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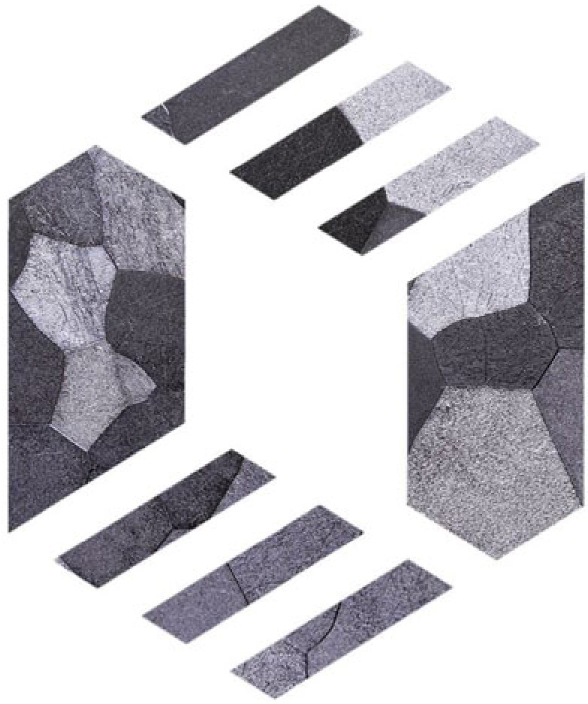

Accelerating Circularity in Construction Logistics by Utilizing and Developing Digital Platforms

Master's thesis in Design and Construction Project Management

JONATAN HULTERSTRÖM
BJÖRN JONASSON

DEPARTMENT OF TECHNOLOGY MANAGEMENT AND ECONOMICS
DIVISION OF INNOVATION AND R&D MANAGEMENT

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Department of Technology Management and Economics
Chalmers University of Technology
SE-412 96 Gothenburg
Telephone +46 31 772 1000

Cover: Conceptual visualisation of circular building materials. Created by MRC for circularmaterials.de

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Summary

The construction industry is facing increasing pressure from climate regulations, which are expected to become even stricter in the future. This has in turn led to an increased interest in circularity as a tool to meet future demands. Construction logistics has shown potential to bring positive synergies in addressing many challenges faced by the industry, including circularity. Additionally, the digital maturity of the industry is relatively low, presenting challenges to new initiatives. This thesis investigates the interface between digitalization, circularity, and construction logistics, exploring how *Digital Logistics Platforms* (DLPs) can contribute to enabling circular material flows. Previous research in this area is limited, making this thesis a valuable contribution and a potential starting point for future research. The aim of this study is to help practitioners in the construction industry better understand the current state of circularity and identify how they can utilize digital tools, such as DLPs, to improve their circular performance. An abductive research approach was employed, combining a literature review with an extensive interview study involving 30 interviews across 29 organizations representing a diverse range of actors in the Swedish construction industry. The findings reveal that while it is seen as an increasingly important trend, achieving large-scale circularity remains a challenge. Material producers and property owners are highlighted for their capacity and potential to drive large-scale initiatives. Collaboration between actors is defined as crucial, as individual companies often struggle to drive circular initiatives on their own. This thesis presents a framework differentiating the term circularity into three different types. The framework can be used by practitioners across the construction industry to identify both their own role and potential in circular initiatives but also which actors and competences they need to collaborate with to succeed. The landscape of DLPs available on the Swedish market is mapped, identifying three categories of platforms: multifunctional DLPs, calendar specialized DLPs, and niche DLPs. These platforms have the potential to enable circular material flows by providing integrated services and digital functions. However, this requires greater transparency and digitalization of material inventories across the industry. The development of DLPs can position them as a crucial enabler for circular practices in construction, serving as the mortar to the bricks in the interface between digital and practical activities. Ultimately, the findings of this thesis can help actors across the Swedish construction industry identify their role within circular initiatives. Once this is realized, the mapping and investigation of DLPs can be used to understand which digital tools are applicable to further drive circularity.

Keywords: circularity, circular construction, construction logistics, digital platforms, material flows, reuse, recycling.

Accelerera Cirkuläritet inom Bygglogistik genom Användning och Utveckling av Digitala Plattformar
JONATAN HULTERSTRÖM
BJÖRN JONASSON

Instutitionen för Teknikens Ekonomi och Organisation
Chalmers University of Technology

Sammanfattning

Byggbranschen möter idag hårdare regler relaterade till klimat och hållbarhet, regler som förväntas bli striktare i framtiden. Utvecklingen har i sin tur lett till ett ökat intresse för cirkuläritet som ett verktyg för att tackla framtida krav. Bygglogistik har visat sig ha stor potential att medföra positiva synergier för hantering av flera av byggbranschens utmaningar, inklusive cirkuläritet. I tillägg är den digitala mognadsgraden inom byggbranschen relativt låg vilket leder till utmaningar vid nya initiativ. Denna uppsats undersöker gränssnittet mellan digitalisering, cirkuläritet och bygglogistik för att utforska hur digitala logistikplattformar kan bidra till förbättrade cirkulära materialflöden i den svenska byggbranschen. Det finns begränsat med tidigare forskning på området vilket gör den här uppsatsen till ett värdefullt bidrag och en potentiell startpunkt för framtida forskning. Studiens mål är att bidra till att aktörer i byggbranschen får en bättre förståelse för hur cirkuläritet fungerar i dagsläget och hur de kan identifiera och använda digitala logistikplattformar för att förbättra sitt arbete på området. En abduktiv forskningsmetod valdes där en litteraturstudie utförts i kombination med en utförlig intervjustudie. Totalt 30 intervjuer utfördes med representanter från 29 företag i olika delar av byggbranschen. Studiens resultat visar att även om det ses som en central trend så är storskaligt cirkulärt arbete kantat av utmaningar. Materialproducenter och fastighetsägare uppmärksammas för sin kapacitet och potential att driva storskaliga cirkulära initiativ. Vidare är samarbete mellan aktörer viktigt eftersom enskilda företag har svårt att driva cirkulära initiativ själva. I uppsatsen presenteras ett ramverk där termen cirkuläritet delas upp i tre olika typer. Ramverket kan användas av olika typer av aktörer för att identifiera både sin egen roll och potential inom cirkulära initiativ men även vilka aktörer och kompetenser man behöver samarbeta med för att lyckas. I studien kartläggs landskapet av digitala logistikplattformar inom den svenska byggbranschen, vilket har lett till en kategorisering av tre olika plattformstyper: multifunktionella, kalenderfokuserade och nischade. Plattformarna ses ha potential att bidra till cirkulära materialflöden genom att erbjuda integrerade lösningar och digitala funktioner. Samtidigt krävs större transparens och digitalisering av materialbankar i hela byggbranschen. Utvecklingen av digitala logistikplattformar kan positionera dem som viktiga möjliggörare för cirkulära initiativ där de fungerar som kitt i gränssnittet mellan digitala och praktiska logistikaktiviteter. Slutligen kan uppsatsens resultat hjälpa aktörer i hela byggbranschen att bättre förstå sin roll i cirkulära initiativ. När denna förståelse är skapad kan kartläggningen av digitala logistikplattformar användas för att förstå vilka digitala hjälpmedel som är applicerbara för att vidare driva cirkulärt arbete.

Nyckelord: cirkuläritet, cirkulärt byggande, bygglogistik, digitala plattformar, materialflöde, återanvändning, återbruk, återvinning.

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Last but not least, we would like to thank all of the participants of the interviews, for your time and impeccable interest in circularity and logistics, as well as your willingness to share your experiences for the sake of progress. We hope your knowledge and engagement will spread to all corners of the construction industry through this thesis.

Gothenburg, May 2024
Jonatan Hulterström & Björn Jonasson

Glossary

Acronym	**English**	**Svenska**
BIM	Building Information Modeling	Byggnadsinformationsmodellering
CAD	Computer Aided Drawing	Datorstödd konstruktion
CE	Circular Economy	Cirkulär ekonomi
CCC	Construction Consolidation Center	Konsolideringscenter
CMF	Circular Material Flows	Cirkulära materialflöden
DLP	Digital Logistics Platform	Digital logistikplatform
EPD	Environmental Product Declaration	Miljödeklaration
FL	Forward Logistics	Logistikflöde utgående
GHG	Greenhouse Gas	Växthusgas
GPP	Green Public Procurement	Grön offentlig upphandling
LCA	Life Cycle Assessment	Livscykelanalys
RL	Reverse Logistics	Logistikflöde tillbakagående
SCM	Supply Chain Management	Hantering av logistikkedjan
TPL	Third Party Logistics	Tredjepartslogistik

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1
Introduction

The introduction chapter provides a brief background on the topics of climate change, circular economy, construction logistics, and digital platforms, leading to the aim of the thesis and the formulation of three research questions. Furthermore, delimitations and an outline of the thesis are presented.

1.1 Background

The threat of Climate Change is phasing the construction industry into innovation and adaptability. On the global scale, the construction sector alone was responsible for over a fifth of *greenhouse gas* (GHG) emissions in 2019 according to the *Intergovernmental Panel on Climate Change* (IPCC, 2022). Boverket (2024a) has estimated that embodied carbon emissions are a large contributor to CO2 emissions in the construction industry, which is partly due to a sub-optimal management of construction materials. Today a lot of material gets neglected on-site and ends up unused and instead of being brought to new projects, these materials typically get thrown away, ending up at an incinerator or a landfill. If reuse of these materials were considered more, this would have a direct effect on reducing total carbon emissions. Due to developments in sustainability such as regulations and social determination, the reuse of existing building materials has become increasingly popular. This is largely due to the requirements and directives from the EU such as *CSRD* (Corporate Sustainability Reporting Directive) and *EU Taxonomy*. Along with the Swedish national requirement of *Climate Declarations*.

Reusing material is part of the broader term circularity, which derives from *circular economy* (CE) (Geissdoerfer et. al 2017). CE is an alternative to the more commonly used form of linear economy which means that materials are produced, used, and lost at the end-of-life stage after one life cycle. In contrast, CE means that the materials that are produced will be used again in several life cycles, maybe for different purposes or recycled and used differently (Kircherr et al., 2017). In the context of logistics when handling reusable/recyclable materials in a circular system, this is referred to as *circular material flows* (CMF) (Bosch et al., 2023).

Supply chain management (SCM) is a wide field encompassing areas such as marketing, economics, logistics, and organizational behavior and is the governing set of activities managing flows of material and information as well as managing relationships across all manufacturing industries (Hobbs, 1996). SCM frameworks have proven crucial to implementing and governing larger organizational strategies, especially within circularity (Kossila, 2022).

Construction logistics is a pillar of SCM in construction and has proven to carry many positive synergies with it in relation to efficiency, safety, transportation and profit (Sullivan et al., 2010). The project-based nature of construction adds complexity to the logistic aspects since different projects have varying conditions. According to Ding et al. (2023), the use of *forward logistics* (FL), i.e. the flows going into the project, is prioritized. Whereas *reverse logistics* (RL), i.e. flows going out from the project, are less common. With detailed planning and optimization of construction logistics, the industry has great potential to decrease its carbon footprint by minimizing the usage of fossil fuels and unfilled loads (Ding et al., 2023). This could be achieved by incorporating RL more into projects, creating a loop where FL and RL are integrated, which in practice would mean that there are systems for coordinating the logistics in such a way that each extracted building material will be placed back into FL subsequently. These are central themes in theory about circular logistics on an overarching level where the goal is to develop business models that prolong the traditional lifespan of products and materials while maintaining their value and capabilities (Kossila, 2021). Bosch et al. (2023) identify construction logistics activities as having a great potential to further contribute to circular material flows in the construction industry. Through careful consideration, planning and collaboration it is found that logistics activities could develop and improve circular performance.

A recurring strategy for innovation and development for any modern sector is through digitalization and data optimization, where the construction industry has long been criticized for lagging behind. Today the construction industry utilizes digital tools for drawings and 3D modeling using *building information modeling* (BIM) and *computer aided drawing* (CAD). The industry also uses digital tools such as *digital twins* for facility management (Lee & Lee 2021). Construction logistics has traditionally not been very digital and relied on whiteboards and phone calls for governance and communication. Recent development has seen the rise of *digital logistics platforms* (DLP), starting out as a digital extension of the whiteboard and then developing into a more comprehensive tool for managing other types of construction logistics activities These platforms may have the potential to increase awareness and accessibility of circular materials in the construction industry and by extension, provide efficient workflows and collaborations.

Despite the importance of circularity, construction logistics and digitalization individually appear to lack comprehensive research examining the interface between them. Bosch et al. (2023) made an important contribution in developing a framework of activities and scenarios for how construction logistics can contribute to circular material flows and Ding et al. (2023) systematically analyzed the academic discourse around FL and RL in construction to provide clarity and an improved ground to stand on for future researchers. Given the large interest in circularity in construction stemming from tighter regulations, the positive effects of dedicated construction logistics and the underdeveloped field of digitalization in construction, an investigation into this interface could be of great importance. This gap in the existing literature presents an opportunity to advance our understanding of how the construction industry can reduce its environmental footprint by utilizing and developing digital logistics solutions to improve circular material flows.

1.2 Aim

This thesis aims to investigate how the interface between construction logistics, circularity, and digitalization can contribute to increased circular material flows within the Swedish construction industry. The described process can be further divided into different aims that together contribute to the overarching target. Firstly, the aim is to capture an image of the current state of circularity in the construction industry and the needs of its actors to transition to circular practices. Secondly, the aim is to map existing DLPs available to the Swedish construction industry and what functions they have. Finally, these two will be combined with the aim of displaying how requirements for circularity can be met by DLPs, and what functions that need to be developed further. Ultimately, the thesis aims to guide practitioners of all kinds in the Swedish construction industry to understand better the current state of circularity and how they can utilize DLPs from their point of infliction to increase their circular practices.

1.3 Research Questions

Three research questions have been formulated to systematically investigate the aim. Firstly, there is a question targeting the current state of circularity and potential for the future. The second question is formulated to map out and understand available DLPs in Sweden and how they can be utilized for circular practices. Lastly, the third question targets the development of improved functionality of the platforms, to become better at handling circularity in construction.

RQ1 *How are workflows for circularity and construction logistics portrayed today and how may they be portrayed in the future?*

RQ2 *What is the current state of Digital Logistics Platforms in Sweden, and how do they facilitate circularity?*

RQ3 *Can increased circularity in construction be supported by improving functionality in Digital Logistic Platforms?*

1.4 Delimitations

This thesis focuses on circularity and construction logistics as they currently stand in the context of the Swedish construction industry with examples from projects and interviews with professionals. The geographical limitation was consciously made to limit the scope, to fit the frame of a master's thesis. Sweden, and the Gothenburg region in particular, is the place of origin of the report and despite discussing rules, regulations, and practices in Sweden, the context also provides partly applicable results to the other Nordic and some EU countries, since they follow similar regulations and technical solutions. The EU taxonomy provided by the EU Commission frames the definition of sustainable development, alongside the national equivalents of "Climate Declarations for Buildings", *miljödeklaration för byggnader* in Sweden. A decision has also been made to investigate specifically construction projects of buildings, and not infrastructure projects since their practices and objectives differ too much.

This thesis aims not to develop a new digital platform, but rather to map existing ones available to and commonly used by actors in the Swedish construction industry. The ones that were evaluated were selected based on their occurrence in interviews and research, meaning that there could potentially be other platforms available that are not covered in this report. Furthermore, the investigation of DLPs will focus on their theoretical implementation rather than practical. A survey of many users has not been conducted and it is not the user-friendliness that is in focus. This is largely due to the lack of research in this field making it challenging to build a solid theoretical framework to later evaluate answers from. This may lead to our suggestions for new functions and descriptions of the applicability of DLPs not being completely applicable to reality in the way it would have been if many users were surveyed. The analysis of DLPs instead aims to map and display what functions are currently available and how they can be used to increase circular practices.

Finally, it is important to note that the state of circularity is very dynamic with new initiatives and practices being developed, entailing that some findings of this report might not be as applicable in the future. As a result, this thesis aims not to provide clear right and wrong answers and recommendations, but rather a general framework where practitioners can orient themselves and understand what their roles can be in the dynamic environment today and moving forward.

1.5 Outline

This thesis is structured by a sequenced approach starting with the *Introduction* chapter. This chapter includes a background with a baseline overview, which explains the relevant problems and characteristics of the topic. Following are the Aim, Research Questions, and Delimitations, all of which give further definitions and details of what the research includes. In the second chapter, *Theoretical Frameworks*, relevant concepts, and theories are presented and tied to existing literature and publications. This is to deepen the knowledge and definitions for the reader, clarifying what is most relevant to know. The third chapter, *Methodology* explains which methods were used to find empirical data, in accordance with the aim of the thesis. The methodology further defines the research processes and provides an answer to the question of how the topic is being researched. The fourth chapter, *Results*, provides collected data from interviews, visualized in tables, figures, and texts. This covers what has been discovered concerning each research question. The fifth chapter, *Discussion*, includes a deeper discussion and analysis of the results acquired from the research, combining interview findings with literature. The discussion does not only relate to each research question individually but also synthesizes the relationship between them. Lastly, the *Conclusion* provides a summary of the thesis and related areas uncovered for future research.

2
Theoretical Framework

The Theoretical Framework consists of the existing theories and perspectives mainly described in contemporary research and documentation. The framework includes four main sections, each explaining in detail what findings in research and literature have been discovered up until now. The first section *Sustainable Development and Circularity in the Construction Industry*, establishes the starting point for the main problem, followed by an investigation of the tools and principles within *Supply Chain Management & Construction Logistics.* Then the current theory and development of *Circularity in SCM and Logistics* is covered. Lastly, the *Development and Standards of Digital Tools in Construction* and Logistics provides an overview of the digital landscape in the construction industry.

2.1 Sustainable Development and Circularity in the Construction Industry

The construction industry is experiencing new influences. More actors are pushed towards changing their outdated habits of working due to changes in legislation and on a social level. Many companies are facing an *"adapt-or-die"* situation, where the ones who embrace sustainable development can gain an advantage in the market, while others choose to keep going with the *"business-as-usual"* mentality (Buser & Andersson, 2021). The industry is anticipating more and harder legislation to follow suit to comply with climate neutrality and national sustainability goals, leading to more innovation and initiatives to make breakthroughs in the industry. As of today, there are many ways to approach the problem and no clear path to guide the way, therefore the industry may turn to research to find and share knowledge to increase their chances of survival. Many initiatives are being shaped but are not always able to be up-scaled due to economic restrictions (Lima, 2023).

2.1.1 Climate Impact of the Construction Industry

The immediate threat of Climate Change is shifting the construction industry into innovation and adaptability. On the global scale, the construction sector alone was responsible for a fifth of *greenhouse gas* (GHG) emissions and upwards of a third of the CO2 emissions through 2019 as stated in the buildings chapter of the *Intergovernmental Panel on Climate Change* (IPCC, 2022). In the same report, it was estimated that operational carbon emissions, mainly energy used for heating, contributed 82% of the total CO2, in comparison to the 18% contribution from embodied carbon emissions mainly from the production of raw materials. In Sweden, reducing operational carbon has been the primary focus and has been done successfully partly through the increased use of renewable energy and efficient heating systems (Boverket, 2024a). Despite these efforts, the construction industry remains one of the main sources of GHG emissions in Sweden, lying slightly above the global average at 21.7%. This indicates that the amount of embodied carbon emissions from raw materials has stayed relatively unchanged (Boverket, 2024b).

Sustainability goals in the Construction industry have long been regarded as nice-to-have, rather than a must-have (Parrish, et al., 2014). New sustainable paths are being developed such as the implementation of the EU Taxonomy. This allows for common ground with several regulations and demands, to reach net-zero emissions by 2050 (European Commission 2019). The EU Taxonomy is a facilitator for sustainability, to help investors and companies to make informed decisions, providing a classification system with clear definitions to understand what environmentally sustainable activities are. It is, however, not a rating system or a certification.

In the Swedish construction industry, sustainability has been addressed through legislation of *"Miljödeklarationer för byggnader"* which translates to *"Climate Declarations for buildings"* in English (Boverket 2023). These climate declarations imply that each project needs to account for and display the total emissions from new projects presented in CO2 equivalents. This is typically done by conducting a *Life Cycle Assessment* (LCA) report for each phase of the project lifecycle and displaying the emissions associated with each stage separately. There are currently no demands or thresholds of how large the climate impact of a new project can be in order to receive a building permit. A governmental investigation into this matter is however ongoing and it is expected that the final result and subsequential decision in parliament will lead to stricter regulations in relation to how large emissions from new projects can be, starting in 2027 (Boverket, 2023). The new regulations and thresholds are expected to be introduced in stages with tightened standards being introduced in 2035 and 2043 to remain in line with the national strategy of reaching climate neutrality by 2045.

2.1.2 Circularity

One of the main activities described in the EU Taxonomy is *Circular Economy* (CE). As opposed to a traditional *Linear Economy*, where a resource is produced, used, and disposed of, CE is seen as a regenerative system, where a resource is used throughout several life cycles before eventually being disposed of. According to Geissdoerfer et al. (2017), CE is defined as a regenerative system, in which resources, waste, emission, and energy leakage are minimized by "closing the loop". This can be achieved through prolonging, repairing, reusing, refurbishing, and recycling the resource. The main idea is to replace the current framework system of the 'end-of-life' concept with a waste hierarchy (Kircherr et al., 2017). Several frameworks define the hierarchy of circular principles where the higher up a principle is on the scale, the more desirable it is (Vegter et al. 2020). The 3R model which includes *reduce, reuse, and recycle* is the forerunner of what is later going to become the more elaborate 4R framework, which also includes *energy recovery* (King et al., 2006). The 4R framework is also the core of the EU Waste Framework Directive pyramid model (European Commission, 2008).

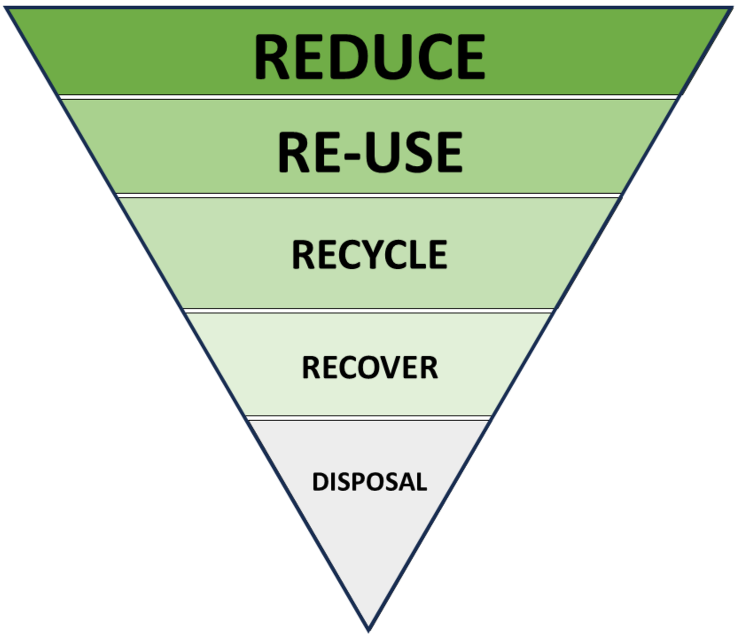

Figure 2.1: *Waste Hierarchy Pyramid, modified from European Commission (2008).*

Another figure that describes the waste hierarchy and the actors involved is the Butterfly Diagram introduced in the report *Towards the Circular Economy Vol. 1,* by the Ellen McArthur Foundation (2013). The butterfly diagram represents two different wings of life cycles. The green wing on the left side represents the biological nutrients, however, these are not included in the scope of this thesis. The blue wing on the right side represents the technical nutrients, also known as the building material products in the case of the construction industry. The reuse hierarchy is described using circles where the smallest circle is the most beneficial, and the largest circle is the least beneficial. *Prolong/repair (reduce)* means that the material is optimally used for as long as possible for the intended purpose. *Reuse (reuse)* is the part where the material is reused in its current form but in a new context. *Refurbish (reuse)* means that the material will need some kind of upgrade or reconditioning to fulfill its requirements. With *recycling (recycle)*, the material is extracted and reshaped into something completely different than it was before. Any material that isn't included in the blue circles will inevitably become a *system loss (recovery/disposal)*, which in other words implies energy recovery or landfill. The linear flow of material would go through the stages of grey arrows without ever being considered included in the blue circles. Whereas a circular flow means that the material is included in the blue circles and is circulating inside the system at least more than once (Ellen McArthur Foundation 2013).

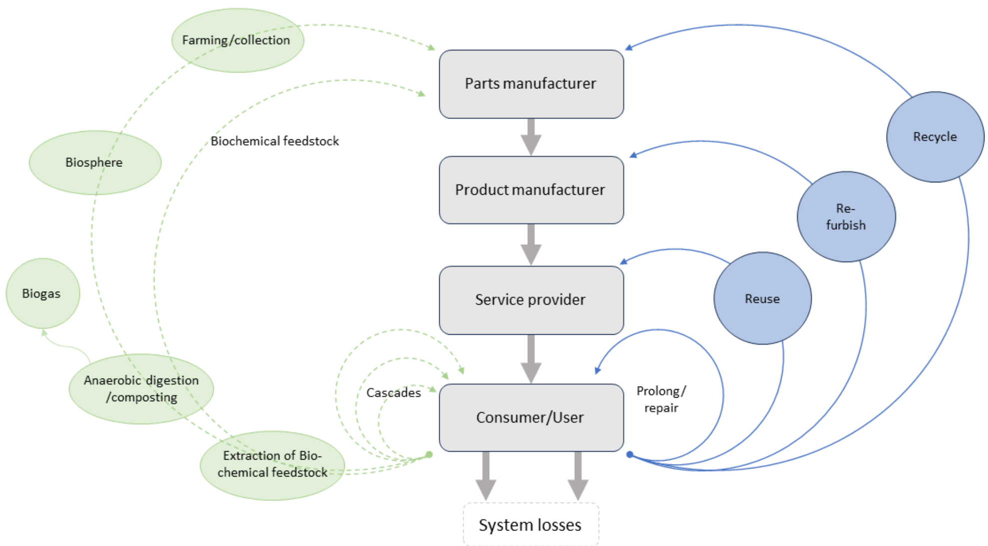

Figure 2.2: *Butterfly Diagram, modified from Ellen McArthur Foundation (2013).*

As a continuation of the butterfly diagram, researchers Achterberg, Hinfelaar, and Bocken, (2016) have elaborated on this theory and suggested a concept of retaining value in the circular economy chain. This is presented by the Value Hill concept, comparing the traditional LE with CE. It is described using a hill where the user stands on top, displaying that the most value of the material or product is achieved. The activities on the left side are adding value to each step. While the right side displays the decline in value. By adopting a circular approach, some value can still be retained if handled accordingly. This essentially means that most value can be retained if it is decided that the material or product is handled early on during the post-use phase. Or ideally, prolong the material through maintenance and repairs.

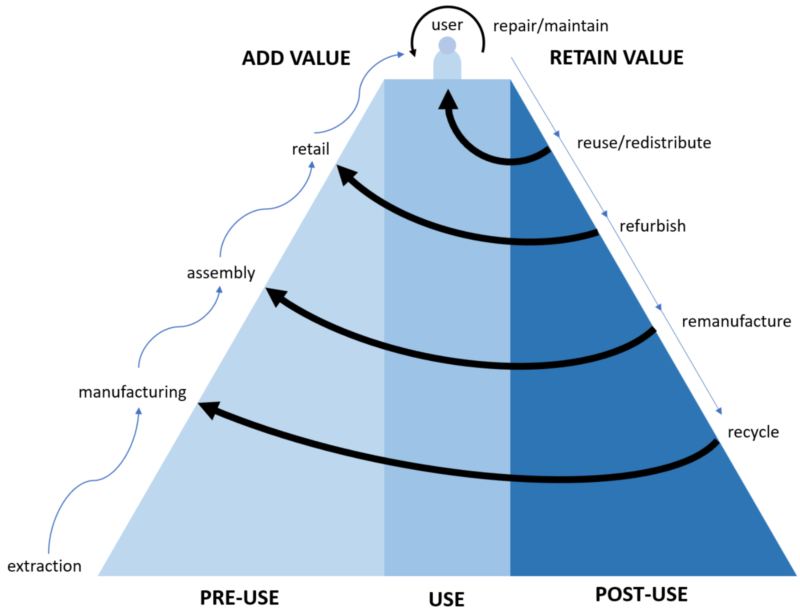

Figure 2.3: *Value Hill of Circular Economy model, modified from Achterberg et al. (2016).*

2.1.3 Circularity in Construction

To summarize how this applies to construction, circularity in construction essentially means that materials and products are firstly prolonged by maintenance and repairs. If this is not possible, they will be recovered through careful dismantling, reconditioned if needed, and then re-applied in another construction project. This leads to a decrease in waste and use of raw material resources, which in extension reduces overall climate impact (Zhang et al., 2022). According to Wennesjö et al., (2021) at IVL (The Swedish Environmental Research Institute), over a fifth of construction projects in Sweden have great potential to incorporate reused products and materials. This further shows that the reuse of existing construction materials is a viable option for incorporating CE and thereby increasing sustainability in the construction sector. The same report by IVL further estimated that the market for reusable products and services in the Gothenburg region, is 14.6 billion SEK, stating that there is good reason to invest and implement activities to achieve a market for reuse on a large scale. However, there are several barriers tied to this. One of the main barriers is believed to be the business models (Wennesjö et al., 2021). There are no current frameworks sophisticated enough to address reuse in a holistic way. Wennesjö et al. (2021) further argue that the flow of materials needs to be increased to stimulate the market and create incentives for up-scaling. This is confirmed by Charef et al., (2021), adding that there is an abundance of additional barriers tied to the construction sector due to its irregularity of contents depending on building type, location, project management, organizational structure, building regulations, and material usage among others, suggesting a high level of complexity hindering the integration of circular initiatives.

2.2 Supply Chain Management & Construction Logistics

The term Supply Chain Management (SCM) saw rise in the early 1980s as actors throughout many industries recognized that intra- and inter-firm collaboration and control were a key resource in dynamic and increasingly globalized market environments (Christopher, 2011). Individual firms no longer competed as autonomous entities but rather as links in more complex and widespread chains, and their success started depending more on management's ability to integrate business processes into the surrounding supply chain network (Lambert & Cooper, 2000). Moreover, Vrijhoef & Koskela (2000) highlight that the introduction of SCM largely coincided with the emergence of new production strategies like lean and just-in-time (JIT). These strategies are closely connected with SCM principles and represent a flow view of production compared to the more traditionalist *transformation view.*

There are different ways of defining what SCM is. Some scholars describe SCM in operational terms involving processes that enable flows of products and materials, some view it as a management philosophy, and some as a process for implementing a management philosophy (Mentzer et al., 2001). Hobbs (1996) elaborates on this describing how SCM is an interdisciplinary field encompassing areas such as marketing, economics, logistics, and organizational behavior while Christopher (2011) describes it as *"The management of upstream and downstream relationships with suppliers and customers in order to deliver superior customer value at less cost to the supply chain as a whole".*

A more comprehensive definition is provided by Lambert & Cooper (2000) stating that "SCM is the integration of key business processes from end user through original suppliers that provides products, services, and information that add value for customers and other stakeholders". While the details of what is included in the definition of SCM might vary there is a wide consensus among scholars that the supply chain should be viewed as a network of actors rather than a linear chain. This system-based understanding is described as paramount to grasp the dynamic environment of modern-day industrial landscapes where developing technology, processes, and regulations present both challenges and opportunities to actors within supply chain networks (Akkermans & Dellaert, 2005; Christopher, 2011). Further, Larson & Halldorsson (2004) argue that SCM is built on successfully managing relationships where positive synergistic effects are created through network links when focus is not only put on individual system components but also on how they relate to each other.

2.2.1 Supply Chain Management

Lambert & Cooper (2000) present a framework for successful SCM consisting of three closely interrelated elements: supply chain *business processes*, *network structure*, and *management components*.

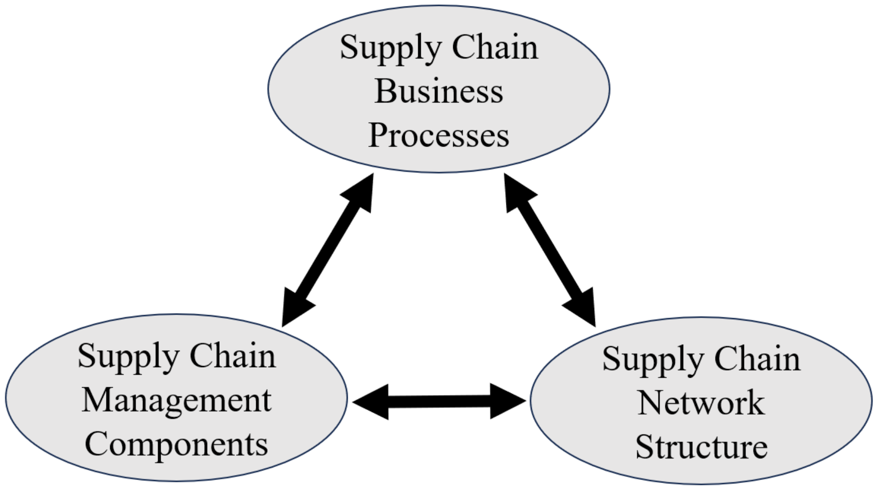

Figure 2.4: *SCM Framework, modified from Lambert & Cooper (2000).*

All organizations are part of at least one supply chain, and most are part of several. The network structure of the chains is made up of the *members of the supply chain*, the *structural dimensions of the network*, and the different types of *process links across the supply chain* (Lambert & Cooper, 2000). Which of the supply chains that are possible to integrate and thus should be managed is a fundamental challenge within SCM. Christopher (2011) highlights the length of the supply chain, the complexity of the product in question, and the number of suppliers available as some of the most fundamental aspects to consider while determining the degree of integration needed in any given situation. Lambert & Cooper (2000) further add that not all links throughout a supply chain need to be integrated and managed, arguing that the most appropriate degree of SCM is highly situational and dependent on unique circumstances.

Business processes start with the identification of and focus on, end customers. Then how the information will flow and be used and finally how the practice will be adjusted based on new information (Lambert & Cooper, 2000). The end goal is to satisfy the end user in a way that is beneficial to all involved actors by streamlining the processes of the supply chain network. In order for this to work efficiently, a process approach is needed. Further, business process links need to be differentiated to distinguish and define which ones are the most important to successfully deliver value in an optimal way.

Planning and control of operations is described as a transcendent management component in SCM. Other components change during different stages of a supply chain´s lifecycle but there is always an underlying strategic component that steers them in a desired direction (Lambert & Cooper, 2000). The intra- and inter-firm work structure governs the level of integration of supply chain processes and enables organizations to shift focus between different areas of the supply chain network as needs present themselves. As most supply chains involve some type of industrial manufacturing, governing the flow of products and information to and from production facilities are also central SCM management components, especially if the product is complex and many actors are involved along the supply chain (Christopher, 2011). Finally, more classical themes like management methods, leadership structure, culture, and attitude are highlighted for their importance as components that can have a large effect on SCM performance (Lambert & Cooper, 2000).

Logistics is closely related to SCM but similarly to the definition of SCM, there are different understandings of how this relationship is constructed. Larson & Halldorsson (2004) present four different interpretations of how the terms interrelate. The *traditionalist* approach views SCM as an integrated part of logistics, similar to the findings of Lambert & Stock (1998) who labeled SCM as *"logistics outside the firm"*, reducing it to the logistics activities that involve inter-firm collaboration with other actors in the supply chain network. According to Larson & Halldorsson (2004), the *relabeling* perspective stems from the ambiguity that arose when the term SCM was introduced. Because of the perceived similarities, industrial actors started using SCM and logistics interchangeably thus giving rise to the relabelling perspective. Contrary to the traditionalist approach, the *unionist* perspective views logistics as part of SCM. This approach mainly stems from a view of SCM as an interdisciplinary field that subsumes and draws on several other fields including logistics, marketing, sales, R&D, forecasting, production, purchasing, information systems, finance, and customer service (Mentzer et al., 2001). *Intersectionist* is similar to unionist but differs in the fundamental view of SCM. Instead of subsuming logistics and other fields, it is described as a broad strategy that cuts across business processes containing strategic and integrative elements from these processes (Giunipero & Brand, 1996).

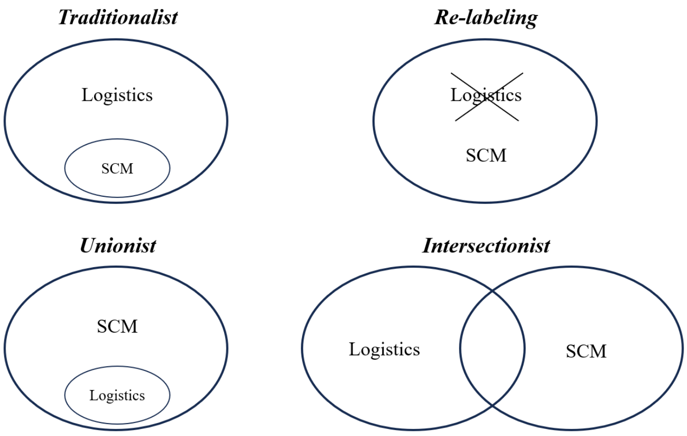

Figure 2.5: *SCM Perspectives, modified from Larson & Halldorsson (2004).*

The Council of Logistics Management (CLM) has defined logistics as *"that part of the supply chain process that plans, implements, and controls the efficient, effective flow and storage of goods, services, and related information from the point of origin to the point of consumption in order to meet customers"* (Lambert & Cooper, 2000). By that definition it becomes clear that a unionist or intersectionist perspective on SCM versus logistics seems to dominate the discourse in both literature and practice which is also supported by more recent work on the subject e.g. Abrahamsson et al. (2019).

Logistics processes can be divided into two types, forward and reverse logistics, (FL & RL). FL refers to the traditional linear flow of goods and materials from the point of origin to the point of consumption (Bowersox et al., 2020). The primary focus of FL is on delivering products to customers in a timely and cost-effective manner to meet their requirements. In contrast, RL involves the movement of goods from the customer back to the manufacturer or distributor and serves the purpose of recapturing value (Stock & Mulki, 2009). Activities can include product returns, repairs, remanufacturing, recycling, and proper disposal (Pokharel & Mutha, 2009). The key difference between FL and RL is the direction of the product flow as FL moves goods from supplier to customer, while RL moves goods from the customer back to the supplier or manufacturer (Jayaraman & Luo, 2007). Effective management of both forward and reverse logistics processes is crucial for organizations to optimize their supply chain efficiency and customer satisfaction.

2.2.2 Construction Logistics

The traditional construction project lifecycle encompasses several stages from conception, planning, designing, and procuring to production and management of the finished building. During the production phase, the construction site becomes a temporary production plant where numerous disciplines converge and engage in widespread activities that contribute to the final result (Sullivan et al., 2010). Construction logistics concerns planning, organization, coordination, and control of the materials flow from the extraction of raw materials to the incorporation into the finished building and can be seen as a part of the larger construction supply chain network (Sullivan et al., 2010). Goyal et al. (2022) explain that the goal and spirit of logistical activities are to achieve a number of rights in relation to product, quality/condition, quantity, time, and place.

Despite many similarities, the construction industry has several unique attributes that brings on both challenges and opportunities in relation to SCM and logistics in other industries. Sullivan et al. (2010) exemplify this by comparing how other production industries like car manufacturing have large, dedicated plants that are meticulously planned to support an ongoing flow of parts coming in and products going out. In comparison, every construction project can be seen as a production plant that is temporarily installed on often disadvantageous sites with limited space for materials handling and deliveries. The temporary nature of projects is furthermore not seen to warrant rigorous and optimized logistical solutions since the focus lies on the project being built and everything around it being dismantled in a short timeframe (Sullivan et al., 2010).

Another aspect that distinguishes the construction industry from other industries is the involvement of the client throughout the project development (Winch, 2003). The client is the owner and financer of a project and can sometimes be the same as the contractor building but mostly it is an external either public or private real estate developer that's been responsible for the idea and initial stages before production starts. According to Challender & Whitaker (2019), the client is a central figure that plays a substantial role in the successful end result of a project. Especially the ability to govern and place demands on the project is described as having a large impact on the attention directed to logistics (Sullivan et al., 2010). Vrijhoef and Koskela (2000) highlight that the clients can also assume the role of the main developers of new SCM principles and techniques as they are the main providers of funds to the industry and thus can place demands on how projects are governed and carried out.

According to Bosch et al. (2023), construction logistics encompass the construction site, the supply chain, and the crucial interface between them. Dubois et al. (2019) identify three main configurations that construction firms can adopt to organize their logistics and transport activities: The project-based configuration is the most common approach, where logistics and transport are managed independently for each individual construction project. This decentralized, project-focused approach allows for flexibility in adapting to the specific requirements of each job site. How-

ever, it also results in limited coordination and integration between projects, leading to potential inefficiencies and higher costs. The lack of a broader, supply chain perspective can make it difficult to leverage economies of scale or optimize material flows across the organization.
In contrast, the supply-based configuration shifts the focus to the supply side, with logistics providers and suppliers playing a more central role in coordinating transport and warehousing activities (Dubois et al., 2019). This approach can improve the reliability and efficiency of material deliveries, as suppliers are better positioned to manage the logistics and ensure timely availability of resources. The downside is that this configuration may reduce the construction firm's direct control over logistics decisions, and there could be challenges in aligning the objectives of different supply chain partners.

The integrated configuration represents a more holistic, centralized approach to logistics and transport management in construction (Dubois et al., 2019). By coordinating activities across multiple projects and integrating with the broader supply chain, this configuration can lead to increased efficiency, cost savings, and improved overall supply chain performance. The integration of planning shared resources, and collaborative decision-making can help construction firms optimize material flows and reduce waste. However, implementing this approach may require a higher level of organizational capability and investment in technology and information-sharing systems.

The choice of configuration should be based on the specific characteristics and requirements of the construction projects, as well as the maturity and capabilities of the construction supply chain. Firms may also need to adapt their approach over time as their projects and supply chain relationships evolve. Regardless of the configuration, effective logistics and transport management are described as a critical success factor in the construction industry (Dubois et al., 2019).

Sullivan et al. (2010) describe that logistics often becomes an afterthought in construction, leading to an underdeveloped and inefficient state of traditional construction logistics in large need of improvement. Current logistics practice is often unsafe, uncoordinated, and ad-hoc as sites get crammed with activity, tradesmen have to look for material instead of working, and the material is damaged. This is described as one of the main reasons why the construction industry as a whole suffers from low productivity. Ekeskär and Rudberg (2016) further exhibit this issue, explaining that workers spend 30% of their time waiting and 20% of their time moving materials and equipment to the right place. Additionally, less than 40% of examined deliveries were completed without damage and at the right time.

Together with the aforementioned differences between construction and other production industries with integrated logistics and SCM processes, there are also cultural barriers to a more integrated logistics approach. Sullivan et al. (2010) describe that the industry has traditionally been resistant to change, with a conservative culture that favors established approaches over innovative methods, creating a significant barrier to implementing integrated logistics practices. The fragmented nature of the industry, with many small and medium-sized enterprises involved, creates challenges in coordinating a shared vision and approach to logistics management. Furthermore, the construction industry's reliance on implicit knowledge rather than formal documentation also hinders the adoption of integrated logistics, as there is no cohesive framework to guide all stakeholders (Sullivan et al., 2010).

Uncertainty around accurately predicting material flows and pricing logistics involvement makes contractors reluctant to implement radical changes, as they fear significant cost increases and clients often believe that project costs already account for appropriate logistics (Sullivan et al., 2010). Additionally, the construction industry's strong focus on short-term cost-cutting, rather than long-term value creation, discourages investments in innovative logistics solutions that may have higher upfront costs but greater long-term benefits (Aloini et al., 2012).

Despite the presented cultural and practical barriers presented, Sullivan et al. (2010) highlight that a more dedicated approach to logistics is gaining traction in the industry and could serve as a much-needed solution to the problems related to productivity faced by the industry with a reduction in waste, waiting time, and cost (Ekeskär & Rudberg, 2016). Furthermore, Abrahamsson et al. (2019) find that the implementation of integrated construction logistics strategies can improve efficiency by 25-30% and reduce transportation by 60-80 %.

The dedicated approach started with the idea of freeing up time for skilled construction workers to not have to spend time on things non-construction, such as carrying material and handling waste (Sullivan et al., 2010). This method soon proved to not only free up time for workers but also to improve health and safety as well as reducing waste. Applying this type of approach is, depending on the size of the project, done by using a team of logistics specialists that are there to provide a holistic support service for the entire project.

The construction industry has traditionally relied on in-house logistics management, with contractors and subcontractors responsible for their own material procurement and delivery to the site (Sullivan et al., 2010). However, the increasing complexity of construction projects, coupled with the industry's resistance to change, has led to the emergence of third-party logistics (TPL) providers as a means of improving logistics efficiency. TPL providers offer specialized expertise and resources that can complement the construction firms' core competencies (Aloini et al., 2012). By outsourcing logistics functions to these external partners, construction companies can leverage economies of scale, access advanced technologies, and benefit from the TPLs' experience in optimizing material flows and supply chain coordination (Janné & Rudberg, 2022). This shift towards the utilization of TPL services represents an important evolution in the construction industry's approach to logistics management and is one of the fundamental differences between traditional and dedicated approaches. The integration of TPL providers into the construction supply chain has the potential to address many of the cultural and operational barriers that have traditionally hindered the adoption of more effective logistics practices (Sullivan et al., 2010).

2.2.2.1 Construction Consolidation Center

Another significant development in construction logistics has been the establishment of construction consolidation centers (CCCs). These off-site facilities serve as hubs for receiving, storing, and distributing materials to construction sites, often using just-in-time delivery strategies (Sullivan et al., 2010). The implementation of CCCs also represents a shift away from the traditional, fragmented approach to material management, where multiple suppliers deliver directly to the construction site. The benefits of CCCs include reduced vehicle movements, improved material visibility and control, and better coordination of deliveries, all of which can lead to increased productivity, reduced costs, and enhanced sustainability (Sullivan et al., 2010: Guerlain et al., 2019). By centralizing logistics activities and optimizing material flows, CCCs help construction firms overcome the cultural and operational challenges that have historically hindered the implementation of integrated logistics practices.

The benefits of a more dedicated approach to logistics and in particular CCCs in reducing construction waste are well-documented as for example Lundesjo (2009) demonstrated the ability of CCCs to divert up to 84% of waste away from landfills. Through the centralization of logistics activities and the optimization of material flows, Construction Consolidation Centers (CCCs) can significantly reduce waste creation in several ways.

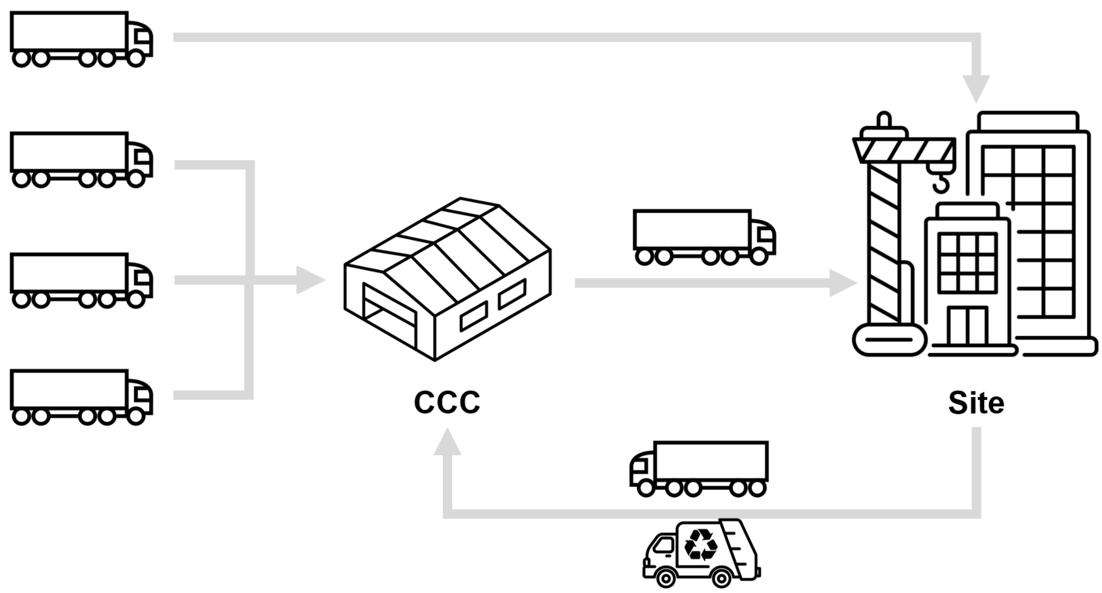

Figure 2.6: *Construction Consolidation Center (CCC) concept including reverse logistics, modified from Muerza & Guerlain (2021).*

First, by delivering materials in work packs designated for specific areas of the building, CCCs can minimize the amount of waste generated from unused materials and excessive packaging (Sullivan et al., 2010). Second, CCCs can house a dedicated, specialized team to manage the segregation and reclamation of waste materials, allowing for the reuse of surplus items rather than sending them to landfills (Sullivan et al., 2010). Third, the centralized control and visibility of materials afforded by CCCs can help construction firms reduce over-ordering and the associated waste from damaged or unused items (Sullivan et al., 2010). Finally, CCCs can provide a central collection point for refuse contractors, preventing delivery vehicles from returning to the site empty and reducing overall congestion and emissions (Sullivan et al., 2010).

The author's own involvement in a project that achieved a 99.24% reduction of waste to landfills further demonstrates the transformative potential of CCCs in addressing the construction industry's waste management challenges (Sullivan et al., 2010). The implementation of CCCs is not without its challenges, as the integration of these logistics hubs into the construction supply chain requires a holistic change in the industry's approach. However, the compelling evidence of their ability to divert waste from landfills and enhance the overall efficiency of material management makes a strong case for their wider adoption (Lundesjo, 2009; Sullivan et al., 2010).

2.3 Circularity in SCM and Logistics

The drive towards improved sustainability has become a top priority for companies across all industries, with a focus on reducing climate impact and increasing circularity in business models and supply chains. For a business model to be truly sustainable it must be profitable while being in accordance with existing laws and regulations (Kossila, 2021). This can be further connected to the triple bottom line as a circular business model in itself is not sustainable if it is not financially, ecologically, and socially sustainable which is described as a challenge for industrial actors.

As organizations look to implement more circular strategies, the underlying SCM and logistics functions play a critical role in enabling the transition. Kossila (2022) describes how SCM serves as the governing mechanism for a company's interactions with its broader network of firms and stakeholders, making it an integral part of executing circular initiatives. One key aspect of circularity in SCM is producer responsibility, where manufacturers are responsible for ensuring the return and recycling of their products at the end of their useful life. This can be voluntary or mandated by legislation, as seen in Sweden with regulations around items like tires, batteries, and pharmaceuticals, as well as mandatory by the trade organization Golvbranschen, which coordinates the circulations of plastic carpets. By incentivizing producers to design more circular products and packaging, these systems help drive higher levels of material recovery and recycling.

Beyond just product take-back, circularity in SCM also requires rethinking the marketing and logistics of circular materials. Kossila (2021) proposes an extension of the traditional 4Ps of marketing (Price, Product, Place, Promotion) to include "pre-product" and "post-use" considerations, underscoring the need to holistically plan for a product's entire lifecycle. Traceability is also critical to avoid greenwashing and ensure the integrity of circular claims (Kossila, 2021; BEAst, 2023). Technologies like the BEAst platform can play a key role in enhancing transparency and traceability across construction supply chains.

Remanufacturing, or *"factory renovation"*, is another important circular logistics strategy that can preserve product value by refurbishing and reusing components, often at a lower energy and material cost than producing new items (Kossila, 2022). While applicable across industries, this approach may hold particular promise for the construction sector, where it could help extend the lifespan of building materials and components. Effective storage and inventory management are also crucial in circular supply chains, which must accommodate a wider range of material flows beyond just raw materials, components, and finished goods - including pre-owned products and sorted waste streams. Careful management of these diverse inventory types is needed to balance storage costs and ensure materials are available when needed for reuse or remanufacturing (Kossila, 2022). Ultimately, realizing the full potential of circularity in SCM and logistics requires a holistic, collaborative approach across the value chain. Public sector procurement, guided by frameworks like the EU's Green Public Procurement (GPP) initiative, can play a key role in driving market demand for circular solutions (Kossila, 2021; Upphandlingsmyndigheten, 2023).

2.3.1 Circularity in Construction Logistics

According to Wennesjö et al. (2021), there is a gap connected to the physical flow of reusable materials in construction. Construction logistics is referred to as the bottleneck of circularity because the physical flows themselves need to be organized sustainably. This means that the potential reduction of the climate impact of reusing the material also needs to outweigh the increased climate impact of handling the material, for example by the increased number of transports (Bosch et al., 2023). The implementation of efficient construction logistics is necessary to achieve this in practice (Wennesjö et al., 2021). A previous study by Abrahamsson et al. (2019), concluded that consolidation and terminal solutions can decrease the number of deliveries to construction sites by up to 80 %. This indicates that similar solutions facilitating reused materials may see a similar effect. However, there is a wide knowledge gap between the effects of construction logistics and circularity in the industry, which makes actors cautious about investing in new business models and trying to implement circular practices (Bosch et al., 2023).

2.3.2 Drivers and Barriers for Circular Construction Logistics

The following drivers and barriers for circular construction logistics have been found by Bosch et al. (2023) and are presented with the following main categories.

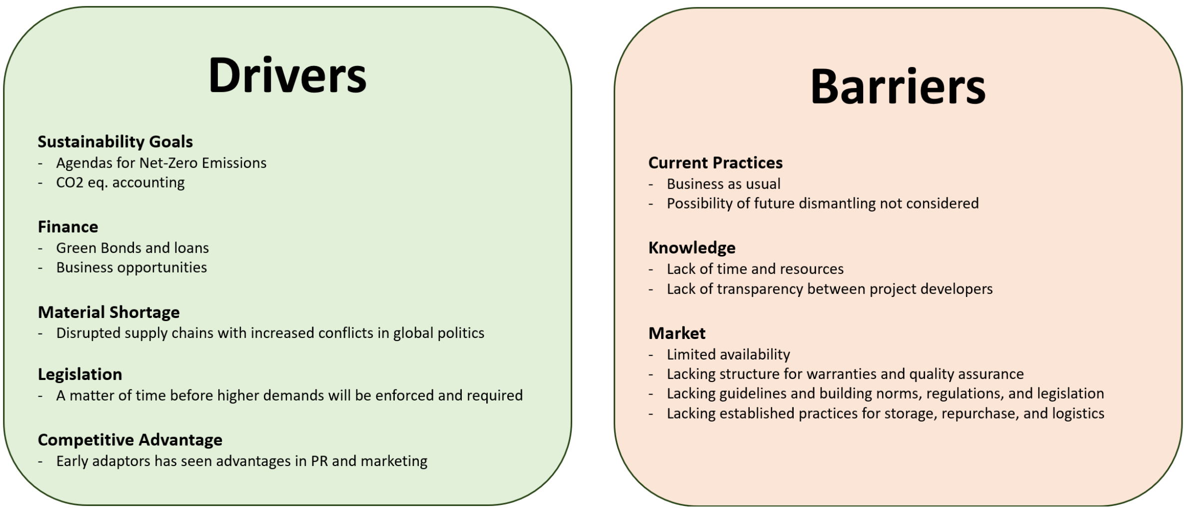

Figure 2.7: *Drivers and Barriers in Circular Material Flows, modified from Bosch et al. (2023).*

It is recurrently proposed in the literature that the Sustainability goals and agendas would be the main drivers for CMF to be considered (Bosch et al., 2023). However, more examples of financial gain have been discovered in cases where a similar supply and demand have correlated, creating new business opportunities. This, in combination with higher costs for waste disposal, has started making it financially viable to reuse certain materials and building parts of buildings. As a result of the global disruption of supply chains, more organizations have started considering resilience and longevity more important. To implement more reused materials means to directly decrease the need for extraction of new raw materials and skip complex supply chains, while simultaneously saving not only climate resources but also time for the company itself. Some organizations also see a competitive advantage through profiling and embracing circular practices, gaining traction and new opportunities as a result.

The main barrier and challenge presented for CMF in construction is the overall mentality of the construction industry at large, not being used to the idea of saving resources and reusing them (Bosch et al., 2023). The consumption of new materials has, however, been predominant for over 50 years. Before then reuse was arguably considered more natural and necessary, due to the limited supplies of construction materials and costly upkeep using new materials. The way the construction industry is working aims to conclude the building process with a structure and function that is long-lasting and desirable, however, it is not usually constructed with the consideration of future dismantling and disassembly, to renew itself or find new solutions for the tenants' changing needs (Bosch et al., 2023). Another commonly referred challenge with CMF is the lack of knowledge in the industry, not simply knowing how to work with this in a time-efficient and valuable manner. This in turn makes the market for reused products somewhat limited and hard to expand. Lacking standards and guidelines of warranties, building norms, and logistics among others, are currently hindering the upscale of CMF to achieve its potential effects.

2.3.3 Four Scenarios of Circular Material Flows

For the organization of CMF in construction Bosch et al. (2023) presented four logistics scenarios, created to understand what requirements and opportunities different types of projects have to achieve circularity. Each scenario adds a layer of complexity and provides a good framework for the discussion of circular logistics.

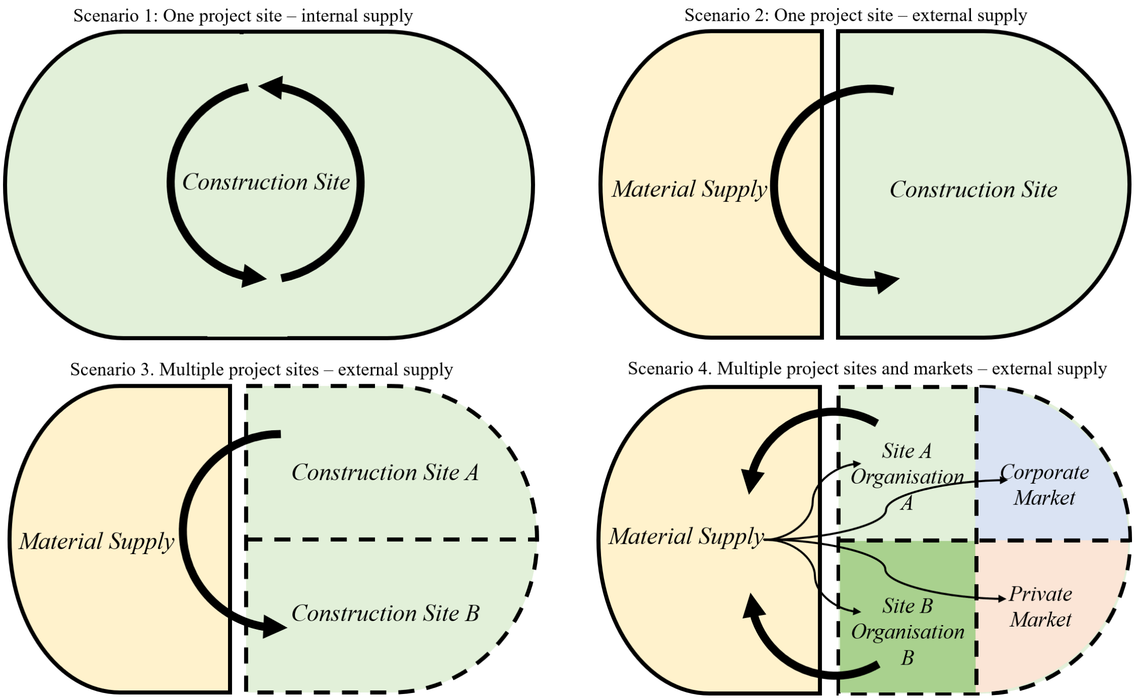

Figure 2.8: *The Four Logistics Scenarios for CMF, Modified from Bosch et al. (2023).*

Scenarios 1 and 2 focus on reusing materials internally in the same construction project. The only difference is that in scenario 1 the material is retrieved on-site and can be reused in its current condition. In scenario 2, the reusable material needs to leave the construction site to be reconditioned, stored, quality tested, etcetera. In scenario 3 the reusable material has to leave the original construction site, entering the material supply, to later be implemented in a new project, in this scenario the same organization is managing both construction sites. In scenario 4 things become a bit more complex, the precondition is the same as scenario 3, with a material being required to leave its original site and enter the material supply. However, unlike scenario 3, scenario 4 can implement the reusable materials into a new construction site, managed by a different company. In scenario 4 the reusable materials could also potentially end up in a secondary market, either a corporate market where other companies buy the reused material as a reused product, or it may even be sold to the private market. The study concludes that all of these scenarios have the potential to combine construction logistics for reused materials with construction logistics for newly produced materials that are not reused, making it realistically viable to combine transportation for both types of materials to reuse a larger percentage of construction materials (Bosch et al., 2023).

2.3.4 Gap-exploiter in Circular Construction

Kossila (2022) argues that upscaling and encouraging circular practices require more than one user to have sequential possession of a product, meaning that there is a role to be filled to fully retain the value of the product (i.e. capitalizing on the value hill framework). Such a role can be filled by a Gap Exploiter, who retains value by offering a service of refurbishment, redistribution, or similar. This exploiter is by definition an independent actor who is not responsible for the original product but chooses to engage with it in order to find a viable business model. Essentially the Gap Exploiter is a facilitator that provides a niche service or business. In the aspect of circular construction, such a facilitator or mediator could be an actor that provides logistic services for reused materials, to be used, refurbished, and sold again to the same or a new user. By increasing the value of a used product through refurbishment, there is potential to circulate the product back into use, as an alternative to becoming waste (Kossila 2022).

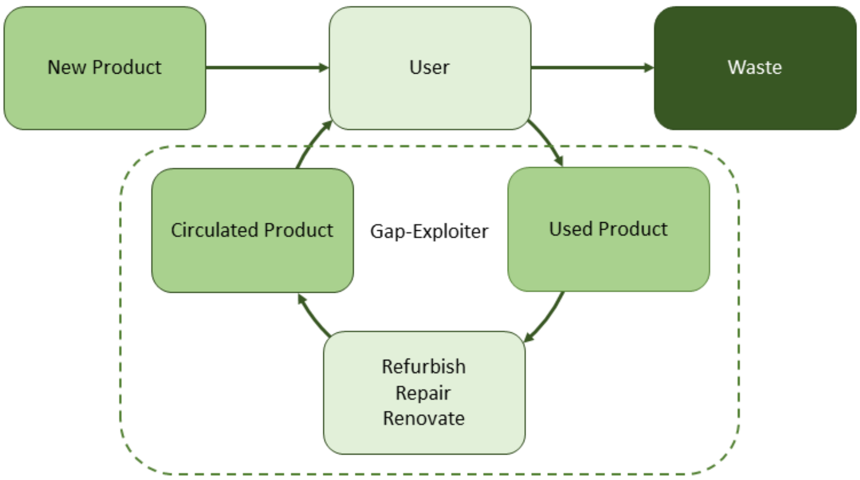

Figure 2.9: *Gap Exploiter model, modified from Kossila (2022).*

2.4 Development and Standards of Digital Tools in Construction

The development of digitalization in construction has long been criticized for lagging behind other related industries. Slowly but surely, this is being addressed and several initiatives and standards have been developed in search of efficient workflows and practices. One example of efficient implementation of digital tools in construction projects is the introduction of Computer Aided Drawing (CAD) and Building Information Model (BIM). These are specialized in project design and development but are not always adopted and utilized in the actual building processes of the physical building (Singh et al., 2011). Despite this, a shift has been observed in the recent decade. Both the introduction of digital twins and the adoption of specialized tools for logistics have been added to the toolbox. These tools have largely been adapted from traditional digital tools for logistics in the automotive and product production industries. These are currently being developed and adapted to better facilitate and address the logistical challenges in construction (Lee & Lee 2021). According to Bosch et al. (2023), there is a need for development and innovation within the field of construction logistics to achieve improved circularity. This includes methods and competence for handling and packaging retrieved material. Digital logistic solutions are described as central to reliably and efficiently identifying, tracing, and handling inventory balance of reused materials. There is a possibility to develop solutions at various levels from single materials to system-encompassing initiatives. These systems are crucial to both individual actors but also for system-wide control and coordination in the network. It is also desired that these systems can be integrated with internal purchasing portals to enable reused material in the same places as new (Bosch et al. 2023). Apart from Bosch et al. (2023), the research field of digitalization of construction logistics in relation to circularity is underwhelming, hence the focus of this thesis.

2.4.1 Digital Standards for Construction in Sweden

A recurring issue within the industry is the low level of digital maturity when compared to similar industries. To drive the implementation of digital communication and working standards in construction, an initiative based on the Peppol Directive, called BEAst (Swedish: Branschens Elektroniska Affärsstandard) has been introduced in Sweden. This standard aims to "increase efficiency and simplify construction logistics, lower costs for all parties, shorten lead times, and minimize the number of errors". The BEAst initiative contains several types of digital standards for different areas of the construction industry, such as BEAst BIM, BEAst Supply, and BEAst Label. These provide a framework and suggest digital workflows for more efficiency. BEAst provides support and promotes utilizing digital tools and services during the construction process. In addition, BEAst also provides guidelines for contract creation including how to include digital standards in the procurement process.

3 Methodology

This chapter describes the methodology chosen for the thesis, along with why and how the research was conducted. In section 3.1 the overall research process is set up and overviewed. The following section 3.2 describes the interview procedure and collection of empirical data in detail. In section 3.3 the method for data analysis is described and discussed. Lastly, the limitations, ethics, and sustainability aspects of the method will be addressed and reflected upon in section 3.4.

3.1 Research Process

This thesis was conducted with an abductive approach focusing on contributing to theory and continuing into practice. This approach is referred to as a process in which the researcher is consistently shifting between the collecting of data and verification with literature or additional sources (Dubois & Gadde, 2002). This approach was seen as beneficial throughout the thesis due to the knowledge gap in the theory regarding combining construction logistics and circular construction practices, suggesting that this thesis may be quite explorative. In addition to the flexible abductive approach, the process was intentionally also shifting between the inductive and deductive approaches as a result of the different nature of the research questions addressed in this thesis. Initially, an inductive approach was used to understand the current landscape of the existing digital platforms dedicated to logistics tied to RQ2, mapping their functionality and other considerations without any presumptions of what was readily available. Throughout this process, it was later discovered that additional platforms, other than traditional DLPs, can contribute to circularity in construction logistics. These were then differentiated into semi-logistic platforms due to the characteristic of specifically catering to one or a maximum of two of the identified logistics activities. Once the digital platforms and their functions were mapped and a framework had been developed, based on the findings of Bosch et al. (2023), a deductive approach was used to pinpoint the needs of the Swedish construction industry, in relation to the existing landscape of both construction logistics and circularity as formulated in RQ3. Here the authors had an idea of what to expect due to contemporary challenges of sustainability in construction and previous notations about the issues of reusing construction materials. By adopting this double-coined approach, the authors gained knowledge of RQ1 simultaneously, adding to the existing literature by gradually confirming parts of the previous research with our findings, combining it with our findings regarding the aspects of logistics.

This methodology is coherently a qualitative research process in which the empirical data is provided in verbal descriptions and observations of interview respondents. In contrast to a quantitative research process, in which numbers, statistics, or calculations are typically mainly considered for the collection of data (Bell et al., 2022).

3.2 Interview Study

In the lack of existing literature and information regarding the chosen research questions, a qualitative research approach was chosen, focusing on conducting many interviews with a wide net of professionals representing different branches of the construction industry. As these interviews are the foundation of the data collected, several individuals in similar roles were chosen to gain wider recognition of the topics addressed, as well as minimize the issue of personal opinions and agendas. Furthermore, existing literature linked to the research questions was studied to better understand the answers of the respondents and connect these.

The interview candidates were picked for their professional involvement in either circularity, logistics, or digitalization within profiled Swedish organizations or professional backgrounds. Either profiled towards circularity or due to the influence internally in their respective organizations. Mostly the two were combined. This was because the authors wanted to consider actors who are already involved in the circular movement in the Swedish construction industry, to get their view of the present and the future. The main target was individuals with significant expertise confirmed by their work and outspoken relevance. The number of interviews was balanced between a need for many perspectives combined with a lack of time and resources. No group of respondents was less than two different people from two different companies, to ensure a diverse and trustworthy image of each professional area.

An Interview Guideline (Appendix A) was developed consisting of mainly of semi-structured and open-ended questions. The opening of each interview consisted of a streamlined structure with initial general and administrative questions, followed by a specialized middle part towards their participation of circularity and logistics, but specifically tailored to the branch of the respondent, e.g. architect, contractor, or developer. Lastly, some wider questions were asked about the state of the industry and what it requires to scale up its contribution towards a circular economy. The questions were largely semi-structured and designed to be open-ended, inviting for discussion and reflection in the interviews. To counteract the discontinuation of a certain question, follow-up questions were occasionally used mindfully to clarify statements, discuss the topic deeper, or engage the respondent to address the question that was being posed. All interviews were recorded either by computer or dictaphone and transcribed in full. Each transcript was then individually categorized into columns of questions, answers, and summaries. Which in turn was uploaded and coded in the qualitative research software NVivo.

The first stage of interviews focused mostly on collecting evidence to understand and get a grasp of the current landscape of Digital Platforms and collect expertise. For this, several sustainability consultants, researchers, and digital tool providers were interviewed. This was to achieve an initial foundation and validation of the theory and draft the actual mapping of the digital tools readily available in the industry. In the second stage of interviews, the authors focused more on architects and supply distributors to gain insight into the needs and hindrances they perceive in working with circularity. The third round of interviews focused on property owners, developers, and so-called gap-exploiters, this was to finalize the data collection with the discussion of what can be done and examples of what is currently being done to incentivize the use of digital and sustainable practices. Lastly, contractors in construction and dismantling were interviewed to better understand the physical issues and viability of dismantling and incorporating reused materials in new construction and how to enhance these processes using efficient construction logistics. In total, 30 respondents were interviewed across 7 different branches of the construction industry, representing 29 unique organizations. The interviews were usually conducted in an online meeting setting using Microsoft Teams; however, four interviews were conducted in an office setting and one of the interviews was conducted using email correspondence due to lack of availability.

Label	Company	Role	Date	Type
A. Consultants:				
A1	Bauburo In Situ & Zirkular	Senior Architect	2024-03-15	Teams
A2.A	AFRY	Sustainability Consultant	2024-03-01	Office
A2.B	AFRY	Sustainability Consultant	2024-04-08	Teams
A3	White Arkitekter	Sustainability Specialist	2024-03-21	Office
A4	Tengbom	Regional Manager	2024-03-25	Office
A5	WSP	Project Manager	2024-04-03	Email
B. Research Institutes:				
B1	Linköping University	Adjunct Professor	2024-02-20	Teams
B2	Linköping University	Assistant Professor	2024-03-19	Teams
C. Construction Companies:				
C1	PEAB & BEAst	Logistics Director	2024-03-01	Teams
C2	Kålltorps Bygg	QEHS	2024-04-26	Teams
C3	JM	Logistics Director	2024-04-11	Teams
C4	Normans	Contracting Manager	2024-04-08	Teams
D. Digital Tool-providers:				
D1	LogiPlan (Logeco)	Product Manager	2024-02-29	Teams
D2	Collecct	Executive	2024-02-29	Teams
D3.A	MyLoc	Business Partner	2024-03-07	Teams
D3.B	MyLoc	Senior Consultant	2024-03-25	Teams
D4	Serviplan (Lambertsson)	Digital Developer	2024-03-18	Teams
D5	Lognet (Bygglogistik)	Logistics Manager	2024-03-28	Teams
D6	Palats	Executive	2024-03-22	Office
D7.A	Alrik	Executive	2024-04-05	Teams
D7.B	Alrik	Executive	2024-04-05	Teams
D8	ProMate (Wiklunds)	Product Manager	2024-04-11	Teams
E. Property-owners:				
E1	Fabege	Sustainability Manager	2024-04-04	Teams
E2	Castellum	Sustainability Coordinator	2024-04-04	Teams
E3	Vasakronan	Executive	2024-04-02	Teams
E4	Framtiden Byggutveckling	Project Manager	2024-04-05	Teams
E5	Business Region	Process Manager	2024-04-12	Teams
F. Supply Distributor:				
F1	Beijer Byggmaterial	Project Manager	2024-03-19	Teams
F2	Ahlsell & BEAst	Logistics Director	2024-03-27	Teams
G. Gap-exploiters:				
G1	IVL & CCBuild	Digital Developer	2024-03-07	Teams
G2	Wiklunds	Reuse Expert	2024-04-09	Teams

Figure 3.1: *List of Interviewees.*

3.3 Empirical Analysis

The coding process is an alternate process deriving from the paradigm model provided by Strauss and Corbin (1998). It started by collecting Parent Codes (categories) based on phenomena and themes found in the interview transcripts, e.g. current practices, corporate needs for increased circularity, current usage of digital platforms, and so on deriving from casual, intervening, or contextual conditions. Then, all transcripts were coded based on references, looking at the summaries, quotes, and specific answers to the principal questions. Several strings of data and examples were added as Cases or Child Codes (sub-categories) based on specific answers as well as individual project cases and initiatives that were recognized by at least but not limited to, two independent respondents. See Appendix B for a full list of Parent Codes, Child Codes, Grandchild Codes, and Cases. This part is referred to as the action/interacting strategy.

Following this process, consequences were achieved where a structure of the empirical findings section was founded based on the predetermined research areas and questions. These were then analyzed using a framework of the four scenarios of circularity in construction logistics provided by Bosch et al. (2023) in combination with the authors' preface of the three types of circularities in construction practice. In this way, a structure was created that facilitates most of the interview answers that can be deemed relevant to the scope of the thesis.

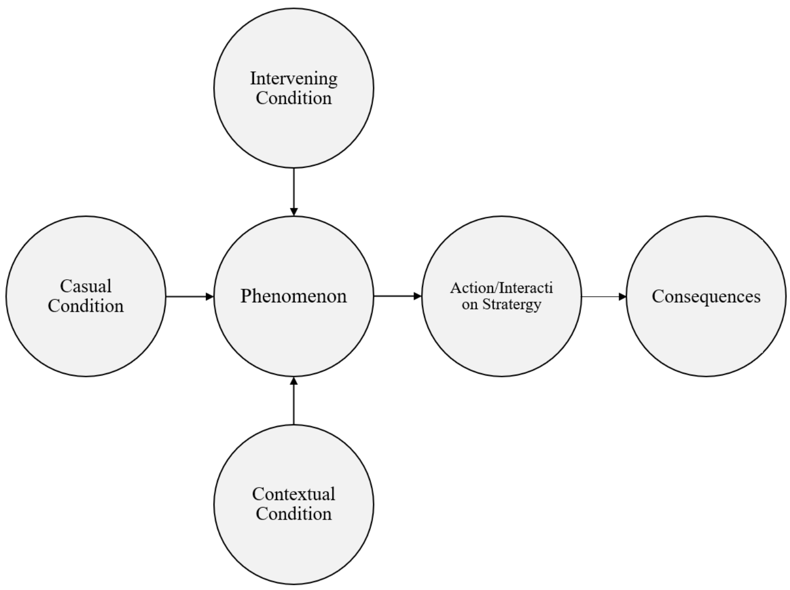

Figure 3.2: *Paradigm Model modified from Strauss and Corbin (1998).*

3.4 Trustworthiness and Ethical Considerations

To establish a scientific basis for this research, the thesis will aim to be carried out in an ethical, and sustainable manner while remaining trustworthy in its contribution to science. This means the thesis will include strategies to positively impact society and ecology while remaining ethically responsible. Within the method of gaining knowledge on the subject, respondents, and decisions of inclusion must be made ethically, not excluding certain stakeholders' interests, or misrepresenting their intent. Objectivity is an important factor in maintaining the trustworthiness of the study and it is commonplace to highlight relevant, well-rounded, full-spectrum facts, as opposed to surgically picking out the things that enhance the stance of the authors' research. It is also critical to work for a positive effect on society and sustainability without subjective interception. The thesis will inherently have a strong sustainable position, starting with the actuality of the ecological aspects in terms of the efficient use of raw materials and logistics solutions, and will therefore not be the main focus of this section.

Trustworthiness will be established through the practice of credibility, transferability, confirmability, and dependability as presented by Stahl & King (2020). In which the authors present strategies such as data triangulation for credibility, where several independent sources of subjective data could potentially become more trustworthy if the sources have conflicting interests or are in competition with one another. In terms of transferability and dependability, the authors provide a mindset where a continuation of established views or practices has over time gained more trust in a wider range, suggesting that similar findings over and over again will converge to more dependable and trustworthy results. In this thesis, this is done by validating interview findings with literature and vice versa, as well as challenging the view of the interviewees with contrasting statements made by their peers in the industry to gain more depth. Lastly, confirmability as such, is described to be achieved through the reach of objectivity, precision, and accuracy of the empirical data provided. The qualitative researcher must aim to get as close to the objective reality as possible, to maintain a high degree of trustworthiness. This is however up to the readers and reviewers to individually conclude.

Regarding ethical considerations, all respondents were subject to informed consent, and verbally agreed to be recorded and transcribed. They all had the option to read, grant, or reject any direct statements included in the thesis before publication. No personal names are used, instead, an individual label is assigned to the respondents, accompanied by a simplification of their professional role and company name. The choice to use a simplification of the professional role, in contrast to their company role, is to increase the level of anonymity since a role such as CEO or CFO would be too revealing. These considerations are all in accordance with the principles of confidentiality, anonymity, and data protection as described by Flick (2020), stating that informed consent is an ethically sustainable way of preserving the anonymity of the interviewee, while still maintaining relevance to the area that is being studied. All quotes are originally in Swedish and were translated into English by the authors.

3.5 Discussion of the Methodology

Since the methodology consists of a flexible approach, being abductive as well as combining inductive and deductive approaches, the study may be criticized as somewhat unstructured or indeterminate, however, the authors argue that there is an advantage of having an adaptive and flexible approach since the thesis is considered explorative. The lack of literature covering the conjunction of construction logistics and circularity in construction made it difficult to solely rely on the theory provided since they contained little evidence of being relevant in the chosen setting. However, the literature used to build the theoretical framework is deemed relevant and trustworthy as a result of containing well-recognized and cited sources and being validated throughout the interviews.

By turning the attention to the professionals in practice, a path towards the objective truth and consensus can arguably be achieved. The risk of relying more on the interview data is that some of the respondents may exaggerate, underestimate, or perceive problems more subjectively than they would objectively appear. It is undeniable that the stakeholders have different views and agendas regarding implementation and suggestions of the topics discussed, however, the authors were positively surprised by the amount of interest and initiative seeking many of the respondents were. Of course, this may be why they said yes to an interview in the first place, but in perspective, 27 out of the 33 candidates said yes immediately to an interview, with three candidates redirecting the proposal to a colleague, and only three candidates turning it down due to lack of time or interest. This further shows that the topic of the thesis is contemporarily relevant and has a high status on many people's agendas.

The potential drawback of allocating the most amount of time towards conducting interviews may affect and limit the reach of data due to time restrictions. However, it can be argued that the consistency and expanded view of different actors in the industry are the more important factors and take precedence over having too much data to effectively handle. The authors tried to minimize this issue by systematically coding and gathering the data in NVivo which greatly increased the efficiency of aggregating the available data into the results section of this thesis.

A potential for improvement would be to delve deeper into a narrower scope to extract more specialized information, however, the topic and research questions selected for the thesis allowed for a more explorative approach, which is somewhat broader by definition.

4
Results

The main findings from the interviews are distilled and presented in this chapter. First, an overview of the current state of circularity in the Swedish construction industry is presented. Followed by a preface of three types of circular practices, which create a structure for the analysis. Then an examination of the existing DLPs on the Swedish market and their functions is provided. Lastly, requests and suggestions from the industry for new functions and improvements to DLPs are shown.

4.1 The Current State of Circularity and Construction Logistics in Sweden

Circularity is described as one of the most enticing and interesting trends within the Swedish construction industry. Interviewees representing different parts of the industry unanimously agree that circular practices and processes will establish themselves to a much larger extent over the coming years. This development is largely due to two principal and interconnected reasons. Firstly, new and stricter regulations around climate impact and emissions are already in place and are expected to become even stricter in the future when emission thresholds are expected to become part of the permit process for new construction developments. This is leading to actors within the construction industry wanting to position themselves ahead of time to remain competitive and ahead of the curve. Second is a described change of mindset in the industry where many actors mention that they themselves and their organizations want to join the journey towards climate neutrality and contribute to the green transition. Several interviewees describe how this is the morally right course of action and something that all actors across construction should contribute to.

The combination of financial and emotional drivers has created a state where actors in the industry are actively looking for ways to increase their circular initiatives. Interviewees describe how this is something inevitable that they both want and have to work with to ensure future competitiveness. There is also a stated sense of frustration because of the lack of large-scale initiatives and processes aiming to increase circularity as many actors want to contribute but few know exactly what and how to do it. Insecurities range from the lack of internal competence, capacity, and priorities to the fact that other more pressing issues must be dealt with before work with new circular strategies can commence. There are also external barriers such as the lack of organizational and streamlined solutions, that make circular initiatives increasingly challenging and less profitable than traditional processes.

Property owners and material producers are described as the two main groups with the largest potential impact towards increased circularity. Public and private property owners are highlighted because of their potential to create circular demands in projects, and since they are providing the funds to the industry. Interviewee E3 representing one of Sweden´s largest property owners, explains that their work with circularity is challenged by the aforementioned lack of circular initiatives makes circularity difficult to implement as any measure taken becomes more expensive than traditional methods. This, in turn, leads to a state where profit targets clash with circular aspirations and one must be chosen over the other. Specialized actors and consultants acknowledge these barriers and external demands but still explain that without the support of their clients, they are unable to initiate large-scale circular initiatives in projects. Interviewee C4 from a demolition contractor company, explains that his company would like to work as much with circularity as possible, but that they can only go as far as their clients allow them, meaning that more often than not, the time aspect sets the boundaries, generally being very constrictive.

> *“If we have enough time and resources we could technically reuse pretty much anything... but economically, we cannot regulate ourselves what can be reused or not, the market has to decide that.”*

- Quote by C4

Producers are described as the actors required to step up, in order to achieve large-scale circularity of previously used or leftover material. With their production capacity, many interviewees see great potential that they could also include processes where material is taken back and reconditioned using the same methods that were once used to produce them. This is further explained to be a reasonable solution to the issue of certification and quality assurance as producers already work with it for new products and materials. Similarly, the producers already have established supply chain networks for distribution where reconditioned material could be reintroduced and it is also highlighted that these networks could also function in reverse direction taking back large volumes of material for reconditioning in a financially viable way. There is, however, also a need for many other actors to contribute to this process and handle different aspects like transportation, certification, inventory management etcetera. A sustainability coordinator at a large commercial real estate company said:

> *”Imagine if the large real estate companies would agree to share their reuse inventories, this would require a third party to arrange the transports, and perhaps storage and certifications... We need someone who is great at solving this problem, so we could trade desirable and accessible reused products, that are stocked up and ready to go.”*

- Quote by E2

It is apparent from the interviews that the bulk of initiatives and pilot projects of reuse practices are currently made on a small scale. Some circular initiatives take a wider comprehensive approach, trying to get a grip on the full chain, while others focus more on specific and specialized parts of the flow. This is all done under a sentiment that circular practices are not financially profitable currently and that the profits must be collected from other aspects, like reduced climate impact. Several actors have created solutions for “picking the low-hanging fruits”, meaning that specified circular initiatives have been undertaken in areas with low risk and large potential where certain materials and products are saved in bulk and reconditioned for future use. These initiatives include products such as ceiling tiles, interior furniture, and bricks. Several large real estate companies have started circulating material internally using the reduced climate impact as a ground to secure better conditions for financing through green loans and obligations. Contrary to the specialized focus, some actors are aiming for implementations on a large scale. Their initiatives stem from the realization that they are in a position where they already own several parts of the needed knowledge and resources to take on this challenge. Wiklunds is a logistics company that together with Uppsala municipality has started to create an upscaled reuse hub for the region, including their own digital platform Promate. They also collaborate with CCBuild to market their reused products and attend sessions for knowledge sharing and other similar initiatives can be seen throughout different regions in Sweden. Another example is ReBygg by Kålltorps Bygg, a Gothenburg-based contractor who identified the need for reused products and saw the potential to create a reuse hub in Gothenburg. It was launched in the spring of 2024 and their partnership includes several large real estate companies, with indication and ambition that others will join in the future. Thirdly there is also a reuse hub in the Stockholm urban area started by real estate company Fabege, which is currently upscaling their hub in collaboration with other real estate companies aiming for a situation where products and materials are circulated between several actors in the region. All of these three hubs have similar agendas and motives, however, the company behind each initiative has different backgrounds, this further shows that the reuse initiatives are widely tested, and many actors are interested in how they can become part of and shape the market of reused products.

Despite the large growth in interest in contributing to circularity, an observation has been made that there is a difference between what working with circularity entails for different types of actors in the industry. The difference stems from circularity being used to describe different things, containing different meanings to different actors, creating a necessity for some actors to become mediators and steer the industry towards the collective goal of climate neutrality. At the same time, specialized actors must realize their role in the circular economy and find out how they can contribute. The needs and definitions of what circularity entails can vary greatly if you ask an architect, demolisher, and distributor. This leads to further uncertainty and inefficiency in the circular processes as the broadness of the term can make large-scale initiatives difficult to succeed with. There is an identified need for actors of all types to understand both the specialist components of circularity and the whole system made up of the components in order for circular initiatives to succeed within the given constraints of the construction industry.

4.2 Three Types of Circular Practices in Construction

As ambitions increase and scenarios get more complicated, the need increases to diversify the term circularity in construction. Because of this, a framework of three types of circular activities and processes is proposed to better be able to categorize how the circular economy is done in construction. These derive from the interview data and the themes that were discussed with professionals in the industry. Type I addresses the importance of legal requirements, frameworks, and attitudes to give incentives and promote circular practices. These were mainly discussed with representatives of property owners and confirmed/rejected by other professionals and sets the foundation of what opportunities a project may implement circular economy. Type II addresses the logistical challenges and what activities need to be included to handle the physical aspects of reuse where previously used or leftover materials and products are recovered for future use. This is where the digital solutions are suggested to have the highest impact, and aid projects in developing efficient workflows and practices. Type III is the process in which the reused product is being re-introduced to its new context. Several systems and conditions need to be met to do this efficiently and to have a positive climate impact. The three types are interconnected and cannot be regarded as separate entities in practice, instead, they are adopted for the sake of providing clarity to the results, adding structure to discuss the interview findings.

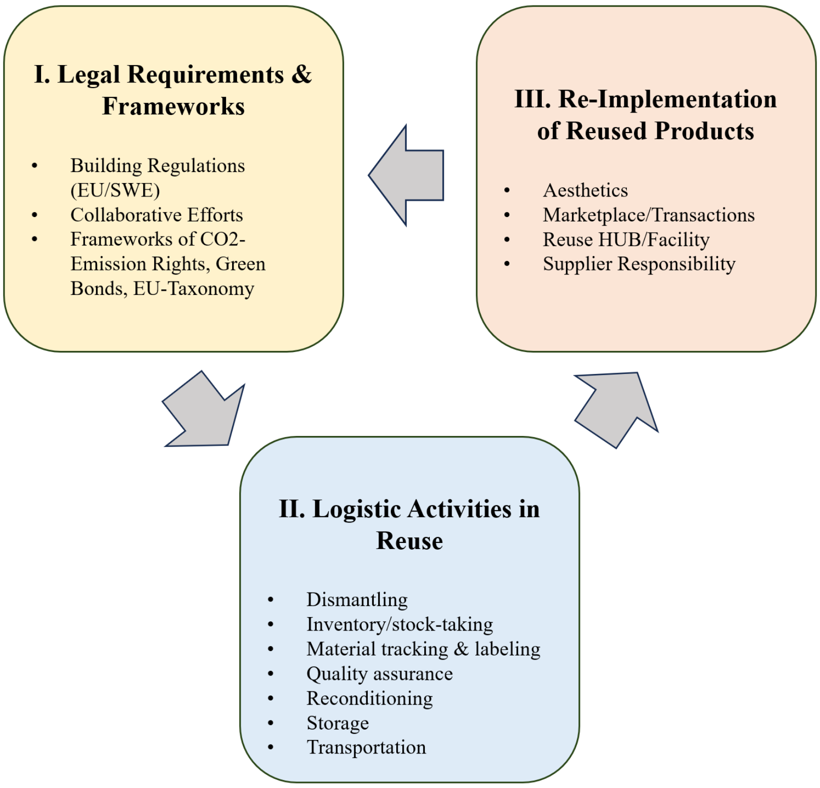

Figure 4.1: *Three Types of Circular Practices in Construction.*

4.2.1 Type I. Legal Requirements & Frameworks

Figure 4.2: *Type I. of Circularity in Construction.*

Type I of circularity in construction predominantly contains prerequisites and early-stage development for new construction projects. This includes aspects such as building regulations and requirements, along with frameworks such as climate declarations, certification classes, and green funding. This type sets the level of ambition and is considered very important by the actors in the industry. It is clear in all of the interviews, that the prerequisites included in a project largely determine its capabilities. By implementing early decisions to aim for high demands of sustainability goals and being open to collaboration, several interviewees expressed that circular practices have been able to be developed, albeit mostly on a small scale up until now. Many interviewees refer to projects they have been involved in and can point to a circular action they have implemented that probably would not have been considered ten years ago. The rising interest and community built around circularity have engaged many actors and seriously consider reuse as a viable path towards climate mitigation. Interviewees E1 and E3, who both represent large property companies, particularly point out that they strive to be one step ahead of what is required of them when it comes to sustainability. They strive to constantly raise the bar themselves through implementing internal circularity indexes and investing more in circular innovation. These actors express that this mindset has granted them more publicity and business opportunities because of their willingness to push beyond the minimum requirements. All interviewees shared the impression that the industry is in a precursory stage of sustainable development, where means of control such as CO_2 limit values and sharper requirements for funding are imminent. Everyone seems to agree that regulatory changes are coming, but exactly what they will include, and what the effects may be, remains uncertain.

> *"I believe there is huge potential for the reuse market in Sweden, but right now the economic incentives are too small... We seek our main bulk of funding through green bonds, which require us to have a strategy for reuse and recycling... This way we receive a lower interest rate which can mitigate expenses for developing circular practices."*

- Quote by E3

Another aspect relating to this type of circularity is early-stage planning for how to capture and reuse larger components of demolition projects like load-bearing beams and structural systems. These components are described to be the most profitable to reuse from a climate footprint reduction standpoint as mainly new steel and concrete structures make up large parts of a new project's climate footprints. In order for this type of circularity to succeed early-stage collaboration is described as paramount as prerequisites must be set for both how to demolish the first building in order to capture the desired components, but also for how these components are to be reconditioned, certified, transported and finally reintroduced in their new environment. An example of the importance of planning and collaboration comes from the ambitious "Kvarteret Omställningen" in Gothenburg where hollow core decks from a demolished warehouse are to be reused in the new project. Because of the lack of existing processes for this type of circularity, the initiation and completion of the extraction of material was conducted in an ad hoc and unstructured way where the demolishers had to extract what they could in a tight timeframe and the captured material then was transported away to a storage site where it is supposed to lay for up to a year until it will be reintroduced in a new building. Actors involved in this project describe how this process would have been much simpler with established processes for collaboration, planning, and execution that could have led to even more reused material being extracted while also saving both time and cost.

4.2.2 Type II. Logistic Activities in Reuse

Figure 4.3: *Type II. of Circularity in Construction.*

Type II in circular practices take off in the logistics activities as identified by Bosch et al. (2023) but are slightly modified to correlate to the responses from the interviewees. The logistic activities were identified as having a significant impact on circular practices in construction. The first activity, dismantling includes the actual activity of extracting certain materials and products that are deemed interesting to reuse. Interviewee C4, a contracting manager for a demolition company, describes how they were able to win several procurement processes thanks to their business approach, offering to dismantle and save most materials. Typically, demolition contractors focus more on quick and efficient demolition, which will accumulate more material waste. The interviewee continues explaining how the demolition industry is progressing towards circularity.

> *"The past three years have seen a notable rise in both the volume and importance of demolition projects, with sustainability considerations playing a significant role."*

- Quote by C4

The activity of inventory and stock-taking has also increased significantly in popularity according to several interviewees representing real estate companies. To understand and work with existing resources, several companies are starting to catalog their material inventories, especially for interior building materials and products. By understanding what is available, the higher the chance is that the resources can be utilized instead of procuring new products by default. A sustainability coordinator at a large real estate company, explains that it is counter-productive to reuse products in smaller batches and transport them for long distances since the climate impact of the transport greatly outweighs the potential savings. Therefore, they want to control and have an overview of exactly what materials they have in stock, and in what quantities.

Furthermore, this ties into control of transport and material tracking, to understand if it is feasible to reuse certain materials. Labeling and material tracking are starting to be utilized in the construction industry, slowly transitioning towards standardized and digitalized workflows, rather than traditional and manual methods. With digital labels, the products and materials can be communicated and shared efficiently, allowing for beneficial information exchange both externally between partnering actors and internally in one organization. Reconditioning is another logistic activity identified as important for circularity in construction. The ability to maintain, recondition, or refurbish a material or product could decide if it is useful or discarded. Several interviewees attest that reused materials feel undesirable or “second-hand”, emphasizing that they would not want it. A proposed solution for this is to take care of the reused material, making it a desirable or “vintage” product with more appeal than before the process, tying into the activity of quality assurance for reused products. This activity is considered costly and underdeveloped by many of the interviewees. This is especially true when discussing the potential of large-scale reuse, where a streamlined system to quality assure products is essential to make it financially viable.

Lastly, the activity of storing reused materials is crucial. The costs of storage and handling materials are currently considered rather high, and many actors are cautious about investing in storage space for reuse. Currently, there are only a few local initiatives in Sweden’s more populated urban areas, such as the examples mentioned in section 4.1. These hubs have common objectives of storing and sharing products to induce the flow of reused products. The actors involved revealed that they are collaborating with digital platforms, mainly for inventory and stock taking as a start, but also for sharing information about dismantling processes and upcoming project needs. Furthermore, actors are emerging with backgrounds in logistics such as haulage contractors, dismantling contractors, and construction supply distributors, that provide new services encapsulating circular practices in different ways. For example, some actors offer dismantling of entire buildings or interiors, transportation of reuse material, material tracking/labeling, and occasionally temporary storage. These services are also a result of an increased interest in reuse and are described by these actors as business opportunities that should not be understated.

4.2.3 Type III. Re-Implementation of Reused Products

Figure 4.4: *Type III. of Circularity in Construction.*

With increased material flows of reused materials, there are added incentives to innovate business ideas and models. As mentioned, this can be seen across the industry today as several actors can benefit from refurbishing, reconditioning, or upcycling a product to add to its value and sell the product for profit. Quality assurance and reconditioning are recurringly addressed by many of the interviewees, often perceiving these activities as time-consuming, costly, and troublesome. Despite this, several gap-exploiters have already created businesses for reconditioning materials and products. Bruksspecialisten is an example of such a gap-exploiter, who specializes in reconditioning used bricks. They receive bricks from demolition sites and refurbish them to create an offering of “new” brick products, that are stocked up and sold similarly to traditional bricks. According to interviewee A2.B, senior sustainability consultant, one of the reasons Bruksspecialisten is successful is because they can quality assure their reuse products with a CE-marking, making it more desirable to be purchased in construction projects. Moreover, many interviewees argue that the original supplier of a certain product category could take advantage of the rising demand for reused products.

Simply by accepting to receive the used products and refurbish them to be sold back to the market for a profit. This would also include a significant reduction of CO2 eq. in the suppliers’ sales, as well as the consumers’ purchases, creating a win-win situation for both parties. Some actors within different product categories have started implementing this into their business offerings, such as Ecophon for Ceiling tiles, ReCarpet for floor carpets, and Tarkett for flooring tiles. Some gap exploiters have emerged with similar ambitions but have chosen a more general approach, trying to refurbish several different types of products at once, as long as they are believed to have a high potential to be sold back to the market. There are also recent initiatives attempting to reuse larger-scale building materials such as Stena Stål for the reuse of steel structures, Moelven for timber structures, and Zurface for natural stone. Interviewee E5, process manager at Business Region, advocates for more actors to take advantage of this unique business opportunity, learning from the existing business models and then adjusting their offerings to supply the reuse market. In practice, however, these gap-exploiters currently face challenges and are still struggling to scale up their businesses, although demand is rising. More actors need to take collaborative responsibility and drive the question further, making reuse the norm.

> *"I wish more actors dare to claim their market share and business opportunities within circularity, sooner or later we will come to the tipping point where reuse becomes the norm... Personally, I cannot see any other solution to this problem, it is just like the movie title, 'Everything, everywhere, all at once'... Not everyone believes in it, but I do."*

- Quote by E5

In "Kvarteret Omställningen", the aim is to reduce the climate impact by 50 %, totaling 200 kg CO2 eq. for each square meter of total floor area. This will be attempted by applying sustainable practices such as energy-efficient design, timber construction, and reuse. The project has secured reused materials including timber frame structures from a former ice rink, concrete hollow-core decks from a former warehouse, and reused slate tiles for façade cladding. Interviewee E4, project manager at Framtiden Byggutveckling, explains how this reuse strategy was initiated:

> *"In 2021 we received a directive from the municipal council to work on pilot projects to halve CO2 emissions... Initially, we calculated reductions independently before engaging with contractors for dialogue and bidding... We decided among three interested contractors after we had dialogues about how we could achieve 50% CO2 reduction."*

- Quote by E4

The same interviewee continued by emphasizing that the project is experimentative and primarily an opportunity to learn and develop sustainable practices. For example, they were positively surprised by how smooth it was to dismantle the hollow core decks from the warehouse and have received many inquiries of interest in how they managed to do it. Indicating that the learnings from this occasion will follow into their future projects.

Concerning the aesthetics of reused products, it has been discussed by several of the interviewees that it is important, at least for now, that the reused products should not feel inferior or less desirable to a new product. There may be a stigma towards the actual wording of "reused product" insinuating that it is torn and in bad shape, which may not actually be the case. Even products that have only been in use for a short amount of time with little to no amount of tear, could potentially be considered reused products. In interviews with architects, the challenge of combining different reused materials seems a little harder to sell as a concept, however, they have experienced a change in the general perception of reused products, finding it seemingly acceptable in some cases leaning towards a "bricolage" approach of aesthetics, creating an artistic dimension of how a building is perceived. The general acceptance of reused materials, however, was described well by Interviewee C4, a contracting manager at Normans, explaining what usually can be reused in their projects:

> *"I have this rule of thumb when it comes to reuse, if you could imagine using the product yourself, probably someone else could too. If you don't want it, maybe you should not expect someone else to want it... It can sound rather harsh, there are of course people that value things differently, but this is generally a good rule for the overarching mindset on reuse."*

- Quote by C4

This is further highlighted by other interviewees stating that the industry as a whole must become better at realizing the potential of reused material and products in new projects. For many parts of new projects, reused material is described to have the same capabilities as new and could thus be used to a larger extent if both a larger supply and demand were created for it. Distributor F1 captures this discussing the amount of new wooden products being used for temporary activities and then thrown away. They highlight how their company has started an initiative to recover leftover or used wooden products to reuse them several times before they are sent for disposal.

4.3 The Current State of DLPs for Circularity and Logistics

Numerous digital platforms are emerging aiming to increase efficiency and support construction projects with their various functionalities. Some of these platforms are specifically designed to address logistical challenges and are called Digital Logistics Platforms (DLP). To map out which Digital Logistics Platforms are available in Sweden, professionals in the industry were surveyed and asked if they are using DLPs, how they are using them, and for what purpose they are using them. Several digital developers and business managers were also interviewed for a comprehensive understanding. It was apparent that different actors are using DLPs but in a variety of different ways. DLPs can be used either directly internally in a project or indirectly through an expert from a consultancy firm. For transparency, it should be noted that several additional DLPs do exist, and their offerings are constantly improving, however, this thesis examines nine Swedish DLPs, since they have enough relevance according to multiple sources. Both developers, representatives, and users of these platforms were included in the interviews. Aside from the nine examined platforms, two additional platforms were mentioned during the interviews, *Dacke Online* and *Loopfront*, which are comparable to inventory-oriented platforms such as CCBuild and Palats. For various reasons, they were deemed less relevant to this specific thesis and not enough data was collected to support a full examination of these two.

A functionality map for the nine examined DLPs was created to get an overview of what functions are provided today that can potentially address the logistics activities identified as important for circular material flows by Bosch et al., (2023). For the existing functionality of available DLPs in Sweden, see the Matrix below:

Platform	Speciality	Dismantling	Inventory	Material Tracking	Quality Assurance	Reconditioning	Storage	Transportation
Alrik	Calendar & Tracking (distributor)	*Can provide reverse transport of selected materials*	*Read inventory*	*Dedicated, Real-time GPS tracking in app*				*Dedicated, Includes CO2 data & Extra capacity 3rd party*
CCBuild	Inventory & Knowledge exchange	*Provides info and status for dismantling*	*Dedicated for creating inventory in mobile app*	*Dedicated labeling, limited tracking*			*Project storage/Market solution*	
Collecct	Waste Managemenet	*Dedicated function to differentiate waste and material*	*Read inventory*	*Dedicated tracking*				*Dedicated calendar for managing deliveries*
LogiPlan	Full integration	*Reverse transport of selected materials/waste*	*Read inventory*	*Dedicated tracking*			*Terminal solution/Viable for storage space*	*Dedicated calendar for managing deliveries*
Lognet	Calendar & Tracking		*Read inventory*	*Dedicated tracking*				*Dedicated calendar for managing deliveries*
MyLoc	Full integration	*Reverse transport of selected materials/waste*	*Read inventory*	*Dedicated tracking*			*Terminal solution/Viable for storage space*	*Extensive calendar for managing deliveries*
Palats	Inventory & Storage	*Provides info and status for dismantling*	*Dedicated for creating inventory in mobile app*	*Dedicated labeling & limited tracking*			*Project storage/Market solution*	
ProMate	Calendar, Inventory & Storage		*Read inventory*	*Dedicated tracking*			*Internal reuse hub/Market solution*	*Dedicated calendar for managing deliveries*
Serviplan	Calendar & Tracking		*Read inventory*	*Dedicated tracking*				*Dedicated calendar for managing deliveries*

Figure 4.5: *Matrix: Functionality of Readily Available DLPs in Sweden.*

All of the examined platforms are currently providing functionality for circular material flows to some extent, what is also apparent from this matrix, is the lack of functionality currently addressing the logistic activities of Quality Assurance and Reconditioning. To get a better understanding of the DLPs, three categories are proposed.

The first category, Multifunctional DLP, are platforms that originate from outside of construction, typically in the manufacturing or transportation sectors. These come with a wide range of functions such as calendar booking, CO2 emission data, and terminal storage organization. They also tend to have high-end IT integration, sometimes at the expense of user-friendliness. These systems are strong at providing a tailored package for their customers, however, they might require a consultant or specific tradesperson to operate the DLP to its full potential. The second category of DLPs is the Calendar Specialized DLP, with the main focus being the functionality of having a delivery/booking calendar, and not extending too far beyond that. The strength of these platforms lies in user-friendliness, allowing for more accessibility to the persons involved in the project. The third category, The Niche DLP, is a platform that specializes in handling one or a few specific logistical activities regarding circularity. One example is the niche activity of waste management, including booking different sorts of actors to deal with specific waste from a construction site. Another example is the niche platforms for inventory and stock taking, commonly referred to as “inventory apps”. These can provide labels and information to further deal with logistical issues such as dismantling, storing, tracking, or selling. No single developer is currently offering all of the aforementioned functionalities in one single platform, however, there are indications of advancements in collaboration and integration between some of these platforms to develop more compatibility and integration between them.

Categories of DLPs		
Multifunctional	*Calendar Specialized*	*Niche*
- MyLoc - Logiplan - ProMate	- Lognet - Serviplan	- Alrik - CCBuild - Collecct - Palats

4.3.1 Multifunctional DLP: MyLoc, LogiPlan & ProMate

The first identified type of DLP is characterized by a high level of functionality and the ability to be customized depending on the project and client. The largest platform on the Swedish market today is ***MyLoc***, which created an adapted version of its original platform addressing the construction industry, called *MyLoc Construction.* The typical project for using this version of a DLP is a large-scale and complex project in a confined urban area. Interviewee D3.B, a senior consultant at MyLoc, explains that a DLP was necessary during the construction of the Citygate project in central Gothenburg, located next to Sweden's most intensely trafficked highway. In addition, there was a fire station nearby with high penalty fees if blocked. The project management chose a TPL solution with a consolidation center a few kilometers from the site. Most of the deliveries were brought to the CC, and stored temporarily until it was time to deliver the material to the site JIT. In this project, MyLoc provided functions for storage (CCC), tracking, calendar booking, checkpoint accessibility, and climate data of transports, among others. ***LogiPlan*** and ***ProMate*** are similar platforms in the way they operate. They also focus on tailoring a solution for their clients including the necessary functionality. The main differences between the three are that LogiPlan focuses more on user-friendliness, ProMate on adaptability and tailoring, while MyLoc focuses on providing full functionality, offering what the client needs. These platforms are usually operated by an expert consultant or a logistics manager from a contractor company. Representatives from these DLPs expressed an interest in developing new and improved functions, particularly for increased circular logistics, and identified some already existing functions that could be provided.

> *"Since we are already using this tracking system with labels, it is only a question of who will create labels attached to a reused product, and describe its properties. So it can be reintroduced to some kind of market... We have thought about tweaking our functions for dismantling projects, but as of now, it is quite rare so we would develop this option manually. However, if there is a rising demand for it we could potentially automate and create a more dedicated function."*

- Quote by D3.B

4.3.2 Calendar Specialized DLP: Lognet & Serviplan

The second type of DLP is quite similar to the first type, however, it has been somewhat simplified and focuses more on user-friendliness and ease of use. The majority of the interviewees signaled that the delivery booking function is the most central, making this the main focus of the simplified DLPs. ***Lognet*** & ***Serviplan*** are both developed for this very purpose, introducing a quite simple digital tool to help book and coordinate deliveries to the construction site, without the need for extensive external help. Their main strength is that the threshold to get started with their tool is lowered and more accessible to personnel on-site, essentially providing a more sophisticated option for a traditional whiteboard. Although aiming for simple workflows, interviewee D5, logistics manager, hinted towards an updated version of their platform, providing more and improved functionality, while remaining user-friendly.

> *"We have seen that the development of DLPs has taken off during the last few years... We aim to evolve our system to meet the growing demands of users... Ideally, we want to streamline various logistical tasks into a single user-friendly platform."*

- Quote by D5

4.3.3 Niche DLP: Alrik, CCBuild, Collecct & Palats

The third type of platform includes a selection of niche platforms that can be utilized for their own specialty or package, often combined with a multifunctional DLP for larger projects. These platforms are referred to as "semi-logistic" platforms throughout this report since their main focus differs from the aforementioned more traditional platforms centered around delivery planning and tracking. Numerous interviewees expressed that they use some niche DLPs for tasks besides calendar bookings already with a common example being the emerging need for property owners to gain knowledge of their existing material stock, CO2 data of transports, and present data of accumulated waste from the project.

Alrik is one type of niche platform, targeted to supply distributors as it provides a dedicated system for real-time tracking of transports, which both the supplier and receiver can access and modify. Interviewees D7.A and D7.B, executives at Alrik, explain that they want to help digitalize the construction industry to become more efficient. By targeting distributors, Alrik improves the link between suppliers and contractors. According to D7.B, the distributors can provide expertise and knowledge to any given construction project and hold the power to drive change and improve overall efficiency at the construction site through smart deliveries.

Collecct is a provider of a niche DLP that focuses on waste management and accurate differentiation of waste from construction projects. They aim to simplify the administrative tasks for contractors and suppliers included in project processes regarding waste management, such as scheduling waste pickups, sorting, and data collection for accurately reporting waste and climate data. With their consulting services, they aim to pair actors in the industry to increase circular practices and support new business ideas. They are collaborating with both large contractors, medium-sized real estate companies, and smaller contractors focusing on renovation projects. One of their main functions is to provide data for waste and climate reporting, in accordance with CSRD. To drive and advocate for circular practices, efforts have been made to start pilot projects with different partners to share knowledge of circular waste management and its role in the construction industry.

It is not uncommon for a property developer to hire a consultancy service from an architect, sustainability coordinator, or even a reuse specialist from a contracting/dismantling/logistics firm, to try and find exactly what existing materials and products may be a resource that could find use in a different context. Usually, this process starts by conducting a thorough inventory of what materials and products currently exist in stock, either in a building, storage space, or similar. To do this efficiently, there are a few emerging semi-logistic DLPs such as ***CCBuild***, and ***Palats***. Both of these provide a mobile application where it is possible to create labels, take photographs, make descriptions for materials, and eventually sell them as products. The effects of the company getting a grip on its existing stock could lead to new collaborations and create a wider market for reused construction materials and products. Such has been done and is currently in development by several constellations of the different interviewees' companies, in various contexts. Several current initiatives are piloting the concept of a 'reuse hub', where they are typically using one or several DLPs to control and accelerate their efficiency and create workflows in their new businesses. However, which platforms are considered best practices, and for what kind of projects are not yet established. Interviewee G2, Reuse Expert at Wiklunds, expresses the importance of available support in their day-to-day workflows.

> *"Integration between (DLP) systems is essential to streamline inventory management and sales processes... Different projects may require different data for reuse and climate savings, necessitating adaptation... There are numerous platforms and it is difficult to choose one, most important for me as a user, is the availability of support in my day-to-day workflow."*

- Quote by G2

The main difference between CCBuild and Palats is the background of how they came to be. CCBuild is an initiative established from research done by the Swedish environmental institute IVL, aiming to support and drive collaboration and knowledge transfer of circularity in construction. CCBuild has created different apps and digital offerings dependent on suggestions from professionals in the industry. Palats on the other hand, is a business research start-up with ambitions to develop a dedicated IT structure to improve the time-consuming process of creating digital inventories and labels. CCBuild provides a similar inventory application but with a different interface. Both are commonly used on their own and by some actors in combination with one another since they provide slightly different workflows. CCBuild is the predecessor and has its strength in being a collaboration space, while Palats has the edge in improved digital interfaces, according to some interviewees. However, these platforms are rapidly gaining traction and developing, resulting in them coexisting in healthy competition.

4.4 Utilizing DLPs in Circular Material Flows

In this section, the use and potential of existing DLPs will be evaluated according to the four scenarios framework of circularity in construction logistics, presented by Bosch et al. (2023). Interviews have uncovered a wide array of needs from actors involved in different stages of circularity for them to succeed with their circularity commitments. The following section delves deeper into how these needs can be met by existing digital platforms, highlighting which processes are covered and which might need further development.

4.4.1 Scenario 1: Materials and Products Circulated Within One Project

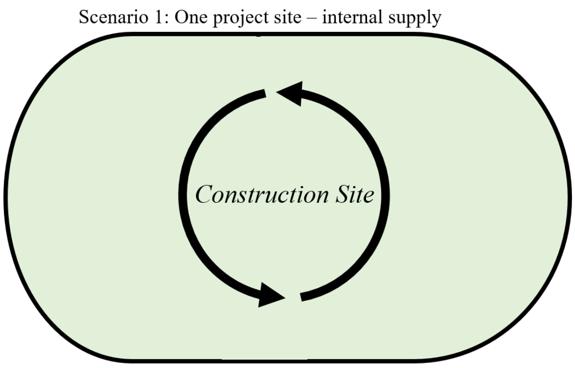

Figure 4.6: *Scenario 1 of Circular Material Flows.*

Currently, there are several large real estate companies working with scenario 1, however, it is limited to one single site which means it is not scalable. An example is when a large real estate company is storing excessive windows or doors somewhere inside of the original building, anticipating future use. CCBuild and Palats have functions available to aid these actors in keeping inventory stock of their materials, at this stage providing a way to register them, describe their properties, and locate where they are stored. When it is time to use them again, designers know where the materials are and can include them with certainty that they exist. The scenario is a good introduction to circularity, being somewhat simple since it focuses on single projects and is supplied well by digital platforms today. This is essentially a step more digitalized than having an Excel spreadsheet of materials or physical books of product receipts. Introducing this platform requires minimal planning in the early stages to learn the processes, depending on the internal structure and data. Inventory of what has the potential to be reused without needing to be removed from the site is a good precondition to start a circular process. CCBuild and Palats also offer a function for climate calculations, which is becoming increasingly important among clients. The main issue with this scenario is that it lacks the scalability needed to make it attractive. However, it presents a great starting point for actors who wish to introduce circularity in their operations and set the process in motion.

4.4.2 Scenario 2: Materials and Products Circulated Within One Project Connected to a Distribution Network

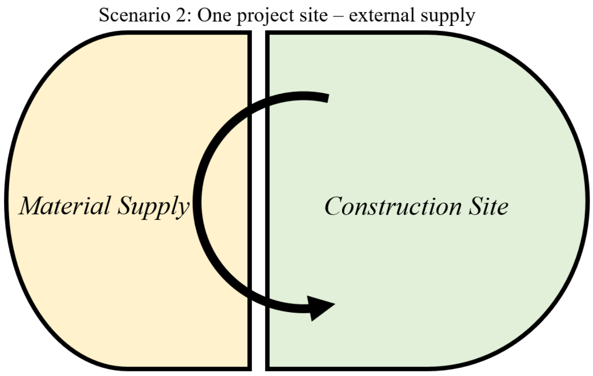

Figure 4.7: *Scenario 2 of Circular Material Flows.*

This scenario follows the same logic as Scenario 1 with the main difference being that material will have to leave the construction site and be handled by a specialized actor. Typically to refurbish or recondition a certain product. This procedure requires some sort of transportation, which leads to more planning and coordination. Scenario 2 bears several similarities with the previous example in terms of project type. The upside however is that the incentive for scalability is higher, as the volume of material that leaves the site can be bulked, stored, and reconditioned to a larger extent and thus regain their value. For this scenario to be efficient, the distribution network has to be divided into internal and external. Platforms such as Alrik can manage the deliveries and provide climate data on them, directly understanding what the threshold value is to make a profit in terms of climate impact. A few real estate companies have come quite far in the development of internal circularity where the material is transferred from a project to a storage center or warehouse, before returning. For example, in projects of office alterations where a company needs to cut back on office desks for six months to free space for lounge areas, and later decides to bring back the desks to provide space for newly recruited staff. This process is working quite well with platforms like CCBuild and Palats, where the office desks can be tracked and controlled.

Reimplementation also becomes straightforward as knowledge about what products will be available can be known to designers. This all hinges on planning in the early stages, as buildings have to be scanned ahead of time so that developers and designers have time to identify what materials can be reused and what processes are needed for them to be dismantled correctly and then sent for eventual refurbishment.

4.4.3 Scenario 3: Materials and Products Circulated Between Multiple Projects Within the Same Organization Connected to a Distribution Network

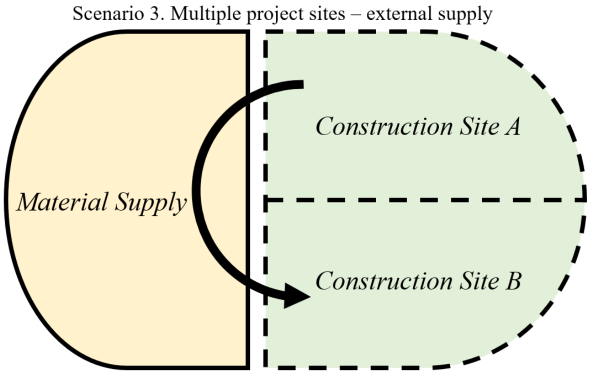

Figure 4.8: *Scenario 3 of Circular Material Flows.*

Scenario 3 builds on the two previous scenarios. Materials are sent to the material supply and processed through logistic activities such as refurbishment, storage, transportation, etcetera. The material eventually arrives at a new construction site where it is implemented again. Several real estate companies have experience with this scenario, explaining their challenges in each project being a unique financial entity. This means that transactions must be made between projects if materials are to be relocated, which makes larger-scale implementation difficult. Inventory apps such as Palats and CCBuild function well for keeping inventory in this scenario but are challenged in other logistic activities and transactions. The issue of transactions can be tricky according to several interviewees. Sometimes materials are donated between internal projects rather than sold to simplify the administration. The incentive for real estate companies to send and receive materials internally is to minimize emissions rather than balance project-specific economies. Some platform providers indicate that a solution to efficient transactions is being developed and is essential to scale up the flow of materials. DLPs that are multifunctional or have calendar specialization, can be utilized to solve some of the logistic issues the inventory apps are lacking. They allow for dedicated transport planning, such as time scheduling and filling returning freight carriers with reusable materials for example. In an instance from an interview, there was a faulty delivery where a project site received a surplus of windows, instead of getting rid of them as waste, they were brought back to the supply distributor and sent to a second construction site. This was planned using a platform, which indicated that one project had a surplus while another had a deficit of windows. This pairing could be developed as a function to match the needs of ongoing projects, resulting in less surplus material going to waste.

Pre-planning and creative thinking were also lifted as important factors to make it profitable and simple to reuse materials between different projects. From interviews with architects working with reuse projects, it was brought up that some materials and products could see a new use case in a different environment. For example, old computer monitors that are remade into light fixtures. By matching needs in new creative ways, even more materials may avoid landfills.

4.4.4 Scenario 4: Materials and Products Circulated Between Multiple Projects and Organizations/Markets Connected to a Distribution Network

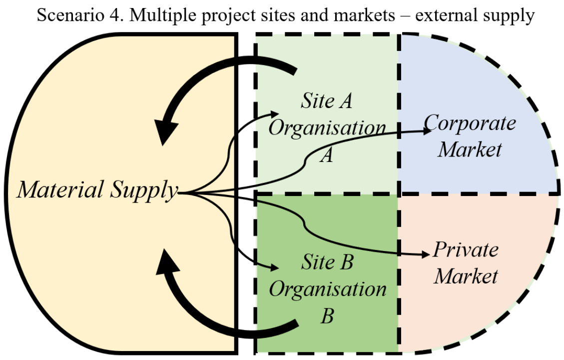

Figure 4.9: *Scenario 4 of Circular Material Flows.*

In Scenario 4 multiple material flows are happening simultaneously. The goal of scenario 4 is to optimize the flow of reused materials and products seamlessly between different projects, actors, and markets. This means that reused material regardless of origin project, site, or company, can be easily distributed to a wide range of possible consumers for their next life-cycle. The consumer could be a construction project, a real estate company, a third-party reseller, or even a private person if applicable. The interviews have revealed that collaboration and knowledge through various platforms are central to achieving such flows. During the interviews, the DLPs were discussed and identified as potentially playing a big role in this scenario, especially if it is developed specifically for it. For this to happen several companies need to be more transparent and digitalize and share their inventory of materials. DLPs could provide transport, transactions, reconditioning/quality assurance services, climate data, etc., in one integrated digital environment. Currently, the functionalities provided by the DLPs are different from platform to platform and targeted towards different consumers. An example of such integration could be a collaboration between two or several platforms, co-developing their functions to resonate with the emerging needs of the industry. Niche platform providers like Collecct can collaborate with another DLP provider to allow for more efficient transports and connect actors looking for specific materials that would otherwise end up in landfills.

Wiklunds is a TPL company that has achieved certain parts of scenario 4, albeit on a small scale. They use several platforms efficiently to keep track of acquired materials and can resell some of them to partnering projects and markets. To achieve scenario 4 fully, more actors would need to be integrated and working together. The potential of the reuse market is underestimated according to several interviewees, saying that there are few initiatives created to exploit this potential. Material producers are often described as key players in reselling materials to both the private market and the corporate market since the producers have the expertise to refurbish and quality-check products before being reintroduced. However, reuse hubs will still be needed to gather bulks of products to send back to these producers, otherwise, the climate impact of the transport will be too high.

4.5 New Functions for DLPs Requested by the Industry

The interviewees had many opinions of possible improvements and requested functionality they value in digital logistic platforms to incorporate circularity into their workflows further. The following list will cover the most common themes and needs mentioned in the interviews:

Quality Assurance

It is commonly requested throughout many interviews that quality assurance through a digital system would be helpful. As currently there is little to none quality assurance of reused materials inside of the DLPs other than the occasional self-rating in a 1-5 scale and a picture. For most projects, this is not sufficient enough to make a decision, let alone convince management that the reused product is good enough. To achieve a streamlined workflow and quality assurance products more efficiently, the digital platform could play a role. The issue however remains that the physical product might need a physical inspection, especially if there are high technical requirements for structural properties, sound insulation, or fire protection. However, for products and materials with low technical requirements, a more digital and streamlined procedure might be sufficient.

System Integration

The interviewees, even developers of platforms, requested a higher level of system integration between specialized platforms to better improve their offerings. If more systems talk to each other and can provide added functionality, more incentives for purchasing the DLPs may be created. One example of this is the procedure of creating labels and checking inventory in a specialized DLP, to later transfer the data automatically to a logistics service with transportation options. While some companies expressed openness towards collaborating between platforms, there is still uncertainty as to what such collaboration might look like.

Transaction Systems

Digital transaction systems are identified by all of the interviewees as a necessity to efficiently trade reused items between different companies, consortiums, and even internally between own projects. Transaction systems with satisfactory receipts and data for bookkeeping are essential both for juridical purposes but also for organizational purposes such as budgeting, climate declaring, and internal accounting.

Usage of Terminal Solutions

The functionality of Terminal solution is discussed by several of the interviewees, stating that although the functionality exists today it is not very often utilized for the purpose of reuse specifically. However, the providers of terminal solutions state that there is a possibility to adapt and develop this function towards reused products if the demand occurs from the clients. This could potentially become a reality if large-scale reuse hubs start to emerge.

Waste Management

New and improved functions for waste management, and differentiation of waste, in particular, are sought after by users and could be implemented in DLPs to a higher extent. There is limited data on waste fractions provided by waste management companies today. This data could potentially be enhanced and integrated into a DLP. This can be used internally to set goals and control the waste flow more efficiently. By understanding how many tons of waste the project generates, and better yet how many tons of each waste fraction, materials for reuse could potentially be identified and saved more frequently.

Access to Climate Data

It is certain that accurate Climate Data, predominantly considering CO2 emission data, is very important for many of the users. For the transport-oriented DLPs, the main concern is regarding transports where combustion of fossil fuels is calculated. Whereas in the inventory-oriented DLPs, the substitution of a reused product's CO2 data is the main concern. Several users value this function to fulfill requirements for green bonds, climate certifications, and building EPDs.

Overall User-friendliness

To even consider implementing a DLP into the everyday workflow, the interface and user-friendliness were expressed by far to be the most important among the interviewed users. Several suggestions for interface changes and convenience for the single user were mentioned.

Reconditioning Services

Among the interviewees, many suggested that the original producer or tradesperson of a certain product or material could take more responsibility for opening for retake or buy-back of their materials. In the best case, these producers could potentially recondition and resell these reused and up-cycled products for a profit. By providing a service accessible through a certain DLP or separate digital platform, this retake procedure could become more effective and smooth for the parties involved, eventually resulting in more availability of reused products on the market and less impact on the climate.

Real Time Delivery Tracking

Several contractors and suppliers expressed the value of real-time tracking to better control and plan efficient deliveries to the construction site. While this is not inherently focused on circularity, the tracking system could adequately be applied for reverse transportation and returns of excess material, rather than resorting to waste transports just to get it off the site.

Many of the requested functions already exist, however, few people know how they can be utilized for circularity. This further suggests that knowledge of digital tools and workflows is a struggle for many companies within the construction industry. Also, there are several suggestions and requests for specific alterations of platform functions to target specific projects. There are also the requests for new functions not necessarily defined, rather highlighting a problem and leaving the function for the DLP developers to uncover.

4.6 Future Expectations of Circularity in Construction

In the interviews, the closing question focused on future expectations of circularity and logistics, where recurring themes were explored. One of these themes is the optimistic approach most of the interviewees kept. Saying that much is changing, and the topic of reuse and logistics is on everyone's tongues. The interviewees anticipate this to increase even more moving forward, saying that it is not a matter of whether reuse and logistic challenges will be solved, it is a question of when it will be solved. However, it is unclear who should bear the main responsibility for solving it. Some think that distribution networks with sophisticated digital solutions could be the key to achieving this, others think it comes down to legal requirements and economic incentives. A representative from a large real estate company speculates that there is a high chance of future legal requirements impacting the industry immensely in terms of sustainable operations, however, there is a large uncertainty about what exactly will transpire. A representative from Business Region also predicts the future direction to be uncertain, as some believe a centralized marketplace is crucial, while others prefer traditional procurement methods, making the development of the reuse market tough to predict. However, some of the leading real estate companies suggest that embracing sustainability involves learning to navigate and adapt to new ways of working, even if it means departing from traditional practices that may have been in place for decades. Meaning that there is an opportunity to profile more towards circular practices and being well-equipped for what may come.

Another common theme is the introduction and implementation process of digital tools, regardless of the problems that are being addressed. Several interviewees from contractors or real estate companies brought up that the internal digitalization level is low, not everyone understands new technology which can make new advanced digital tools inaccessible. However, as the younger generations start working in these companies, the digitalization level is slowly rising through internal education and knowledge sharing. Interviewees attest to learning from, and educating their colleagues when new digital tools are introduced. As professionals in the industry start working more with digital tools, the barrier is slightly lowered and the effects of efficient digital workflows can start to pay off. In addition to the DLPs discussed in this thesis, 3D visualization for logistics and databases for materials in environments like BIM could also play a significant role in helping stakeholders better understand spatial constraints and optimize logistical operations.

Coordination and collaboration were also identified by many of the interviewees as the future of circular practices. No one seems to contradict this statement, perhaps since the incentive to go all out as an alone actor could be very risky and hard to motivate. By splitting the responsibility between several actors and participating in partnerships, the risks could be lowered. Such collaborations are already starting to shape through initiatives such as "Handslaget" in Gothenburg. And the interviewees indicate that the future seems to entail even more collaborative effort and partnerships. Transparency of projects and available material for reuse is another thing many would like to see in the industry, making it easier to plan ahead and incorporate reused material earlier in the design phase of a project. This is where the concept of Reuse Hubs becomes very relevant and popular among the interviewees. By acquiring material in a network of several companies, it becomes much clearer what is available to use for new projects, without the need to order as many new materials. It is not foreign to some interviewees that suppliers that are slacking with reused product offerings, may lose some of their market shares to the reuse hubs, since their new products eventually may become less sought after. Some of the founders of such a reuse hub stated that if the suppliers do not want to do it, we will do it instead.

According to the interviewees, the future holds a completely new way of thinking about reuse, not as a secondhand or lower-quality project, but actually as a resource available to be reimplemented. One observation is from a large contractor company stating that their construction workers feel that it is valuable not to be wasteful of material, finding enjoyment in using and reusing temporary construction material as much as possible, but due to lack of time in the construction process might be forced to be more wasteful to save time. The representative of that same contractor company said that they ideally would like to spend less time transporting the construction materials on-site to save time to innovate and enhance waste management.

5

Discussion

The results and interview findings are combined and verified with the theoretical framework to be synthesized in this discussion chapter. This follows the structure of the topics presented in the results while providing a broader perspective and integrating different themes. The discussion takes off with the current state of reuse and logistics in practice, what is working well, what needs improving, and why that is. Following this are the current state of DLPs in Sweden and how they are being utilized. Afterward, the implementations and possible adaptations to increase circularity using DLPs are discussed. Lastly, future expectations from interviewees are discussed to understand what the future of circular logistics might entail.

5.1 The Current State of Circularity and Construction Logistics in Sweden

The current state of circularity in the Swedish construction and real estate industry is a clear reflection of mainly Kossila (2021) and positions circular strategies as central to the development of the industry. Tougher regulations and requirements related to climate impact are clear drivers and actors within the industry are expecting them to play a larger role in operations in the coming years, despite their exact scope being unknown at this time. One important aspect that was not mentioned in the literature but clearly reflected in interviews was the desire to contribute to sustainability and circularity expressed by a majority of the interviewees. The desire was explained to stem from an internal will to do good rather than from being forced by stricter rules and regulations. Many interviewees transcended a view of impatience and will to speed up work with circular initiatives. The biggest barriers were described as structural limitations in the scale of current initiatives and a lack of developed comprehensive solutions. Many respondents expressed that they wanted and were willing to contribute but did not know how to go about it. Furthermore, many examples were presented of actors that have started to adjust their business models and strategies in accordance with the Value Hill and Butterfly diagram frameworks developed by Achterberg et al. (2016) and The Ellen McArthur Foundation (2013). Especially the concept of capturing value in a broad sense was presented, moving away from the traditional focus on strict financial profit and instead accounting for aspects like reduced climate footprint to motivate initiatives.

SCM has a clear role to play in the development and implementation of circular strategies in the studied industry, confirming the findings of Kossila (2022). Integration of business processes and collaboration across a wide network of actors is described as paramount to successfully implementing large-scale, sustainable and long-term circular initiatives. The focus on relationships and broad understanding of the industrial dynamic highlights the importance of the softer aspects of SCM presented by Akkermans & Dellaert (2005) and Larsson & Halldorsson (2004). It can further be noted from the interviews that a unionist or intersectionist perspective on the relationship between SCM and logistics dominates the practical discourse. Interview questions directed at logistics were often elaborated on by respondents to include aspects closer to the definition of SCM than logistics, once again highlighting the importance of collaboration and a system view of circularity in combination with practical logistics activities in improving circularity. The interface between practical logistics activities and the wider logistics network has been identified as a clear target for DLPs. They have the ability to digitalize and diversify the material flows enabling more actors to enter the network and contribute with either specialized or general knowledge and capabilities .

Of the many aspects of logistics activities presented, planning was highlighted as integral for successful construction logistics in general and especially to contribute to increased circularity, connecting to the findings of Sullivan et al. (2010) about the benefits of a dedicated approach to construction logistics. There are currently few structures in place for large-scale circularity in the Swedish construction industry making it challenging to succeed without dedicated planning and collaboration among different actors. Barriers to circularity include the state of knowledge and attitude towards logistics as interviewed contractors stated that their logistical challenges in other areas were more pressing and in need of attention, leaving little room for the development of circular strategies. This state presents a clear opportunity for TPLs to further develop their knowledge and offerings to help steer the industry toward circularity. CCCs also present interesting opportunities for TPLs in this area as they allow for focus on both FL and RL flows and have been proven to reduce waste and improve overall logistics performance .

On this mission, DLPs can play a large role in the implementation of circular processes as well as integration and collaboration between actors. Several functions are already in place with a demonstrated record of successful implementation. At the same time, the findings of this report highlight that many of the desired functions in digital platforms already exist, meaning that many actors are unaware of both how they can contribute to circularity but also what tools are at their disposal.

The framework with three types of circular practices was developed for several reasons. Throughout the interview process, it became apparent that circularity meant drastically different things to different actors where one viewed it as a means to secure attractive green funding, another to minimize waste costs during demolition, and a third to integrate reused material in a new project to meet procurement requirements. These three motives are all clearly different but at the same time interconnected in the overall circularity process. The framework enables the term circularity to be differentiated while at the same time giving all types of actors from specialists engaged in single activities to large real estate companies responsible for entire networks of circulated items, the ability to better understand each other and the circular construction environment. This comprehensive understanding and collaboration was highlighted as integral throughout literature about SCM, logistics, and circularity by Lambert & Cooper (2000), Kossila (2021), Christopher (2011) and also described by interviewees as limited in the industry today.

The framework is also a reflection of the circular initiatives that have recently been undertaken in the construction industry. CCBuild gathers actors from all over the industry and Handslaget property owners in western Sweden, to create networks and platforms where ideas and collaboration are allowed to spur. Specialized actors have started gathering single material types like bricks, carpets, and indoor ceilings to recondition and sell. More comprehensive grips have also been taken like REbygg in Gothenburg, the collaboration among large real estate companies in Stockholm, and Wiklunds´ operations also in the Stockholm region. These are all examples of what Kossila (2021) describes as gap exploiters and the pattern is similar to what is described in literature. All these actors have identified gaps in the current industry and realized that they possess certain capabilities that enable them to exploit these gaps.

REbygg and Wiklunds are especially interesting in this regard as the gaps they are exploiting are quite large in comparison to just reconditioning one kind of material. Both actors highlight how they realized that they already possessed most of the capabilities needed to launch large-scale initiatives and decided to use those capabilities. Both initiatives are also governed by similar digital platforms that allow for primarily handling inventory.

Despite these larger and more comprehensive initiatives a majority of interviewees highlight that circular initiatives that really have an impact on the entire industry will require large producers and distributors to take action. It is described that only they have the capacity to handle the amounts needed but also the competence to understand what actions are needed to reintroduce products at the highest possible point of the value hill presented by Achterberg et al. (2016). This type of producer responsibility was discussed by Kossila (2021) and described as an effective way to induce circularity in entire industries either voluntarily or by regulations. It´s been proven to work at small scales by Beijer in the case of reusing wood and is in line with Kossila's (2021) arguments that actors should consider two additional P:s in the traditional 4P-marketing mix where a product's lifespan includes pre- and post-use value and activities. The producers are also the ones most capable of remanufacturing and reconditioning their own products which present an interesting solution to the issue of certification and quality assurance currently holding back circularity in construction. The combination of superior value capturing and the ability to certify and then reintroduce material through established supply chains presents an interesting opportunity for producers and distributors to pioneer large-scale circularity in the Swedish construction industry. This notion also connects to Kossila's (2022) findings regarding producers' responsibility and how it either regulated or self-induced by an industry can be a way for the construction industry to nudge itself towards increased circularity.

The frameworks in this thesis, both the three types of circularity but also the four scenarios presented by Bosch et al. (2023) were used in order to anchor and create structures reflecting the current state of circularity in the construction industry. Despite the structure provided by the frameworks it is important to note that they are not mutually exclusive as most circular initiatives transcend scenarios and include different types of circularity. The uncertainty in the industry combined with the aim of wanting to capture the state of circularity however made it necessary to break down and structure the findings in this way. In turn, the hope is that understanding the theoretical structures will benefit actors in understanding both their own potentially niched contribution but also how this contribution relates to other actors across a wider network.

This sentiment relates to the discussion of how the industry is grappling with implementing large-scale circular initiatives and establishing truly sustainable business models that are financially, environmentally, and socially viable in accordance with Kossila (2022). As the circumstances and properties of construction projects are highly dependent on the situation, so must the approach to circularity to achieve maximum value capturing. By using the frameworks presented in this thesis actors could more easily position themselves and their projects within this context to develop the right circular solution. Building on this notion, the same principles are applicable to different material types and products. Bricks and ceiling tiles have already proven to be relatively unproblematic to circulate back into new projects and could thus provide guidance for similar future initiatives. For these material types and products, the scale and volume of operations become key as they will be re-integrated into the material supply chain and new projects without much adjustment compared to previously unused products. The current initiatives in these processes closely resemble the model of gap-exploiters presented by Kossila (2021) and seem to be the most beneficial way forward until larger producers and distributors start integrating them into their business models.

Other materials and especially structural components require more collaboration between actors, stretching between different scenarios and types of circularity described in this thesis. The described needs from interviews go hand in hand with the dedicated approach to construction logistics described by Sullivan et al. (2010). The aforementioned project by Framtiden is a great example of how collaboration and involvement of actors with the right competence can lead to large-scale circularity in individual projects. The processes however need to become more streamlined to reduce time consumption and other financially costly activities. Here, initiatives like Handslaget have the possibility to bring property owners and other actors together and provide a platform where they can collaborate and plan for future projects where demolition in one project corresponds with new development somewhere else.

5.2 The Current State of DLPs in Sweden

Currently, there are several DLPs available on the Swedish market addressing the issues included in Type I, II, and III of circular practices in construction presented in Chapter 4.2, mostly applying to the logistic activities in Type II. Some platforms have their origin in industries outside of construction and are later adapted to function specifically to the processes in construction. Other DLPs were created by digitalizing and planning the traditional delivery systems, commonly operating through manual methods relying on whiteboards, phone calls, and on-site verbal communication. Thirdly, some DLPs derive from solving one or several specific issues, targeting niche parts of the construction industry, and trying to solve these issues in innovative ways.

The current understanding of what DLPs are and what functions they can provide is generally lacking in the construction industry. Many actors, even those who already use DLPs, are not always aware of their functionality and there are uncertainties about how DLPs can contribute to increased circularity. There is an identified need for education and knowledge sharing on this topic to utilize these tools on a larger scale, highlighting the importance of collaboration and common initiatives. It also raises the potential for TPLs and other actors to become specialized in managing digital solutions for construction clients, increasing overall efficiency and minimizing climate impact while further improving the role of the logistics specialist highlighted by Sullivan et al. (2010) for its potential to drive development in construction logistics.

While the interviews revealed that DLPs are seen as having significant potential to enable circular material flows within individual construction projects, the diversity of platform types and developers could pose challenges in reaching the large-scale implementation envisioned by industry stakeholders. The DLPs currently in use by several actors generally work well on a small scale where more simple tasks are handled internally by one actor, as demonstrated by examples in Scenarios 1, 2, and 3 from Chapter 4.4. However, for the potential to upscaling and usage of DLPs, more actors need to start collaborating in the digital environment. The general sense among DLP developers is promising in this regard, as they state that they are willing to start developing their functions to increase circular practices as requested.

When speaking to interviewees, it became evident how different actors are trying to impact the development of DLPs. Some DLP providers take the approach of tailoring functionality to tend to the various needs of their clients, as a part of their offering. While this may be a successful approach for some DLPs, other providers argue that the customers do not always know what functionality they want, or that a problem may be solved in a new more efficient way. Hence, the newer DLP providers tend to innovate and provide new functionality in a more pre-determined and packaged solution. There are recurring descriptions from users, indicating that they do not necessarily prefer one approach over the other. The interchangeability of a tailor-made solution can be preferred in some cases, but this might limit the functionality in the end, since these solutions often implicate a more advanced interface which may compromise user-friendliness and effectiveness. The alternate approach of providing pre-existing functions is usually more thoughtful in terms of graphic design, usability, and interface, although this comes with the risk of not being sufficient for all types of projects, due to the special circumstances involved in the construction process (Sullivan et al., 2010).

DLP users describe their workflows very differently depending on the project and the platform used. There is currently no consensus on what the best practice for utilizing DLPs is since the goal of using them can vary from client to client. By adopting digital standards for the usage of DLPs, similar to BEAst, users and developers may find more streamlined and efficient workflows for the digital planning of circular material flows.

5.3 Utilizing and Developing DLPs to Increase Circularity in Construction

From the interviews, it became clear that the users of Digital Logistics Platforms had several requests and ideas for improved functionality that could support and provide more efficiency to their workflows. However, it was equally important that this was to happen without compromising on the user-friendliness of using the platform. The developers and representatives of the various DLPs showed openness and enthusiasm in trying to facilitate these new demands for their customers. The discussion also arises about how some of the existing functions could be tweaked and improved to better facilitate logistic activities for reuse, especially regarding transport, climate data, and reuse hub operations. The main hindrance to this development is mainly a financial question tied to the cost of implementing these platforms. Even though the theory of efficient logistics has been proven to increase efficiency and save costs by numerous scholars, (Abrahamsson et al., 2019; Aloini et al., 2012; Ekeskär & Rudberg, 2016; Janné & Rudberg, 2022) clients are still hesitant to invest in logistic services such as a DLP, not realizing their true value and benefits. It is however anticipated by some of the interviewees that if less focus is put on the upfront costs of acquiring a DLP, and more focus is put on long-term economic growth in combination with values of climate impact such as CO2 eq., there may be a “doubled value” in the implementation of certain DLPs, saving on costs from logistics while also minimizing climate impact. Because of this effect, DLPs may have the potential to be the mortar to bricks of circular construction logistics. It is however important that the platforms become more integrated to overcome the small-scale syndrome and fulfill this potential.

Since the logistic activities of quality assurance and reconditioning are currently lacking from most DLPs, there may be a business opportunity to innovate and provide new solutions addressing this problem. One of the platform providers discussed their idea to automize the sorting of reusable materials through visual scanning combined with AI, to make a streamlined and fast first sorting for initial material quality. This could lead to the correct resources being put towards certifying the most eligible materials, not having to go through the ones not fulfilling minimum requirements. This is however at an early idea stage and is currently being tested, however, the initiative and innovative ambition indicate that cutting-edge technology could potentially be applicable to improve circular practices as well. Reconditioning, however, is in its nature a more physically challenging activity, requiring expertise in restoration and production. Most interviewees agree that the most obvious and ideal provider of reconditioning is the original producer or competitor with equal expertise in said material. This would mean that a window specialist or distributor could potentially create a business around retaining used windows, quality assures them, and refurbishing them, to later sell back to the market regardless of buyer, making the window specialist a so-called “Gap-exploiter” (Kossila, 2022). The way DLP developers see the reconditioning activity as a part of their digitalized platform would be mainly for providing the traditional logistic activities to already reconditioned products such as transportation, storage, and transaction services. It could thus be argued that reconditioning in itself may not be a logistic activity but in terms of what the process of reconditioning means, many logistic activities will always be required, making the process a logistic activity as its whole.

6
Recommendations

This chapter will provide a set of short recommendations based on the main findings of this report, summarizing a selection of helpful insights from professionals in the industry wishing to improve their circular practices. The recommendations stem from input from professionals who have either implemented these solutions themselves or encouraged others to implement them in the future. The recommendations correlate to the Three Types of Circular Practices, as presented and explained in detail in section 4.2. The recommendations are also sorted according to each main topic defined within their respective type of circular practice.

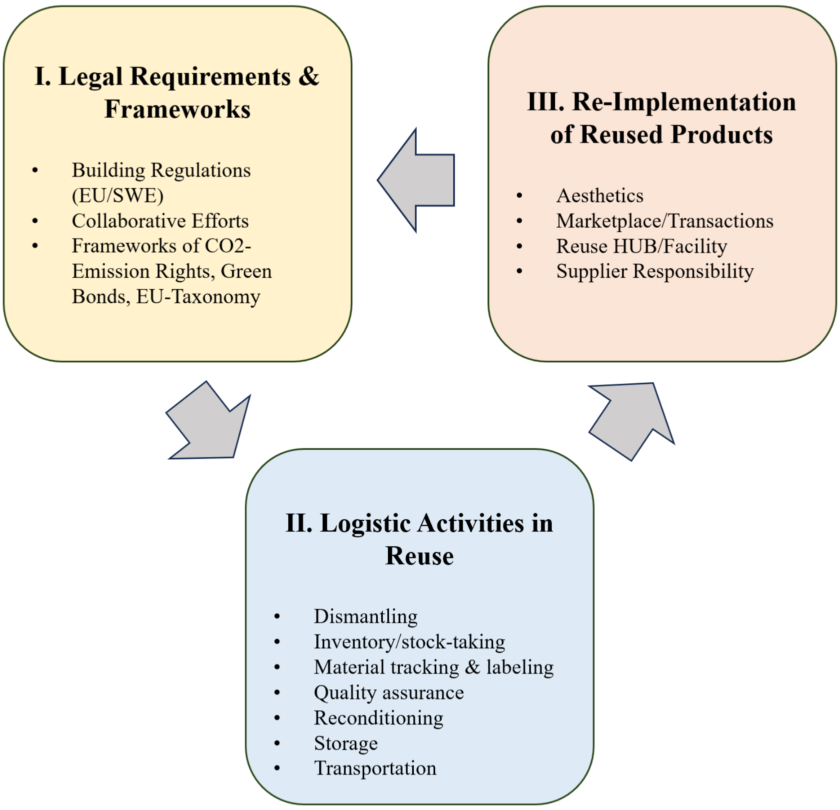

Figure 6.1: *Three Types of Circular Practices in Construction.*

Recommendations for Type I. Legal Requirements & Frameworks		
Type	**Topic**	**Recommendation**
I	Building Regulations	*When feasible, consider expanding beyond minimum requirements and regulations to push circularity even further, implement own indexes for circularity measuring the values besides the economical, be proud of the progress and share successful implementations with other actors.*
I	Collaborative Efforts	*Be susceptible and open to collaborative initiatives, create partnerships with actors who align with your own company's visions. Sharing knowledge and creating a community for collaboration is essential to drive circular practices forward.*
I	Frameworks of Emission Rights, Green Bonds, EU-Taxonomy	*Evaluate and consider existing frameworks closely and try to identify what this implies not only to your own company but for the industry as a whole, draw benefits from green bonds to experiment and progress circular initiatives by being proactive, the EU-Taxonomy provides useful information and guidelines so make sure to use them.*

Figure 6.2: *Recommendations for Type I.*

Recommendations for Type II. Logistic Activities in Reuse		
Type	**Topic**	**Recommendation**
II	Dismantling	*Increase integration between inventory apps and traditional logistic DLPs to handle dismantled products holistically in the digital space, from extraction to reimplementation.*
II	Inventory	*Develop inventory apps further with feedback from professionals, considering multiple types of users and products.*
II	Material Tracking	*Advance tracking capabilities and transparency between supplier and receiver through real-time tracking and follow-up.*
II	Quality Assurance	*Provide information needed to perform quality assurances for the reused products & materials. Develop new functions for DLPs targeting the issue of quality assurance.*
II	Reconditioning	*Include options for reconditioning services as a part of the DLP stock to see potential upcycling opportunities and offerings.*
II	Storage	*Provide dedicated functions to store and sell stock of reused products. The value chain can be applied, large complex materials go straight to the new site, stackable products could be stored in reuse hubs, and smaller volumes of some products might be sold to the private market through existing auction sites.*
II	Transportation	*Integrate third party transportation solutions to be available on demand, powerful when combined with existing transports already going to or from a construction site.*

Figure 6.3: *Recommendations for Type II.*

Recommendations for Type III. Re-Implementation of Reuse Products		
Type	**Topic**	**Recommendation**
III	Aesthethics	*Reconsider traditional norms of aesthetics increasing openness to design using reused and reconditioned materials for unique designs such as bricolage and vintage expressions.*
III	Marketplace/Transactions	*Develop and use existing marketplaces and push for increased and streamlined digital transaction systems to stimulate the reuse market, it should become at least as easy as buying completely new products.*
III	Reuse HUB/Facility	*Contribute to existing hubs locally and consider partnering up. If no existing hub is present advocate for starting one, once the hub is setup make sure to use it and stimulate the material flow by trading with partnering companies. Learn and share your experiences.*
III	Supplier Responsibility	*Encourage the suppliers towards offering more reuse products to your projects, suggesting they retake worn materials to refurbish and create new products, or at least retake excessive materials that would otherwise be considered waste on-site.*

Figure 6.4: *Recommendations for Type III.*

7 Conclusion

The goal of this thesis has been to investigate how the interface between construction logistics, circularity, and digitalization can contribute to increased circular material flows within the Swedish construction industry. The described process can be further divided into different aims that together contribute to the overarching target. Firstly, the aim was to capture an image of the current state of circularity in the construction industry and the needs of its actors to transition to circular practices. Secondly, the aim was to map existing Digital Logistics Platforms (DLP) available to the Swedish construction industry and what functions they have. Finally, these two were combined to display how requirements for circularity can be met by DLPs, and what functions that need to be developed further. Ultimately, the thesis aims to guide practitioners of all kinds in the Swedish construction industry to understand better the current state of circularity and how they can utilize DLPs from their point of infliction to increase their circular practices.

Based on the aim, the following three research questions were formulated:

RQ1 *How are workflows for circularity and construction logistics today and how may they be portrayed in the future?*

RQ2 *What is the current state of Digital Logistics Platforms in Sweden, and how do they facilitate circularity?*

RQ3 *Can increased circularity in construction be supported by improving functionality in Digital Logistic Platforms?*

To answer the research questions an abductive research approach was chosen where a literature review covering circularity, Supply Chain Management, construction logistics, and digitalization was conducted together with an interview study. The interview study consisted of 30 interviews with actors from 29 companies representing large parts of the Swedish construction industry to obtain a nuanced and thorough image of the industry.

The following section will evaluate and conclude this thesis based on the three research questions.

RQ1: What is the Current State of Circularity in the Swedish Construction Industry?

The current state of circularity in the Swedish construction industry is still largely in its infancy with few truly large-scale difference-making initiatives undertaken. There is however a large interest in working with circularity among actors in the industry and new initiatives and ideas are constantly being developed, indicating a quick development in the coming years. This interest is mainly driven by stricter regulations being imposed as well as a sense that contributing to sustainable working methods is the morally and ethically right thing to do. The circular initiatives of today are generally specific, targeting one type of product and material to create financially viable business models. There are also examples of actors taking more comprehensive grips gathering other actors and taking responsibility for the entire chain of circularity. Large producers and distributors are highlighted for their potential to contribute to large-scale initiatives and the general sentiment is that truly sustainable circular practices will not be possible without a producer taking responsibility for them. Property owners also play a large role in the circular movement as they are the ones funding the industry and thus can create demands for circularity in new projects undertaken, forcing other actors in the industry to adapt. Despite the limited potential for large-scale circular initiatives today, some work can still be done by collaboration among existing actors and competence. For this, a framework to nuance and differentiate the term circularity into three types has been presented to aid professionals in grasping and understanding the entire picture of circularity. Using the framework, all kinds of actors can gain a better understanding of what is needed to successfully implement circular initiatives, how their competence fits into the process and what actors and tools they need to collaborate with.

RQ2: What is the Current State of Digital Logistics Platforms in Sweden?

In this thesis nine available and widely used platforms in Sweden have been examined, all of which are different and can be utilized for multiple purposes. The platforms have existing functions addressing the logistics activities deemed important for circular material flows, with varying capabilities. Three categories of DLPs were identified, *High integration*, *Calendar specialized*, and *Niche specialized*. The platforms are generally described to be working well on smaller scales and individual projects. Furthermore, recent development has seen an increase in them being used for circular material flows, governing activities such as transportation and inventory among several actors and projects. While interviewed users of platforms describe DLPs as useful for enabling circular material flows, the diversity of platform types and developers could risk prolonging the potential of upscaling digital processes. Similarly, because of the many actors providing platforms, there are different opinions about and processes of how platforms are to be developed. Some developers tailor functionality for their clients on demand while others invent functionality before offering it to their customers potentially creating a differentiated rather than unified digital environment. While the usage of DLPs is increasing there is still a sense of underutilization present. Many actors are unaware of which functions are available to them which in turn opens the possibility for swift future development.

RQ3: How can DLPs be Utilized and Developed to Increase Circularity in Construction?

By connecting the examined DLPs to four scenarios for circular material flows in construction it was concluded that DLPs are being used but predominantly on smaller scales. With the introduction of large-scale initiatives, DLPs can potentially provide even more benefits in coordinating and providing functionality that can be fully utilized. This also opens for new and improved functionality to be developed for DLPs, especially within the realm of system integration where actors in the industry have a large need to be able to communicate and collaborate between projects and organizations. System integration would also improve efficiency in current initiatives where several platforms are utilized for functions within the same project instead of having one single digital solution. A list of functionalities for increased circularity was created from requests by the interviewed DLP users. Among those requests, the most recurring ones were the functions for quality assurance, system integration, and improved user-friendliness. Further development within these areas would provide the industry with much-needed tools to tackle their dynamic environment with increased demands for circularity and digitalization.

To conclude, this investigation into the interface between circularity, and construction logistics has yielded a view of the Swedish construction industry as underdeveloped yet eager to evolve. Circularity is one of the most prominent trends in the industry and Digital Logistics Platforms have the potential to aid further circular development with their current functions and by developing new ones. The future development of large-scale circular practices hinges largely on the attitudes and actions of large producers, distributors, and property owners. For other smaller actors and specialists, circular initiatives will require collaboration and understanding to fully grasp and comprehend which competences and tools are needed to succeed. In these processes, existing and evolved Digital Logistics Platforms can contribute largely to more streamlined, efficient and collaborative practices.

7.1 Future Research and Developement

Several connected areas of research were identified from the research conducted in this thesis. The following topics and themes are suggested as a potential continuation of research in the area of circularity and construction logistics.

The Role of Material Producers

The first and most clear topic that requires further research is how the role and attitude of material producers/suppliers in offering reuse options to their original products. Understanding what role, the producers have in reconditioning and ensuring the quality of their reuse product options. From the interviews, a collection of actors already providing reuse options as an integrated part of their business was found. Starting with these established actors, understanding how they have developed their businesses, and then comparing these with material producers who are not offering reuse products and comparing them.

Efficient Workflows for Inventory and Stock-taking

Another main area viable for future research would be evaluating the workflow process of specific logistic activities identified for circular material flows. Understanding a specific logistics activity more in-depth. Since the logistics activity of creating inventory stock, this could potentially be a good place to start. Looking at how to improve efficient workflows for inventory stock data, and perhaps further integrating these with other DLPs and eventually BIM models, to ease the implementation of reuse products.

Business Models in Dismantling Contracts for Circularity

Another central part of the thesis is the role of demolition and dismantling contractors, who are responsible for the logistic activity of extracting materials viable for reuse. To find new and efficient ways to successfully dismantle and create more stock of reused products, such business models and practices could be evaluated and compared. As more contractors start showing interest in dismantling projects, there are potential improvements to make this more streamlined and viable.

Best Practices and Learnings from Reuse Hubs

The newly established reuse hubs in Sweden can be further studied to find out what is working and what is missing. Comparing operations, business models, and geographical impacts from different types of reuse hubs in Sweden. This could include observation studies and site visits to evaluate and explore how these could be improved.

References

Achterberg, E., Hinfelaar, J., & Bocken, N. (2016). *Master circular business models with the Value Hill.* Circle Economy, Utrecht. https://research.tudelft.nl/en/publications/master-circular-business-models-with-the-value-hill (Collected 2024-05-02)

Agapiou, A., Clausen, L. E., Flanagan, R., Norman, G., & Notman, D. (1998). *The role of logistics in the materials flow control process.* Construction Management & Economics, 16(2), 131-137. https://doi.org/10.1080/014461998372420

Akkermans, H. and Dellaert, N. (2005), *The rediscovery of industrial dynamics: the contribution of system dynamics to supply chain management in a dynamic and fragmented world.* Syst. Dyn. Rev., 21: 173-186. https://doi.org/10.1002/sdr.317

Aloini, D., Dulmin, R., & Mininno, V. (2012). *Risk assessment in ERP projects.* information systems, 37(3), 183-199. http://dx.doi.org/10.1016/j.is.2011.10.001

Bell E., Bryman A. and Harley B. (2015) *Business research methods.* OUP, Oxford.

Bosch, P., Janné, M., Olsson, J., Sezer, A., Sundquist, V. & Wadmark, P. (2023). *Bygglogistikens roll i cirkulära materialflöden.* https://research.chalmers.se/publication/537456 (Collected 2024-02-05)

Boverket (2023). *Gränsvärde för byggnaders klimatpåverkan och en utökad klimatdeklaration.* https://www.boverket.se/sv/om-boverket/publicerat-av-boverket/pub likationer/2023/gransvarde-klimatpaverkan/ (Collected 2024-06-06)

Boverket (2024a). *Bygg- och fastighetssektorns energianvändning uppdelat på förnybar energi, fossil energi och kärnkraft.* https://www.boverket.se/sv/byggande/hallbart-byggande-och-forvaltning/miljo indikatorer—aktuell-status/energianvandning/ (Collected 2024-02-07)

Boverket (2024b). *Utsläpp av växthusgaser från bygg- och fastighetssektorn.* https://www.boverket.se/sv/byggande/hallbart-byggande-och-forvaltning/miljo indikatorer—aktuell-status/vaxthusgaser/ (Collected 2024-02-07)

Bowersox, D. J., Closs, D. J., & Cooper, M. B. (2020). *Supply Chain Logistics*

Management (5th ed.). McGraw-Hill Education.

Buser, M and Andersson, R. (2021) *Circular Building and New Business Models: What Opportunity for the Contractors?* In: Scott, L and Neilson, C J (Eds) Proceedings of the 37th Annual ARCOM Conference, 6-7 September 2021, UK, Association of Researchers in Construction Management, 604-613 https://ris.utwente.nl/ws/portalfiles/portal/276642493/2021_Indexed_Papers.pdf#page=604 (Collected 2024-02-07)

Challender, J., & Whitaker, R. (2019). *The Client Role in Successful Construction Projects.* Routledge. https://doi.org/10.1201/9781315164458

Charef, R., Morel, J. C., & Rakhshan, K. (2021). *Barriers to implementing the circular economy in the construction industry: A critical review.* Sustainability, 13(23), 12989. http://dx.doi.org/10.3390/su132312989

Christopher, M. (2011) *Logistics and Supply Chain Management.* 4th Edition, Prentice Hall, London.

Council of Logistics Management (CLM) (1998), *What It's All About*, Vol. 4 No. 6., Oak Brook, IL.

Council of Supply Chain Management Professionals. (2021).*CSCMP Supply Chain Management Definitions and Glossary.*https://cscmp.org/CSCMP/Educate/SCM_Definitions_and_Glossary_of_Terms.aspx (Collected 20204-4-24)

Ding, L., Wang, T., & Chan, P. W. (2023). *Forward and reverse logistics for circular economy in construction: A systematic literature review.* Journal of Cleaner Production, 388, 135981. https://doi.org/10.1016/j.jclepro.2023.135981

Dubois, A. and Gadde, L. (2002) *Systematic Combining: An Abductive Approach to Case Research.* Journal of Business Research, 55, 553-560. https://doi.org/10.1016/S0148-2963(00)00195-8

Dubois, A., Hulthén, K., & Sundquist, V. (2019). *Organising logistics and transport activities in construction.* The international journal of logistics management, 30(2), 620-640. http://dx.doi.org/10.1108/IJLM-12-2017-0325

Ellen MacArthur Foundation, *Towards the circular economy Vol. 1: an economic and business rationale for an accelerated transition* (2013). https://www.ellenmacarthurfoundation.org/towards-the-circular-economy-vol-1-an-economic-and-business-rationale-for-an (Collected 2024-02-21)

European Commission, 2015.*Closing the loop–an EU action plan for the circular economy.* COM (2015) 614 final. Brussels: European Commission. https://www.eea.europa.eu/policy-documents/com-2015-0614-final (Collected 2024-

02-21)

European Commission, 2020. *A new circular economy action plan for a cleaner and more competitive Europe.* Brussels: European Commission. https://environment.ec.europa.eu/strategy/circular-economy-action-plan_en (Collected 2024-02-21)

European Commission, Joint Research Centre, Battiston, S., Alessi, L., Roncoroni, A. (2019). *The EU sustainability taxonomy: a financial impact assessment*, Publications Office.https://data.europa.eu/doi/10.2760/347810 (Collected 2024-02-21)

Flick U. (2020) *Introducing research methodology (third edition).* Sage, Thousand Oaks.

Fredriksson, A., Abrahamsson, M., Kjellsdotter Ivert, L., Huge-Brodin, M., Engevall, S. (2019). *Slutrapport Fossilfri Bygglogistik.* https://www.diva-portal.org/smash/get/diva2:1658172/FULLTEXT01.pdf (Collected 2024-05-06)

Giunipero, L.C. and Brand, R.R. (1996), *"Purchasing's Role in Supply Chain Management"*, The International Journal of Logistics Management, Vol. 7 No. 1, pp. 29-38. https://doi.org/10.1108/09574099610805412

Geissdoerfer, M., Savaget, P., Bocken, N. M., & Hultink, E. J. (2017). *The Circular Economy–A new sustainability paradigm?.* Journal of cleaner production, 143, 757-768. https://doi.org/10.1016/j.jclepro.2016.12.048

Guerlain, Cindy & Renault, Samuel & Ferrero, Francesco. (2019). *Understanding Construction Logistics in Urban Areas and Lowering Its Environmental Impact: A Focus on Construction Consolidation Centres.* Sustainability. 11. 10.3390/su11216118. http://dx.doi.org/10.3390/su11216118

Hobbs, J.E. (1996) *A transaction cost approach to supply chain management.* Supply Chain Management, 1, (2), pp. 15–27

IPCC (2022) Cabeza, L. F., Q. Bai, P. Bertoldi, J.M. Kihila, A.F.P. Lucena, É. Mata, S. Mirasgedis, A. Novikova, Y. Saheb, (2022): *Buildings. In IPCC, 2022: Climate Change 2022: Mitigation of Climate Change. Contribution of Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* [P.R. Shukla, J. Skea, R. Slade, A. Al Khourdajie, R. van Diemen, D. McCollum, M. Pathak, S. Some, P. Vyas, R. Fradera, M. Belkacemi, A. Hasija, G. Lisboa, S. Luz, J. Malley, (eds.)]. Cambridge University Press, Cambridge, UK and New York, NY, USA. https://doi.org/10.1017/9781009157926.011

Janné, M., & Rudberg, M. (2022). *Effects of employing third-party logistics arrangements in construction projects.* Production Planning & Control, 33(1), 71–83. https://doi.org/10.1080/09537287.2020.1821925

Jayaraman, V., & Luo, Y. (2007). *Creating Competitive Advantages Through New Value Creation: A Reverse Logistics Perspective.* Academy of Management Perspectives, 21(2), 56-73. http://dx.doi.org/10.5465/AMP.2007.25356512

King, A. M., Burgess, S. C., Ijomah, W., & McMahon, C. A. (2006). *Reducing waste: repair, recondition, remanufacture or recycle?.* Sustainable development, 14(4), 257-267. https://doi.org/10.1002/sd.271

Kirchherr, J., Reike, D., & Hekkert, M. (2017). *Conceptualizing the circular economy: An analysis of 114 definitions.* Resources, conservation and recycling, 127, 221-232. https://doi.org/10.1016/j.resconrec.2017.09.005

Koskela, L. (1999). *Management of production in construction: A theoretical view.* http://usir.salford.ac.uk/id/eprint/9429/1/1999 Management of production in construction a theoretical view.pdf. (Collected 2024-05-07)

Kossila, L. (2021). *Circular economy and sustainability in supply chain management.* Lund: Studentlitteratur.

Kossila, L. (2022). *Circular Logistics in the Nordics.* Lund: Studentlitteratur

Lambert, D. M., & Cooper, M. C. (2000). *Issues in supply chain management. Industrial marketing management*, 29(1), 65-83. https://doi.org/10.1016/S0019-8501(99)00113-3

Lambert, D., Stock, J. R., & Ellram, L. M. (1998). *Fundamentals of logistics management.* McGraw-Hill.

Lee, D., & Lee, S. (2021). *Digital twin for supply chain coordination in modular construction.* Applied Sciences, 11(13), 5909. https://doi.org/10.3390/app11135909

Larson, P. D., & Halldorsson, A. (2004). *Logistics versus supply chain management: an international survey.* International Journal of Logistics: Research and Applications, 7(1), 17-31. http://dx.doi.org/10.1080/13675560310001619240

Lima, A. T., Simoes, S., Aloini, D., Zerbino, P., Oikonomou, T. I., Karytsas, S., ... & Bimpizas-Pinis, M. (2023). *Climate mitigation models need to become circular: let's start with the construction sector.* Resources, Conservation and Recycling, 190. https://doi.org/10.1016/j.resconrec.2022.106808

Lundesjo, G. (2009). *Implementing construction consolidation centres.* In M. Kutz (Ed.), Handbook of transportation engineering (2nd ed., pp. 30-1–30-16). McGraw-Hill.

Mentzer, J. T., DeWitt, W., Keebler, J. S., Min, S., Nix, N. W., & Smith, C. D.

(2001). *Defining supply chain management.* Journal of Business Logistics, 22(2), 1–25. https://doi.org/10.1002/j.2158-1592.2001.tb00001.x

Muerza, Victoria & Guerlain, Cindy. (2021). *Sustainable Construction Logistics in Urban Areas: A Framework for Assessing the Suitability of the Implementation of Construction Consolidation Centres.* Sustainability. 13. 7349. 10.3390/su13137349. http://dx.doi.org/10.3390/su13137349

Olhager, J., *Supply chain management - Produktion och logistik i försörjningskedjor.* Lund, Studentlitteratur 2019

Parrish, K., & Chester, M. (2014).*Life-cycle assessment for construction of sustainable infrastructure.* Practice periodical on structural design and construction, 19(1), 89-94. https://doi.org/10.1061/(ASCE)SC.1943-5576.0000187

Pokharel, S., & Mutha, A. (2009). *Perspectives in reverse logistics: A review.* Resources, Conservation and Recycling, 53(4), 175-182. http://dx.doi.org/10.1016/j.resconrec.2008.11.006

Singh, V., Gu, N., & Wang, X. (2011). *A theoretical framework of a BIM-based multi-disciplinary collaboration platform.* Automation in construction, 20(2), 134-144. https://doi.org/10.1016/j.autcon.2010.09.011

Stock, J. R., & Mulki, J. P. (2009). P*roduct returns processing: an examination of practices of manufacturers, wholesalers/distributors, and retailers.* Journal of Business Logistics, 30(1), 33-62. http://dx.doi.org/10.1002/j.2158-1592.2009.tb00098.x

Strauss, A., & Corbin, J. (1998). *Basics of qualitative research: Techniques and procedures for developing grounded theory (2nd ed.).* Sage Publications, Inc.

Sullivan, G., Barthorpe, S., & Robbins, S. (2011). *Managing construction logistics.* John Wiley & Sons.

Ugochukwu, N. A., Goyal, S. B., & Arumugam, S. (2022). *Blockchain-based IoT-enabled system for secure and efficient logistics management in the era of IR 4.0.* Journal of Nanomaterials, 2022. http://dx.doi.org/10.1155/2022/7295395

Upphandlingsmyndigheten (The Swedish Agency for Public Procurement) (2023). *Circular procurement guidance.*https://www.upphandlingsmyndigheten.se/en/sustainable-public-procurement/sustainable-procurement-criteria/ (Collected 2024-05-21)

Vegter, D., van Hillegersberg, J., Olthaar, M., *Supply chains in circular business models: processes and performance objectives.* Resources, conservation and recycling 162, 2020. https://doi.org/10.1016/j.resconrec.2020.105046

Vrijhoef, R., & Koskela, L. (2000). *The four roles of supply chain management in* *construction.* European journal of purchasing & supply management, 6(3-4), 169-178. https://doi.org/10.1016/S0969-7012(00)00013-7

Wennersjö, M., Gerhardsson, H., Moberg, S., Loh Lindholm, C., & Andersson, J. (2021). *Etablering av en storskalig marknad för återbruk i bygg-och fastighetssektorn: Återbruksrelaterade tjänster för att främja en storskalig återbruksmarknad i Göteborgsregionen.* https://www.diva-portal.org/smash/get/diva2:1568781/FULLTEXT02 (Collected 2024-02-21)

Wijkman, A., (2019). *Circular economy in cities requires a systems approach. OECD/EC Workshop on 5 July 2019 Within the Workshop Series "Managing Environmental and Energy Transitions for Regions and Cities Circular Economy in Cities.* Paris.https://www.oecd.org/cfe/regionaldevelopment/Wijkman-2019-Circular-Economy-Cities-Requires-Systems-Approach.pdf (Collected 2024-02-21)

Winch, G. M. (2003). *How innovative is construction? Comparing aggregated data on construction innovation and other sectors–a case of apples and pears.* Construction management and economics, 21(6), 651-654. http://dx.doi.org/10.1080/0144619032000113708

Zhang, C., Hu, M., Di Maio, F., Sprecher, B., Yang, X., & Tukker, A. (2022). *An overview of the waste hierarchy framework for analyzing the circularity in construction and demolition waste management in Europe.* Science of the Total Environment, 803, 149892. https://doi.org/10.1016/j.scitotenv.2021.149892

A

Interview Guideline

The following questions are the basis upon which the interviews were conducted. The questions were thoroughly chosen to act as a starting point and serve to find a baseline for the interview. Being semi-structured, some questions are subject to change slightly and/or be carefully adjusted to underline clarity to the respondents. Occasionally added follow-up questions, and questions specific to a certain respondent are not included.

Opening Questions:

- Can we record and transcribe this interview?
- Is it okay to disclose your professional role and company name in the thesis?
- Could you introduce yourself including your background and your current role at your company?

Specific Questions (Depending on Respondent):

1. *Construction Logistics*
    - How do you work with Construction Logistics?
        - What are the challenges you experience when working with Construction Logistics?
        - What do you require to improve the way you work with Construction Logistics?
        - Which Digital Platforms do you use to perform logistics tasks?

2. *Circularity in Construction*
    - How do you work with Circularity?
        - When in your process do you start thinking of Circularity?
        - What are the most recurring hindrances?
    - To what extent is Circularity being implemented in your projects?
        - What do you require to increase your circular practices?
        - Which Digital Platforms do you use to perform circular practices?
        - How important is the client to drive circular agendas?

3. *Digital Logistics Platforms*
    - How do you work with Digital Logistics Platforms?
        - Which functions are important for your workflow?
        - When in your process do you start thinking of DLP?
        - What are the most recurring hindrances?
    - To what extent is DLP being implemented in projects?
        - What aid can a DLP provide to a project aiming to become more circular?

Perception of the industry:

- What is your perception of the industry today regarding circularity and construction logistics?
    - What opportunities are there?
    - What are the hindrances?
- What needs to be done in order to shift the perception of the construction industry in regard to circular material flows and construction logistics?

Ending notes:

- Is there anything else you would like to add that we have not discussed?
- Do you have any suggestions for candidates for us to interview next?
- Would you like to receive and review a copy of the final thesis when it is done?

B

Codes and Cases

The following codes were used to categorize and provide structure to the collected data from the interviews. The hierarchy is the following top-down order; Parent Code, Child Code, Grandchild Code. Followed by a separate figure of Cases that occurred during interview discussions by two or more individuals.

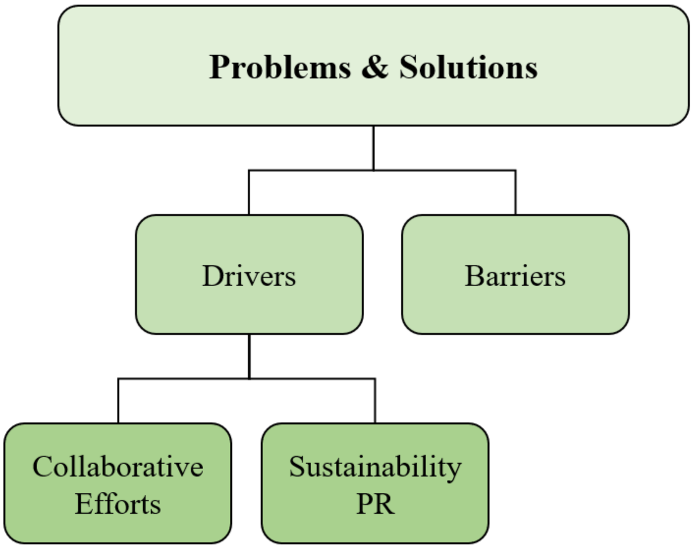

Figure B.1: *Coding Hierarchy of Problems & Solutions.*

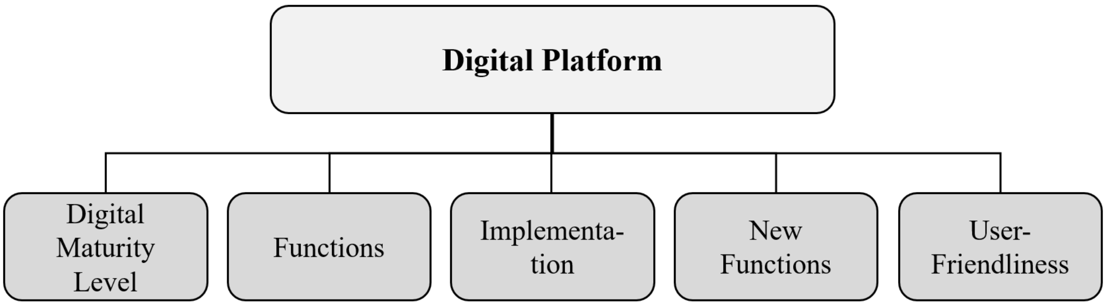

Figure B.2: *Coding Hierarchy of Digital Platform.*

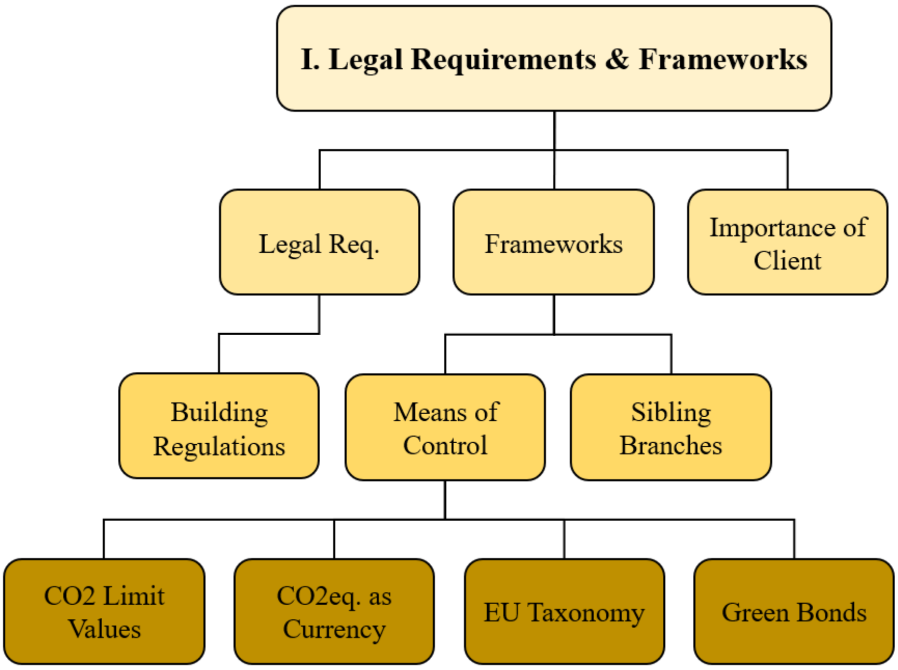

Figure B.3: *Coding Hierarchy of I. Legal Requirements & Frameworks.*

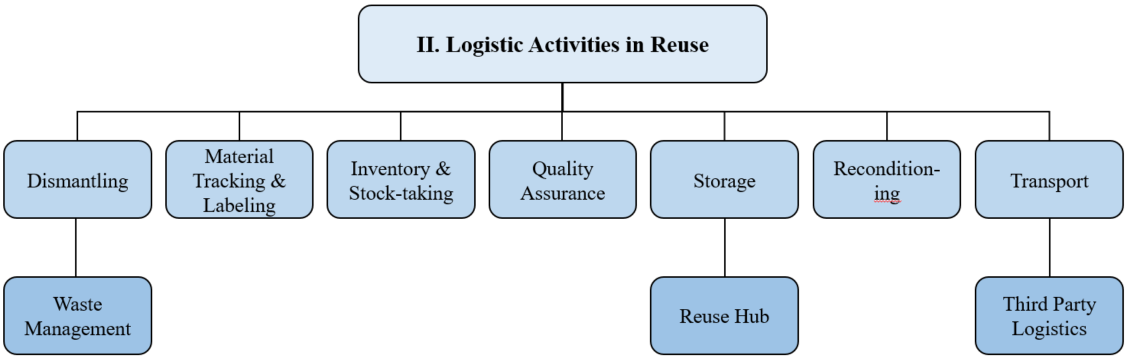

Figure B.4: *Coding Hierarchy of II. Logistic Activities in Reuse.*

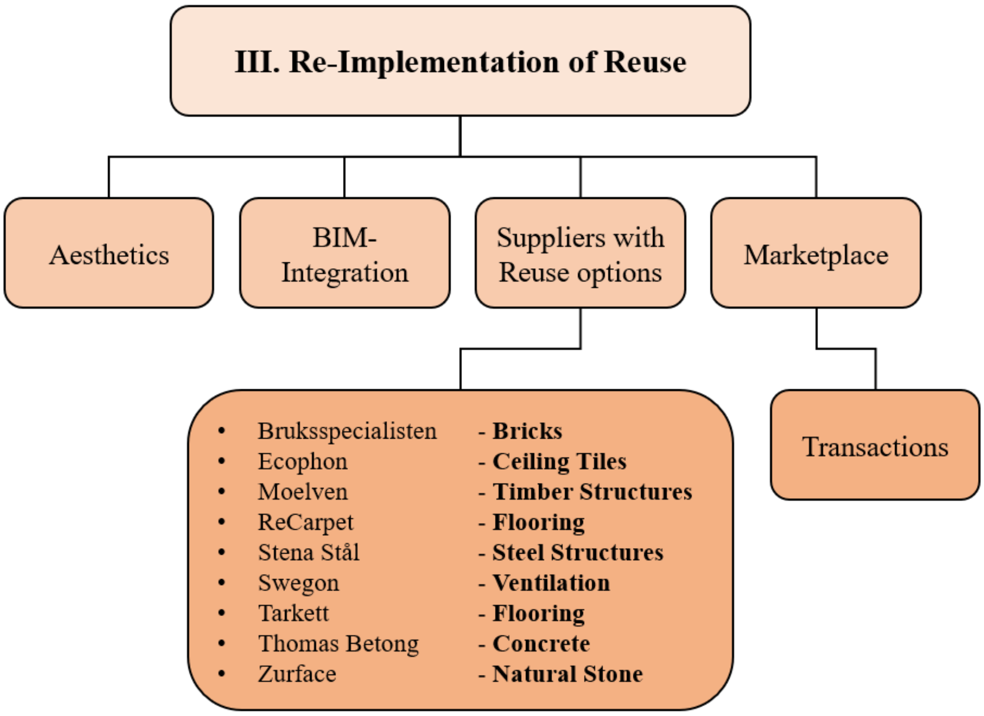

Figure B.5: *Coding Hierarchy of III. Re-Implementation of Reuse.*

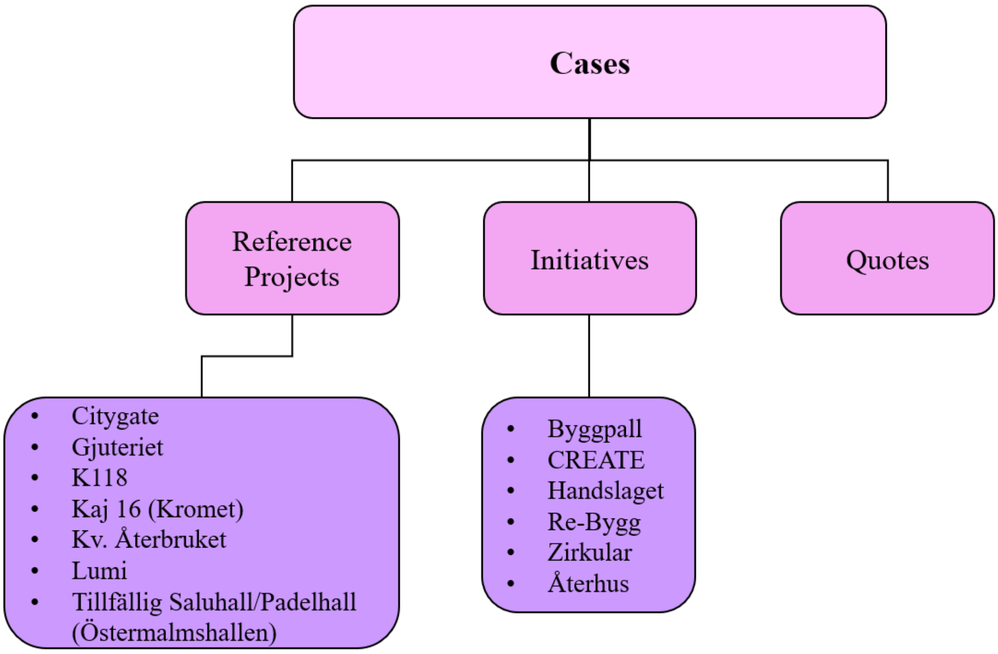

Figure B.6: *Overview of Cases.*

DEPARTMENT OF TECHNOLOGY MANAGEMENT AND ECONOMICS
DIVISION OF INNOVATION AND R&D MANAGEMENT
CHALMERS UNIVERSITY OF TECHNOLOGY
Gothenburg, Sweden
www.chalmers.se

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