 3). Retrieved from <http://www.emerald-library.com>
- Konkurrensverket. (n.d.). *LOU i korthet*. Retrieved from <https://www.konkurrensverket.se/upphandling/lagar-och-regler/lou-i-korthet/>
- Mangialardo, A., & Micelli, E. (2018). Rethinking the construction industry under the circular economy: Principles and case studies. In *Green energy and technology* (Vol. 0, pp. 333–344). Springer Verlag. doi: 10.1007/978-3-319-75774-2{_}23
- Miliute-Plepiene, J., Almasi, A. M., & Hwargård, L. (2020). *Återanvändning av bygg- och rivningsmaterial och produkter i kommuner*. Retrieved from www.ivl.se
- Naturskyddsföreningen. (2022, 10). *Cirkulär ekonomi*. Retrieved from <https://www.naturskyddsforeningen.se/faktablad/cirkular-ekonomi/>
- Park, J., & Tucker, R. (2016). *Overcoming barriers to the reuse of construction waste material in Australia: a review of the literature* (Tech. Rep.). Retrieved from <https://www.tandfonline.com/doi/full/10.1080/15623599.2016.1192248>
- 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. Retrieved from <https://doi.org/10.1080/15623599.2016.1192248> doi: 10.1080/15623599.2016.1192248
- PEAB. (2021). *Utvecklingen av Varvsstaden visar vägen inom återbruk*. Retrieved from <https://peab.se/om-peab/bolagsinformation/press-och-media/nyhetsarkiv/utvecklingen-av-varvsstaden-visar-vagen-inom-aterbruk/>
- Rahman, M. M., & Alhassan, A. (2012, 11). A contractor's perception on early contractor involvement. *Built Environment Project and Asset Management*, 2(2), 217–233. doi: 10.1108/20441241211280855
- Rahmani, F. (2021). Challenges and opportunities in adopting early contractor involvement (ECI): client's perception. *Architectural Engineering and Design Management*, 17(1-2), 67–76. doi: 10.1080/17452007.2020.1811079
- Regeringskansliet. (2020, 12). *En taxonomi för hållbara investeringar*. Retrieved from <https://www.regeringen.se/regeringens-politik/finansmarknad/taxonomi-ska-gora-det-enklare-att-identifiera-och-jamfora-miljomassigt-hallbara-investeringar/>
- RPS. (n.d.). Circular economy: The cornerstone of sustainability. Retrieved from <https://www.rpsgroup.com/insights/consulting-uki/circular-economy-the-cornerstone-of-sustainability/>
- Simmons, L. (2021). *A Guide to Early Contract Involvement*. Retrieved from <https://www.insol.co.nz/blog/a-guide-to-early-contract-involvement>

- Simonsson, F. (2021, 5). *Återbruk av byggprodukter i nybyggnation av bostäder* (Tech. Rep.). Lund: LTH.
- Skanska Sverige. (n.d.). *Epic, Malmö*. Retrieved from <https://www.skanska.se/vart-erbjudande/vara-projekt/249047/Epic%2C-Malmo>
- Skanska Sverige. (2019, 11). *Kontorshuset Epic - en cirkulär milstolpe*. Retrieved from <https://www.skanska.se/vart-erbjudande/vara-projekt/249047/Epic%2C-Malmo>
- Skanska Sverige. (2022). *Nya konst*. Retrieved from <https://www.skanska.se/om-skanska/press/pressmeddelanden/269223/Skanska-bygger-nya-lokaler-for-Konstnarliga-fakulteten-at-Akademiska-Hus-i-Goteborg-for-cirka-1%2C2-miljarder-kronor>
- Sterner, E. (2002). 'Green procurement' of buildings: a study of Swedish clients' considerations. *Construction Management and Economics*, 20, 21–30. Retrieved from <https://www.tandfonline.com/doi/epdf/10.1080/01446190110093560?needAccess=true&role=button>
- Stockholms stad. (2021, 10). *Den cirkulära bygg- och rivningsprocessen*. Retrieved from <https://miljobarometern.stockholm.se/miljomal/handlingsplan-for-cirkulart-byggande/den-cirkulara-bygg-och-rivningsprocessen/>
- Strand Nyhlin, M. (2020, 3). Lendager skalar upp det cirkulära byggandet . *Hållbart byggande*.
- Strand Nyhlin, M. (2021, 2). *Epic Malmö - pionjärprojekt venom återbruk och hälsa. Byggindustrin*. Retrieved from <https://www.byggindustrin.se/byggprojekt/arets-bygge/epic-malmo---pionjarprojekt-inom-aterbruk-och-halsa/>
- Strand Nyhlin, M., & Åfreds, J. (2022). *Återbruk av byggmaterial*. Stockholm: Svensk Byggtjänst.
- Sweden Green Building Council. (n.d.). *Vad är EU:s gröna taxonomi?* Retrieved from <https://www.sgbc.se/utveckling/eu-taxonomin/vad-ar-eus-grona-taxonomi/>
- Waern, M. (2021). *Beställarens roll för ökat återbruk av byggmaterial* (Tech. Rep.). Retrieved from <http://ltu.diva-portal.org/smash/get/diva2:1577927/FULLTEXT01.pdf>
- Yeung, J., Walbridge, S., & Haas, C. (2015, 11). The role of geometric characterization in supporting structural steel reuse decisions. *Resources, Conservation and Recycling*, 104, 120–130. doi: 10.1016/j.resconrec.2015.08.017

A

Appendix A

Interview framework

- Describe your work role and your previous background.
- Do you have any previous experience of circularity?
- Do you work with reuse in your project/your organization today?
 - a) if yes, how do you work with reuse?
 - b) if no, do you have concrete plans to introduce or better implement reuse in future projects?
- Are there requirements for environmental performance or maximum emissions/waste in your projects?
 - a) if yes, are these requirements complied with?
- What do you think are the biggest challenges to implementing reuse in your projects/your organization?
- Which actor do you think must initiate reuse requirements in order for it to be implemented more in the industry?
 - a) What is required for actors to do this?
- How can the different stakeholders collaborate to better implement reuse in new construction?



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