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Circular material flows:

Challenges and enablers in new build and renovation projects

Amanda Åkerberg

LINKÖPING UNIVERSITY

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Abstract

Construction logistics can be described as the process of coordinating the movement of goods and information from their origin to the point of use within a construction context. In a circular economy (CE), retaining the value of materials across multiple use phases depends not only on the physical management of materials, but also on the availability and coordination of information regarding their production, use, and end-of-use (EoU) management.

Actors seeking to integrate circular materials into production or sales channels require information on available supply for planning, while those managing EoU materials require knowledge of potential demand to enable efficient reverse logistics. Information sharing is therefore essential for matching supply and demand and for planning circular material flows. From this perspective, logistics management plays a key role in enabling circularity at scale, particularly in the construction industry—the largest generator of waste in the European Union. In this context, construction logistics related to construction and demolition waste management (C&DWM) constitutes a critical lever for enabling circular material flows.

Focusing on C&DWM, this thesis investigates logistics-related activities, challenges, and enablers associated with the reutilization of construction materials and products in Swedish new-build and renovation projects. Through semi-structured interviews and case studies, the three studies included in this thesis examine how actors involved in construction logistics perceive circularity, how logistics activities support the reutilization of materials and products, and which challenges and enablers influence their implementation. The thesis addresses the following research questions:

RQ1: How do actors involved in construction logistics perceive circularity, their role, and the challenges and enablers associated with increasing circular material flows?

RQ2: What logistics activities can support operations for circular material flows?

Taken together, the findings indicate that enabling circular material flows depends on coordinating not only physical logistics activities, but also information, incentives, and actors across projects, markets, and system levels.

Keywords: Construction logistics, Circular material flows, Circular economy, Construction and demolition waste, Circular construction supply chains, Supply chain coordination

Sammanfattning

Byggbranschen står för en betydande del av de totala avfallsmängderna i Sverige och EU, vilket gör hanteringen av bygg- och rivningsavfall till en viktig länk för att möjliggöra cirkulära materialflöden i större skala.

Materialens återbruks- och återvinningspotential beror, utöver den fysiska förflyttningen, även på tillgång till delbar information. Informationsbehovet skiljer sig mellan aktörer: de som vill integrera cirkulära material behöver information om tillgängligt utbud, medan aktörer som hanterar material i slutet av en användningsfas behöver kunskap om potentiell efterfrågan för att möjliggöra returlogistik och bevara materialens värde. Informationsdelning är därför avgörande för att matcha utbud och efterfrågan samt planera cirkulära materialflöden. Bygglogistik, där material- och informationsflöden samordnas för effektiv förflyttning inom en byggkontext, spelar därmed en viktig roll för cirkulära flöden.

Mot denna bakgrund undersöker denna avhandling bygglogistikens roll i att främja cirkulära materialflöden med fokus på returflöden från svenska nybyggnads- och renoveringsprojekt. Avhandlingen bygger på en intervjustudie som undersökte hur aktörer involverade i bygglogistik uppfattar cirkularitet, hur de ser på sin roll samt vilka utmaningar och möjliggörande faktorer som påverkar arbetet med cirkulära materialflöden. Därutöver genomfördes två fallstudier som undersökte vilka logistikaktiviteter som behövs för att främja cirkulära materialflöden på respektive utanför byggarbetsplatsen.

Sammantaget visar resultaten att möjliggörandet av cirkulära materialflöden kräver mer än enbart transport och lagring, det behövs samordning av information, material, aktörer och incitament mellan projekt, och över olika marknader och systemnivåer.

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List of papers

I. Åkerberg, A. and Fredriksson, A. (2023) ‘Logistics: a key to increased resource utilization and transport efficiency in circular flows of construction material’, *Proceedings of the PLAN forsknings- och tillämpningskonferens 2023*, Trollhättan, 17–18 October.

II. Åkerberg, A., Sezer, A.A. and Nilsson, F. (2024) ‘Circular hubs: Enablers for increasing reuse of construction products’, *Proceedings of the 40th Annual ARCOM Conference 2024: Looking back to move forward*, London, UK, 2–4 September.

III. Åkerberg, A., Brusselaers, N. and Johansson, M. (2024) ‘Circular construction logistics for retaining value of waste material in new build projects’, *Proceedings of the EurOMA 2024 Conference: Transforming people and processes for a better world*, Barcelona, Spain, 29 June–4 July.

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Chapter 1

Introduction

"The time is out of joint. O cursed spite,
That ever I was born to set it right!"

— William Shakespeare, *Hamlet*, Act 1, Scene 5

The construction industry plays a central role in shaping modern societies, providing essential infrastructure and buildings that support economic development and social well-being. At the same time, the sector exerts substantial pressure on natural resources and the environment, making it a critical area in efforts to address climate change and resource scarcity. The need for change is pivotal; however, practitioners, politicians and academics struggle to understand how to make the needed changes to scale circularity on an industrial level. This thesis is not a silver bullet but aims to shed light on logistical challenges and enablers – and provide recommendations on how to overcome these challenges and realize enablers.

This chapter is divided into four sections. Section 1.1 presents the background and positions the research within broader societal and academic discussions. Section 1.2 introduces the purpose and research questions, followed by Section 1.3, which outlines the scope of the thesis. Finally, Section 1.4 presents the overall structure of the thesis.

1.1 Background and problem formulation

The construction industry consumes vast amounts of materials and energy (Rayhan and Bhuiyan, 2024) and is the most waste intense industry within the European Union (EU) (Eurostat, 2024). From a global perspective construction and demolition waste (C&DW) are associated with several negative environmental, economic and social implications e.g., pollution of air, water and soil, loss of natural resources (land use) and financial cost associated with waste management (Rayhan and Bhuiyan, 2024). C&DW management (C&DWM) address these issues, and by enabling increased reuse and recycling of safe materials there is also a great potential to reduce total life-cycle emissions. According to the latest Circularity Gap report, only 6,9% of material resources are of secondary origin, a negative trend since the last report, suggested to relate to consumption of virgin resources growing faster than the rate of materials being reused and/or recycled (Circle Economy, 2025; p11).

To boost its transition into climate neutrality by 2050 the EU has launched a massive policy package "The European Green Deal" (European commission, n.d.). A transition that, paradoxically, calls for more construction works to e.g., improve energy efficiency of the current building stock (Circular economy action plan: The Renovation wave) (European Commission, 2020). Hence, from a societal perspective construction is a necessity, however, considering the current and expected effects of climate change and resource scarcity, the way we currently produce and consume natural resources are not sustainable (Circle Economy, 2023). Thus, fundamental changes are required to move beyond the prevailing linear "take–make–dispose" economy, in which extraction, production, transport, and disposal processes consume large amounts of resources and generate significant waste and CO_2-emissions.

The concept of the circular economy (CE) is commonly described as an alternative to the linear model of resource production and consumption, and its principles are often used to guide policymakers and practitioners in transitioning from the current linear system (Kirchherr et al., 2017). However, even though there has been much published on CE in the last decade, there has until recently been a lack of clear consensus on its definition, and practitioners continue to struggle to implement its principles and strategies into their business models (Kirchherr et al., 2023). Thereby, calling for further research on practical implementation (Ibid.). In 2024, a new ISO standard defined CE as an "*economic system that uses a systematic approach to maintain circular flow of resources, by recovering, retaining or adding to their value, while contributing to sustainable development*", where circularity is defined "*degree of alignment with* *the principles of a circular economy*" (International Organization for Standardization (ISO), 2024, clauses 3.1.1 and 3.1.15).

Currently the majority of C&DW in Sweden is recovered as construction material (e.g., backfilling) or sent to landfill (Swedish Environmental Protection Agency (Naturvårdsverket), 2020). This is unfortunate, as construction waste has a great potential to be reused and recycled if properly managed (Ahlm et al., 2021). However, C&DWM is context-dependent, shaped by varying regulatory environments, the composition of the built environment, and the temporal nature of construction projects as sources of waste, which influence waste fractions and volumes (Rayhan and Bhuiyan, 2024).

Furthermore, approximately 30% of urban freight transport has been estimated to serve the construction industry (Guerlain et al., 2019), and that much of what is delivered to construction sites is suggested to enter the C&DW flow (Kabirifar et al., 2020; Mahinkanda et al., 2023). Improving the management of return flows has the potential to enhance project performance and reduce transport-related emissions. Accordingly, incorporating CE practices into C&DWM can contribute to increased circularity (Circle Economy, 2025, p. 11) and mitigate environmental, social, and economic impacts associated with current industry practices.

In C&DW literature, the CE strategies Reduce, Reuse and Recycle are the most common R-principles (Rayhan and Bhuiyan, 2024). What these principles share is a focus on increasing (1) resource efficiency—by minimizing resource use, reducing future demand through longevity, and enabling recyclability—and (2) resource utilization, by prolonging use through reuse (i.e., slowing material loops) and, when reuse is no longer possible, closing the loop through recycling to enable secondary material use (Bocken et al., 2016).

While early design decisions play a critical role in enabling reuse and recyclability, circularity is ultimately realized through the effective management of return flows that retain material value. The potential for value retention of circular materials is shaped by how products and materials are produced, used, and managed at end-of-use (EoU) and end-of-life (EoL). This potential reflects sequential dependencies among actors across the material life cycle, as well as the availability of adequate information to support material valorisation.

Sorting waste at source is considered an important measure to enable a high recycling rate (Hossain et al., 2017). However, a high sorting rate at construction sites does not automatically translate into high recycling rates (Dahlbo et al., 2015; Fufa et al., 2023). Other factors also influence outcomes, such as limited knowledge of available management options, access to recycling infrastructure, the characteristics of the built environment shaping waste composition, insufficient material information, low market prices for construction materials, and uncertainty in demand for circular materials. Together, these factors relate to how logistics is organized in the construction supply chain and contribute to challenges in retaining the value of circular materials. Hence, construction logistics is a key activity in the development of CE in the construction industry.

Construction logistics is often divided into on-site and off-site logistics (Ghanem et al., 2018), and changes in one of them have consequences for the other in terms of efficiency (Sundqvist et al., 2018). On-site logistics is limited to available space disposition affecting the possibility to store material and placement of equipment such as e.g. load carriers. Furthermore, on-site logistics is also dependent on local infrastructure, transport distances and available logistical equipment and services. However, this dynamic between on-site and off-site logistics is not well investigated (Sundqvist et al., 2018), especially when it comes to return flows as most CE studies in construction focus on forward logistics (Ding et al. 2023).

The construction industry exhibits several structural characteristics that distinguish it from other industries, such as manufacturing, as it involves multiple actors across several layers in temporally bounded project settings (Fredriksson and Huge-Brodin, 2022). These conditions often result in arm's-length and adversarial relationships (Bankvall et al., 2010), which have been used to explain the sector's perceived inefficiency and the difficulties associated with implementing traditional efficiency increasing concepts (Ibid.). The high degree of interdependence among actors and activities, combined with limited formal coordination, has further contributed to the development of strong informal institutions as coordinating mechanisms (Kadefors, 1995), making lasting changes and the adoption of new ways of working particularly challenging. As improved resource efficiency and utilization, in line with the strategies and principles of CE require new ways of managing logistics in construction, understanding the socio-technical context is important as formal (regulative) and informal (normative, cultural and cognitive) institutions may have a strong influence on successful implementation (Olivier, 1997) of new logistical practices.

To summarize, construction activities are central to sustain a healthy growing society. However, the inefficient management of materials and resources in the industry today calls for urgent intervention to mitigate CO_2-emissions, secure future resource supply, and simultaneously ensure affordable housing. An amiable task seeing the challenges of implementing new ways of working, for CE in general, but for any change in construction specifically. Prior research has suggested that construction logistics are a multi-actor challenge (Fredriksson & Huge-Brodin, 2022) and that there is a gap in research on the dynamics of on-site and off-site logistics in construction in general (Sundquist et al., 2018), and especially in the perspective of CE implementation and reverse flows (Ding et al., 2023).

1.2 Purpose and Research Questions

The purpose of this thesis is to investigate logistics-related activities, challenges, and enablers related to the reutilization of construction materials and products from new build and renovation projects in Sweden.

To address this purpose, the study is guided by the following research questions (RQs), which together provide complementary perspectives on construction logistics and circular material flows:

RQ1: *How do actors involved in construction logistics perceive circularity, their role as well as the challenges and enablers for increasing circularity?*

RQ2: *What logistics activities can support operations for circular material flows:*

a. *On-site solutions*
b. *Off-site solutions*

The first research question addresses how actors involved in construction logistics perceive circularity, including their motivations, perceived roles, and the challenges and enablers they encounter in relation to circularity in the industry. The second research question focuses on logistics activities and solutions that support operations for circular material flows. Together, these research questions address both actor perspectives and operational logistics aspects of circular material flows.

1.3 Scope of the Thesis

The scope of this thesis is reverse logistics in the construction industry, with an emphasis on C&DWM and its role in enabling material reutilization through the reuse and recycling of EoU products and materials deriving from new build and renovation projects (see Fig. 1). This includes both on-site and off-site logistics activities related to increasing the circularity potential of return flows from construction projects and enabling the reutilization of these materials. The studies were conducted within a Swedish context.

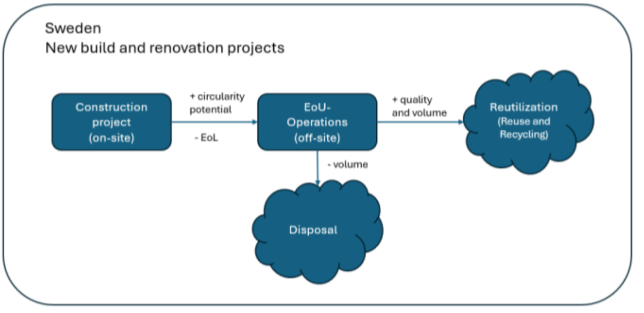

Fig 1. Scope of the thesis

1.4 Outline of the thesis

The thesis is structured as follows:

Chapter 1 introduces the background and motivation of the research and outlines the main problems addressed in the thesis. It also presents the purpose, research questions, and scope of the study.

Chapter 2 provides contextual background and covers some of the main concepts and theories of which the research builds.

Chapter 3 describes the methodological approach of the thesis, including the research design, data collection and analysis methods, considerations related to validity and reliability, and the author's role in the conducted studies.

Chapter 4 presents key findings by summarizing the three papers of which this thesis builds.

Chapter 5 synthesizes the findings across the included papers and addresses the research questions.

Chapter 6 discusses the findings in relation to the concepts and theories introduced in the theoretical background and relevant literature.

Chapter 7 concludes the thesis, reflects on its limitations, outlines directions for future research, and highlights its contributions.

Chapter 2

Theoretical background

This chapter provides a theoretical background for the main concepts addressed in the thesis. The first sub-chapter address the contextual outline framed by the peculiarities of the construction industry and the Swedish regulative landscape. This is followed by a subchapter on CE in relation to the construction industry, moving from concept to barriers and enablers for its implementation. Finally, the third sub-chapter moves from construction logistics and C&DWM to circular construction logistics.

2.1 The construction industry

Construction works have been performed since ancient times. However, around 1850, the construction industry as it is known today began to take form in Sweden, as urbanization driven by industrialization sparked demand for housing in cities (Nordstrand, 2008). It is also around the turn of the century that the real estate market developed and many of the large construction companies in Sweden were established (Ibid.). From then to the present, the industry has grown in complexity due to increased regulation to ensure quality, workers' rights, safety, and health and environmental considerations, as well as technical advancements requiring specialist actors and changing construction practices, such as mechanization and the prefabrication of construction elements (Ibid.).

New materials have been introduced and later phased out; for example, insulation and compound materials containing carcinogenic substances such as asbestos and PCB were introduced in the mid-1900's and subsequently prohibited during the 1970's and 1980's (Naturvårdsverket, 2025b,h). Compared to many other consumer products, materials in the built environment are long-lived (Adams et al., 2017). Consequently, a wide variety of materials are embedded in the current built environment, mounted using different techniques. While some building components are easy to dismantle and safe to reutilize, many are currently considered hazardous or difficult to access.

The construction industry is often described as project-oriented and fragmented, with design and production processes decoupled (Bankvall et al., 2010). It is further characterised by strong resistance to change (Kadefors, 1995) and a decentralized structure (Dubois and Gadde, 2002). As a result, construction projects have been described as temporary factories organized around a unique product, with limited repetition and located at the point of consumption (Vrijhoef and Koskela, 2000). Relationships within the sector are described as arm's-length and oppositional, with poor communication and weak coordination (Bankvall et al., 2010).

Given the high level of interdependence and uncertainty, the construction industry is regarded as complex (Dubois and Gadde, 2002). Uncertainty derives from vague activity specifications, dependence on local resources in unpredictable environments, and time- and place-dependent conditions, such as work teams (Ibid.). While other industries have been suggested to exhibit predominantly sequential dependencies – where the output from activity A serves as the input to activity B (Thompson, 1967, cited in Bankvall et al., 2010) —two additional types of interdependencies are common in construction: pooled and reciprocal, with the latter argued to be the most prevalent (Bankvall et al., 2010).

Pooled interdependencies refer to situations where each part contributes to and is supported by the whole (e.g., shared equipment), while reciprocal interdependencies occur when the output of activity A serves as the input to activity B, and vice versa (e.g., how different installations depend on and must be adjusted to each other). These characteristics have been used to explain the industry's resistance to change (Kadefors, 1995). In the Swedish context, standard industry contracts have also been suggested to reinforce existing practices, further contributing to this resistance (Ibid.).

Competitive tendering has been common praxis in the industry, which has been suggested to favour use of standard parts and imped innovation (Dubois and Gadde., 2002). The contractual arrangement (e.g., general contracting, design–build contracting) dictates the role of contractors and their involvement in the design phase (Nordstrand, 2008). Fredriksson and Huge-Brodin (2022) divide the developer and the contractor into two sub-systems, where the developer sub-system includes the client, architect, and consultants—roles commonly part of the project organization during the design phase (Nordstrand, 2008)—and the contractor sub-system includes the main contractor, subcontractors, construction logistics service providers, suppliers, and transporters, who are commonly involved in the production phase.

The project organization in construction depends on several factors, such as the knowledge and type of the initiating actor, the process phase, and the size and complexity of the building object (Nordstrand, 2008). The initiating actor may be referred to as the client, developer, or property owner. In this thesis, the initiating actor—defined as the juridical entity that initiates construction work on its own behalf, whether an individual, company, organization, or agency—will be referred to as the Developer (in Swedish Byggherre).

Given this complex structure, with many actors and interdependencies, the construction industry in Sweden is suggested to be highly institutionalized (Kadefors, 1995), which paradoxically suggests that the industry is organizationally homogeneous (Ibid.). This institutionalized environment is suggested to be one explanation for the strong resistance to change in the industry (Ibid.), where one indication of institutions is environments in which managers explain economically irrational behaviour by stating that “this is how it has always been done” (Olivier, 1997).

2.1.1 Construction and demolition waste

The construction industry is the largest producer of waste in the EU (Eurostat, 2024), and the EU is, after China and the United States, the third-largest contributor to C&DW globally (Rayhan and Bhuiyan, 2024). In Sweden, the total amount of C&DW is primarily generated by the construction industry (approximately 98% in 2020), although smaller volumes also originate from other industries and municipal households (Naturvårdsverket, 2025f).

From an academic perspective, there is no clear and universally agreed-upon definition of C&DW that covers all aspects of waste, and various approaches exist for classifying sub-flows, with origin being one of the most common (Rayhan and Bhuiyan, 2024). C&DW is a highly heterogenous material flow, in which, in addition to construction materials, a substantial share has been suggested to derive from packaging materials (Josephson and Saukkorpii, 2007). Its composition is contingent on technical factors (e.g., type of construction), market conditions (e.g., availability of local resources), cultural factors (e.g., building traditions), and regulatory frameworks (e.g., national policies and standards) (Gálvez-Martos and Istrate, 2020). Furthermore, the amount of C&DW generated has been suggested to be directly related to population size and economic activity (Kabirifar et al., 2020).

Given that C&DW is contingent on country, due to regulations and culture, and given the suggested influence of regulations for implementation of CE in construction (Illankoon and Vithanage, 2023), this thesis adheres to the definitions provided by the EU waste framework directive (Directive 2008/98/EC). Thus, C&DW is defined as "*waste generated by construction and demolition activities*" where waste is defined as "*any substance or object which the holder discards or intends or is required to discard*" and C&DW management is defined as "*the collection, transport, recovery (including sorting), and disposal of waste, including the supervision of such operations and the after-care of disposal sites, and including actions taken as a dealer or broker*" (Directive 2008/98/EC).

From a construction industry perspective, the majority of the C&DW (weight wise) can be traced back to infrastructural projects (e.g., roads and ground works) as such mineral waste makes up the largest part of the total amounts (approx. 86% in 2022, based on weight) (Naturvårdsverket, 2025f). From an aggregated level the most common treatment of C&DW is recycling into construction materials, followed by landfill and waste-to-energy. Commodity recycling (metals, plastic and paper) makes up for only 2%. Furthermore, approximately 5% is considered hazardous waste, where contaminated soils make up for the majority, followed by contaminated mineral waste and impregnated wood (Ibid.).

The EU waste framework directive (Directive 2008/98/EC) provides definitions for most of the activities, actors, and resources (e.g. classifications) related to WM and these have been adopted into the Swedish Waste code (SFS 2020:614). Some of the defined concepts in the EU waste framework directive are also defined in the standard for CE.

2.1.2 The regulative landscape (Swedish perspective)

Sweden has been a member of the EU since 1995. Thus, policy decisions on EU level both influence (directives) and directly affects (regulations) the national policy landscape, e.g., the Waste Framework Directive (Directive 2008/98/EC) that has been transposed into Swedish law. The country is divided into 21 counties and 290 municipalities. The counties (regional) and municipalities (local) have no law-making power and must always exercise their power in line with national legislation (Naturvårdsverket, 2017). The municipal authorities, through a variety of committees, and county administrative boards (CADs) are the main supervising authorities related to C&DWM (from waste construction site to final treatment) within their jurisdiction, regulated by the Environmental supervision regulation (SFS 2011:13). However, to fulfil their supervising function collaborations with other authorities are often necessary e.g., the police authority in the case of supervision of ongoing transports (Naturvårdsverket, 2024c).

Furthermore, there are several national expert agencies supporting the implementation of law in specific areas, e.g., the Swedish EPA related to waste, the The Swedish national board of Housing, Building and Planning for construction and the Swedish Transport administration for transports. These agencies can issue regulations linked to specific ordinances, provide guidance through handbooks, and offer general advice on how to interpret national policies within their areas of expertise. Table 1 lists some of the more prominent national ordinances and associated orders related to C&DWM in Sweden.

Table 1. A non-exhaustive list of ordinances and related orders shaping the regulative landscape in regard to C&DWM.

Ordinance	**Brief description**
The Swedish Environmental code (SFS 1998:808)	Fundamental decrees and regulates what is waste, actors and their responsibilities
The Swedish Waste code (SFS 2020:614)	Clarifies how waste is to be managed
The EIA Ordinance (Swe. Miljöprövningsförordningen) (MPF) (SFS 2013:251)	Regulates when and what to report or when permits are needed
The Planning and Building Act (SFS 2010:900)	Regulates construction

However, additional ordinances and policies influence how materials are managed. For example, Fredriksson and Huge-Brodin (2022) describe construction logistics as being influenced by three subsystems—the municipal, the developer, and the contractor—across five different layers. Hence, policy on infrastructure influence, or constrain, how logistics are set up and performed. Furthermore, regulations related to the working environment need to be taken into consideration, adding to the number of agencies involved.

When a product or material becomes waste, it is diverted into a new legal framework, from product legislation to waste legislation (Naturvårdsverket, 2025c,g). For waste to reclassify as a product it must undergo a process of end of waste (EoW) (Naturvårdsverket, 2025e), which can be found in the WFD and in The Swedish Environmental code (SFS 1998:808). For some scrap metals and glass there are EU regulations on EoW criteria. However, for most materials there is no standard to lean on. In Sweden there is currently no national criteria for specific materials, though general criteria can be found in The Swedish Environmental code (Naturvårdsverket, 2025c).

The waste producer, defined as "*anyone whose activities produce waste (original waste producer) or anyone who carries out pre-processing, mixing or other operations resulting in a change in the* *nature or composition of this waste*" (Directive 2008/98/EC)—must manage environmental risks (SFS 1998:808), classify waste, and sort C&D and packaging waste into predefined fractions at the point of generation (SFS 2020:614). Exemptions apply when separation is technically infeasible or undermines material circularity (NFS 2020:7). The Waste producer must also ensure that transporters and receiving facilities hold valid permits, describing these measures in the project's control plan, which is required for obtaining building permits (Naturvårdsverket, 2024b). Although the waste producer retains overall responsibility to ensure proper WM, off-site handling is typically performed by a network of transporters and treatment facilities, often coordinated by a waste manager (Nordstrand, 2008).

Waste transport and treatment are strictly regulated. Transporters must keep fractions separated, verify that recipients are permitted to accept the waste, and comply with documentation and notification requirements—particularly for hazardous waste, where transport documents and notifications to the Swedish EPA are mandatory (Naturvårdsverket, 2025d). Cross-border transports are subject to additional rules, with supervision potentially involving the CAB, Swedish Customs, and the Coast Guard (Naturvårdsverket, 2024c).

Treatment facilities must hold permits specifying which fractions they may accept and how they must be managed (SFS 2013:251; NFS 2021:09). Permits for A-class facilities are officiated by the Land and Environment Court, B-class by the CAB, and C-class through municipal notification (Naturvårdsverket, 2025a) Consequently, the sector spans a wide range of actors and facility types, operating in a highly regulated environment.

While the purpose of responsibilities, notifications, permits, supervision and control is to mitigate risks associated with waste, the purpose of the sorting requirements is to facilitate, thus enable, preparations for reuse and material recycling (Naturvårdsverket, 2026).

2.2 Circular Economy in the construction industry

The CE represents an alternative to the prevailing linear economy, which is characterized by a "take–make–dispose" logic. CE has been a rapidly evolving concept, with the majority of academic contributions published within the last decade, leading to ambiguity regarding its definition and scope (Kirchherr et al., 2017; 2023; Senaratne et al., 2025).

In 2024, a new ISO standard providing definitions for the circular economy (CE) and its principles was introduced through the ISO 59000 series by the International Organization for Standardization (ISO). Prior to this standard, one of the most influential definitions of CE was proposed by Ellen MacArthur Foundation in 2013 (Kirchherr et al., 2017), describing CE as an industrial system that is "*restorative or regenerative by intention and design"* (Ellen MacArthur, 2013). This definition conceptualizes CE in technical systems as restorative, aiming to dematerialize economic activities through the recirculation of materials at their highest value, while implicitly requiring the minimization or elimination of hazardous substances that could hinder safe and effective material circulation.

Building on the ISO standard, prior literature and expert opinions Senaratne et al., 2025 proposes the following definition for CE as a concept: *"An idea about an economic system that uses a systemic approach to restore or regenerate nature by intention and design, while contributing to sustainable development"*. Where a *CE strategy* is defined as: *"An overall direction and plan for circular economy implementation in a particular entity"* (Ibid.).

Implementation of CE can be understood as alignment with *CE principles* (ISO, 2024). Prior studies often refer to the R-principles (e.g., Reduce, Reuse, Recycle) in relation to CE implementation (Kirchherr et al., 2017), or to strategies for circular business models that aim to *narrow* (e.g., reduce the need of resources through efficient use of materials and replacement of virgin natural resources through re-utilization of materials of secondary origin), *slow* (e.g., prolong longevity of products) and *close* (e.g., enable reuse and recycling) material flows (Bocken et al., 2016). While the R-principles reflect the priorities of the EU waste hierarchy (Directive 2008/98/EC) and have been widely used in CE research, ISO 59004:2024 instead defines six interlinked principles: systems thinking, value creation, value sharing, resource stewardship, resource traceability, and ecosystem resilience (ISO, 2024).

However, R-principles such as reuse and recycling are included in the standard, and strategies to narrow, slow, and close material flows are acknowledged as implicit within these principles. Accordingly, R-principles can be understood as CE practices, defined as *"activities that contribute to the implementation of a CE in a particular entity"* (Senaratne et al., 2025).

Taken together, these definitions emphasize a systemic approach that aims to retain or add value to resources in a circular flow, thereby reducing waste and dependence on virgin resource extraction. While the principles differ between prior literature and the new standard, the latter both explicitly and implicitly acknowledges elements of earlier frameworks.

Implementation of CE in the construction industry differs from that in other industries (Adams et al., 2017). As described in Chapter 2.1, the industry exhibits distinct characteristics in terms of organizational (e.g., temporality, multi-actor structures, and relationship types) and product-related complexity (e.g., long use phases and low-cost materials embedded within building elements), and is, partly as a result (Kadefors, 1995), perceived as resistant to change. Recent research has focused on circular business models, R-principles, CDWM, CO_2 emission reduction, economic barriers, adaptation to new technologies, and LCAs (Illankoon and Vithanage, 2023). However, from a global perspective CE in construction is still considered to be in its infancy (Swarnakar et al., 2025).

2.2.1 Material reutilization through reuse and recycling

As circular flows of high-value products and materials are central to CE, enabling reutilization at end-of-use (EoU) and safe disposal at end-of-life (EoL) becomes a key capability. Building on ISO 59004:2024, EoU refers to products and materials suitable for reutilization that are no longer needed by the current holder (e.g., redundant construction products), while EoL refers to products that are no longer suitable for reutilization and are disposed of. As this thesis focuses on reuse and recycling, circularity potential is used to describe the potential for a product or material to be reused or recycled, i.e., reutilized, at a given point in time.

The WFD defines *Re-use* as: "*any operation by which products or components that are not waste are used again for the same purpose for which they were conceived*" and *Recycling* as *"any recovery operation by which waste materials are reprocessed into products, materials or substances whether for the original or other purposes. It includes the reprocessing of organic material but does not include energy recovery and the reprocessing into materials that are to be used as fuels or for backfilling operations"* (Directive 2008/98/EC).

The circularity potential is sequentially dependent on how a product has been produced, used, and managed at EoU, e.g., age of product and construction method influence quality and composition (Ahlm et al., 2021), following age product development (Wells and Seitz, 2005) and updated product legislation change demand and requirements on secondary materials and the condition of the materials due to environmental exposure (Rakhshan et al., 2020).

Products can be both reusable and recyclable, though a reusable product is not necessarily recyclable and vice versa (Hosseini et al., 2015). Hence, some factors influencing reuse and recycling potential are shared, while others differ. From a recycling perspective, classification based on chemical content is preferable (Gálvez-Martos & Istrate, 2020), whereas for reuse, product characteristics such as known functionality, aesthetics and brand are important (Akerlof, 1970; Rakhshan et al., 2020).

2.2.2 Recycling

Material recycling is a broad concept covering all processes that turn a waste fraction into a secondary raw material. Recycling can occur through mechanical or chemical processes, resulting in materials with varying compositions and qualities, and different processes impose different requirements on the material input (Nageler-Petritz, 2023).

As use and EoU management impacts the circularity potential of materials, being designed for recyclability does not necessarily mean that a material can be recycled in practice. The recycling potential is generally higher for waste deriving from New Build projects as opposed to demolition projects, due to lower risk of contamination when materials are mixed, as well as easier to trace and retrieve product and material information (e.g., construction plastics Ahlm (2021)).

A CE implies retaining the value of materials at their highest possible quality through reuse and recycling. However, the definition of recycling in the WFD does not explicitly address the quality of the output, other than excluding applications such as fuel and backfilling (see definition above). The "*quality of recycling*" can be defined as the degree to which a material's properties are preserved or recovered during the recycling process in order to maximize its potential to be re-utilized in a CE (Grant et al., 2020).

The Swedish national waste plan 2024-2030 describes high value recycling as when the recycled material keeps its initial quality and economic value and remains traceable in terms of properties, content and past use, enabling it to be used for the same or similar application multiple times and thereby replacing material with a higher climate and environmental impacts (Naturvårdsverket, 2024a).

Conversely, downcycling can be described as *"the phenomenon of quality reduction of materials reprocessed from waste relative to their original quality"* (Helbig et al., 2022), or as a process in which the reutilized material has lower material quality, lower market value, and/or more limited applications (Geyer et al., 2016).

2.2.3 Reuse

Reuse has gained increased interest with the emergence of the CE, although it is not a new phenomenon. Practices such as reuse and preservation have long been applied to retain cultural values (Lanz et al., 2022), and secondary markets are as old as trade. However, the actual volumes of reuse remain uncertain. This is partly due to the lack of specific codes for reused materials and the fact that C&DW statistics reflect only waste received and treated at A or B facilities, where reuse procedures are not systematically captured (Ahlm et al., 2021; Naturvårdsverket, 2024a). Different forms of reuse can be identified, including adaptive reuse (e.g., retaining parts of the building structure), building material reuse (e.g., using building materials in the production of new components), and building component reuse (e.g., reuse of a product with minimal treatment) (Rakhshan et al., 2020).

Several interdependent factors impede the propensity for reuse, including economic (e.g., the absence of a mature market), social (e.g., perceptions of quality, awareness, and risk), and regulatory factors (e.g., incentives and compliance) (Rakhshan et al., 2020). Addressing these challenges may require coordination not only of material and information flows, but also of people and knowledge, as shown in a case study of closed-loop supply chains for consumer products (Gatenholm et al., 2021). In practice, the organization of such coordination depends on how reused products move from construction projects to market re-entry.

A key distinction concerns whether products leave the project site as waste or as products, as this determines whether they enter a waste market or a product market and therefore operate under different legal frameworks (Naturvårdsverket, 2025c,g). When traded for reuse, however, they are legally considered products (Ibid.). The former situation can be described as a *waste-to-reuse pathway*, in contrast to *reuse*, where products leave the project as products.

In the *waste-to-reuse* scenario, a product is classified as waste at one point in time and later requalified as a product. In line with the EU waste hierarchy to “prepare for reuse” (Directive 2008/98/EC), the product first enters the waste market and subsequently re-enters the product market, involving at least one intermediary actor in the waste management industry with permits to transport and manage waste (as described in Chapter 2.1.2), whereas in the non-waste scenario the product status remains intact and the product can be traded directly in a product market.

To operationalize reuse in construction, four scenarios have been suggested: (1) within a project where the product is stored on-site, (2) within the same project, stored off-site, (3) from one project directly to another project, (4) from project to off-site storage, to other project (Bosch et al., 2023). Where the latter could be used to describe the *waste-to-reuse* scenario.

Furthermore, three of the scenarios in Bosch et al., (2023) suggest the involvement of intermediate actors to provide storage and facilitate trade. These intermediary actors and their practices have received little academic attention (Ding et al., 2023), although their forms have been operative for decades.

2.2.4 Prerequisites for reutilization of construction products and materials at End-of-use

Important prerequisites for achieving high circularity potential include the ability to estimate C&DW composition and volumes (Villoria-Sáez et al., 2020), plan for deconstruction (Ding et al., 2023), and ensure on-site sorting (Hosseini et al., 2017). Case studies have shown that high recycling rates (up to 95%) are achievable (Gálvez-Martos et al., 2018), and some projects have also demonstrated high reuse rates, such as Hållbarhetshuset in Sweden, which was built using 70% reused materials (Fabege, 2022). However, as materials differ in their circularity potential, achievable circularity rates depend on the materials embedded in the built environment (Dahlbo et al., 2015), as well as on factors such as project type, building type, and building component type (Mália et al., 2013). Furthermore, fully realizing CE in construction is influenced by broader factors such as regulations, quality assurance, pricing, general awareness, and education on circular applications (Illankoon and Vithanage, 2023).

Estimating the composition and volumes of return flows is important for planning circular material flows (Villoria-Sáez et al., 2020). However, fragmented categorization of C&DW (Rayhan and Bhuiyan, 2024), unknown material composition in the built environment, difficulties in tracing aggregated C&DW data back to projects and suppliers (Gálvez-Martos et al., 2018), and the absence of reuse reporting (e.g., the lack of EWC codes for products) (Ahlm et al., 2021) make such estimations time-consuming and context-dependent.

Deconstruction (Ding et al., 2023), or selective demolition (Ghisellini and Uligati, 2020), can improve sorting outcomes and reduce the risk of impurities and damage. It can be described as a reverse construction process aimed at systematically disassembling buildings to recover materials at their highest reuse value (Hosseini et al., 2015). However, its economic viability remains uncertain (Ghisellini and Uligati, 2020), indicating a need for greater knowledge of cost implications and value recovery.

Similarly, on-site sorting, compared to off-site handling of mixed waste, has been shown to improve recycling rates (Hosseini et al., 2017). However, high sorting rates do not necessarily translate into high recycling rates, as outcomes depend on material composition and the availability of C&DWM infrastructure (Dahlbo et al., 2015; Fufa et al., 2023). Additionally, space on-site is often temporary and limited, highlighting the importance of early involvement of actors managing products at EoU in the planning of sorting.

Following sufficient deconstruction, sorting and EoU handling, additional activities such as minor repairs or refurbishment may be required to enable reutilization.

2.2.5 Evaluating circular performance

To determine whether a strategy has the intended effect on objectives, the ability to measure performance is important. Evaluating performance requires a baseline against which improvements can be assessed. There has been a lack of clarity on how to measure and compare CE performance, for example between different CE practices (Kabirifar et al., 2020).

Furthermore, depending on CE practice and context, different flows can be assessed. For instance, Senaratne et al. (2025) suggest four CE indicators for construction—material, waste, energy, and emissions—each using different measures and metrics. They further propose three additional assessment-related terminologies—CE index, CE measure, and CE metric—with the following definitions:

Circular economy index: *"A quantified number that typically incorporates a combination of indicators to assess overall circular economy performance, facilitating comparisons over time and* *across different entities*". Example: waste/BTA (Villoria-Sáez et al., 2020)

CE indicator: "*A quantitative or qualitative factor that is used to measure different circularity aspects and, assess changes in circular economy implementation*", e.g., material, waste, energy and emissions

CE measure: *"A method of assessing circularity at a more focused or granular level"* e.g., amount of reusable materials or recyclability of EoU materials.

CE metric: *"A unit that is used in circularity measurement"*.

These assessments are suggested to provide feedback to the *CE strategy* and thus influence the CE practice in a plan, do, check act cycle (Senaratne et al., 2025).

2.2.6 Challenges and enablers for reutilization of construction products and materials

Given the challenges associated with implementing CE (Kirchherr et al., 2023), several authors have addressed challenges and enablers in the construction industry from various perspectives e.g,, CE awareness (Adams et al., 2017), policy and practices (Giorgi et al., 2022), technology and tools (Swarnakar et al., 2025), reuse (Rakhshan et al., 2020), development of circular construction supply chains (CCSC) (Abadi et al., 2025). However, challenges and enablers are multi-dimensional—overlapping and interdependent—and their perceived impact and position are context-dependent (e.g., position in the supply chain) (Adams et al., 2017; Rakhshan et al., 2020; Grafström and Aasma, 2021; Abadi et al., 2025), making it difficult to comprehend their full scope in detail. Furthermore, given the complex system characteristics, as one barrier is eased the perceived challenges and enablers are likely to change (Abadi et al., 2025).

Given its systemic characteristics, CE implementation is commonly divided into three levels: macro (regulative), meso (industry or market networks), and micro (firm or individual) (Masi et al., 2018), a division similar to other system theories such as institutional theory (Scott, 2014). Challenges and enablers are often clustered into comparable categories (Grafström and Aasma, 2021; Munaro and Travares, 2023), see Table 2, where "institutional" has been used inconsistently to refer to both regulative (Grafström and Aasma, 2021) and organizational factors (Munaro and Travares, 2023).

Institutions can be described as environments characterized by persistent patterns of behaviour, in which institutional structures influence actors' actions and, in turn, are reinforced by them (Scott, 2014). As the construction industry has been described as highly institutionalized—that is, resistant to change due to organizational complexity (Kadefors, 1995)—this thesis distinguishes between regulative and organizational challenges and barriers, while acknowledging their interrelation within the institutional context.

Owing to material and product embeddedness and fragmented supply chains, studies on CE implementation in construction have adopted different levels of analysis, including the construction industry (macro), building level (meso), and construction products and materials (micro) (Dewagoda et al., 2022). Hence, some challenges in scaling circular flows through high-value reuse and recycling are inherent to the industry, owing to both organizational and product complexity (Adams et al., 2017). This inherent complexity has been suggested to be further reinforced by conceptual ambiguity related to CE concepts (Senaratne et al., 2025).

Table 2. Adaption of common categories of CE related challenges and enablers as identified by Grafström and Aasma, (2021) and Munaro and Travares, (2023), adding product complexity.

Category	**Description**
Regulative *Related: political, legislative, institutional*	Challenges and enablers related to regulative frameworks, standards, norms and policies
Market *Related: economic, financial*	Challenges and enablers related to market mechanisms and incentives e.g., having a negative or positive effect on market mechanisms for reutilization of material
Organizational *Related: institutional*	Challenges and enablers related to organizational structure, can be both inter-organizational and/or interorganizational
Informational *Related: Socio-cultural*	Challenges and enablers related to awareness and knowledge
Technological *Related: operational*	Challenges and enablers related to technologies or infrastructure
Product complexity	Challenges and enablers related to products and materials

In a recent literature review, knowledge and awareness (i.e., informational) was found to be the major barrier category in development of CCSC, where lack of knowledge of concept and implementation was suggested a predominant barrier (Abadi et al., 2025). Which is in line with the findings of (Kirchherr et al., 2017; 2023) that though much has been published in recent years practitioners still struggle to implement its principles, or that they are even aware of implementation given the conceptual ambiguity which makes knowledge sharing difficult (Abadi., 2025). Other barriers mentioned were (Ibid.):

- lack of regulations and standards, where the latter makes it difficult to plan and control
- quality uncertainty, perception of inferior quality of circular materials and products and a lack of quality assurance system for circular materials and products

- lack of infrastructure to effectively manage materials and products EoU

Regulations play a central role in incentivizing demand and ensuring safe reutilization of materials, yet evaluating their effectiveness remains challenging (Dziedzic et al., 2025). Similar to how challenges and enablers have been clustered in previous research, policy instruments have been categorized into regulative (mandatory practices or targets), economic (financial incentives or disincentives), technical (standards), operational (facilitating infrastructure or processes), and communicative (knowledge dissemination and education) (Ibid.). A mix of such policies has been recommended to incentivize CE practices (Graaf et al., 2024; Dziedzic et al., 2025). However, their effects are likely to change over time and may require adaptation as the industry transitions (Abadi et al., 2025), as policies can act both as barriers and enablers. For example, a low landfill tax is unlikely to have a significant effect, whereas a very high tax may encourage informal waste markets (Dziedzic et al., 2025).

The economic viability of circular material flows in construction is challenged by the high availability of low-cost virgin materials (Dahlbo et al., 2015). For circular options to be competitive, treatment (e.g., recycling or landfill charges), transport, storage, and labour costs must be lower than the price of virgin materials (Väntsi and Kärki, 2014; Rakhshan et al., 2020). The waste producer is primarily concerned with treatment, transport, and labour costs, whereas users of recycled materials weigh treatment, recycling, and transport costs against the price of corresponding virgin raw materials (Väntsi and Kärki, 2014).

Economic viability is thus achieved when recycling costs are lower than alternative treatment options (e.g., landfilling or incineration) and when the cost of producing secondary materials is lower than that of virgin counterparts. Additional market and informational challenges include knowledge gaps regarding C&DW availability and potential supply, as well as market requirements for circular materials (Illankoon and Vithanage, 2023). The presence of a non-compliant informal sector further undermines the market for compliant actors

(Naturvårdsverket, 2024a). These factors vary across materials, time, and place, and the continued availability of low-cost virgin raw materials remains a major barrier to recycling C&DW and developing circular business models (Dahlbo et al., 2015).

Besides industry-inherent organizational and informational challenges, such as strong resistance to change and adverse relationships, a lack of knowledge about supply quality leads to a general assumption that the quality of circular materials is lower than that of virgin materials. Stakeholders' perceptions of reutilization are suggested to be interdependent with perceived risks (Rakhshan et al., 2020). Akerlof (1970) describes how quality uncertainty in secondary markets results in mistrust of products within a given category and negatively affects their market value, where brand, certifications, and quality assurance can serve as mechanisms to increase the value of sub-flows.

As reutilization of construction products and materials are partly dependent on access to reutilization infrastructure, viable options are dependent on access to local technology. As such there is a challenge to understand which reutilization option is best at a given place and point in time, i.e., understanding constraints and trade-offs between options (Kabirifar et al., 2020). Reuse is suggested to be prioritized before recycling both in literature referring to the R-principles and in the EU waste hierarchy. However, this strict prioritization has been questioned in a prior study, e.g., is it sufficient to reutilize a material in a way that later impede the recycling potential given that there is a well-functioning recycling option (Singh and Ordoñez, 2016)? Furthermore, Kabirifar et al., (2020) suggested that the effectiveness of different R-strategies should be measured (unclear how) and compared prior to deciding on which strategy to pursue.

A wide range of technologies and tools are applied across different phases of a building's life cycle to create, collect, and analyse data (Ding et al., 2023; Swarnakar et al., 2025). Matching tools to the organizational context is considered essential for efficient CE implementation (Swarnakar et al., 2025). In C&DWM, life cycle assessment (LCA), Building Information Modelling (BIM), and Material Flow Analysis (MFA) are among the most impactful tools globally, followed by machine learning (ML) and Global Positioning Systems (GIS) (Swarnakar et al., 2025). LCA evaluates the environmental impact of EoU scenarios, while BIM—together with material passports and 3D scanning—addresses information gaps and supports risk assessment (Ding et al., 2023; Swarnakar et al., 2025).

Emerging technologies such as AI, Big Data, Digital Twin, Blockchain, and RFID further support prediction, supply–demand matching, building performance, waste reduction, traceability, transparency, and decision-making for efficient resource use (Swarnakar et al., 2025). However, LCA has also been criticized for assuming one-to-one displacement of primary production (Geyer et al., 2016).

This chapter has addressed several challenges and enablers for implementing a CE in general and in the construction industry specifically, highlighting the multidimensional characteristics and interdependencies involved in enabling circular material flows. In addition to physical material flows, financial and information flows must also be coordinated, together with regulatory incentives—phenomena central to logistics management. ISO 59004:2024 identifies reverse logistics as a key mechanism for enabling circular flows and recovering value at EoU (ISO, 2024).

Although logistics management approaches have been applied to construction and to reverse flows, CE reshapes the objectives for coordinating supply chains flows from a linear to a circular logic. The following chapter introduces this perspective and the role of C&DWM in a CE.

2.3 Circular supply chain management and logistics in the construction industry

Construction logistics refers to logistics management applied within a construction context and encompasses both forward and reverse material flows, with C&DW managed in the latter. To understand circular supply chain management in the construction industry, this chapter first examines SCM and logistics in this context, followed by reverse logistics and C&DWM.

2.3.1 Supply Chain Management

The Council of Supply Chain Management Professionals (CSCMP) define SCM as "*Supply chain management encompasses the planning and management of all activities involved in sourcing and procurement, conversion, and all logistics management activities. Importantly, it also includes coordination and collaboration with channel partners, which can be suppliers, intermediaries, third party service providers, and customers. In essence, supply chain management integrates supply and demand management within and across companies*" (Council of Supply Chain Management Professionals (CSCMP), 2025). Where supply chain (SC) is defined as "*a set of three or more entities (organizations or individuals) directly involved in the upstream and downstream flows of products, services, finances, and/or information from a source to a customer*" (Ibid.).

SC vary in complexity depending on scope, as the greater the scope the greater the number of actors and flows to coordinate. Mentzer et al. (2001) illustrate three degrees of SC: a direct SC centers on a focal company and its first-tier supplier and customer, an extended SC extends the chain to include second tier suppliers and customers, and an ultimate SC include all suppliers and the ultimate customer. The authors further distinguish between SCM as a management philosophy—referred to as supply chain orientation (SCO)—and SCM as its implementation in practice. SCO is defined as "*the recognition by an organization of the systemic, strategic implications of the tactical activities involved in managing the various flows in a supply chain*" (Ibid.)

Hence, SCM entails a shared belief among companies within a supply chain of at least three entities that, through a systems perspective, coordinated material flows, and long-term intra- and intercompany collaboration can reduce costs, improve customer satisfaction, and enhance competitive advantage for all firms involved. Implementation of SCM entails integration of processes within and between actors across SC (Mentzer et al. 2001).

SCM originates from the manufacturing industry (Vrijohoef and Koskela, 2000), and implementation of SCM approaches in construction have been slow (Bankvall et al. 2010). Taking into consideration the peculiar traits of construction as compared to the manufacturing industry, Vrijhoef and Koskela, (2000) suggest four roles of SCM in construction, varying in scope and focus, making a distinguishment between the SC and the construction site. The first role emphasizes the intersection between the SC and the construction site, the second looks solely at the SC, neglecting interface to the construction site, the third looks at transferring activities from the construction site to the SC and the fourth looks at the SC and construction site as integrated parts.

Increased supply chain integration in construction has been suggested to improve both efficiency (Bankvall et al., 2010) and sustainable use of materials (Zeng et al., 2018). However, SCO in the construction industry is lacking – both intra- and inter-organizationally- as there are often multiple roles on different levels not synchronizing their activities and suppliers are often involved late in the process hampering their ability to efficiently plan and coordinate supply of material and services (Thunberg & Fredriksson 2018). The result being a non-optimal distribution with increased costs for both suppliers and projects as the project have to manage material that are delivered at non-optimal time, by non-optimal vehicles in non-optimal packaging (Ibid). Where, besides time wasted, this increases the risk of materials being handled incorrectly and ultimately increases the amount C&DW.

One proposed way to improve performance is to reduce temporal complexity in multi-partner project organizations, for example through prefabrication (Havinga et al., 2023). Other studies on material utilization or the CE in construction advocate an activity- or task-based focus rather than an actor- or resource-based perspective, as activities define the need for both actors and resources (Bankvall et al., 2010; Furlotti and Soda, 2018; Havinga et al., 2023). Hence, while some scholars argue for industry transformation through industrialized construction, others emphasize the need to adapt SCM theories to existing industry conditions (Bankvall et al., 2010).

2.3.2 Logistics management

Logistics management is closely related to SCM and operations management (Mentzer et al., 2008), and commonly regarded as a sub-area of SCM, involving the management of both physical (material) and non-physical (information) flows from the point of origin to the point of consumption in order to meet customer requirements efficiently. The Council of Supply Chain Management Professionals (CSCMP), defines logistics management as "…*that part of supply chain management that plans, implements, and controls the efficient, effective forward and reverses flow and storage of goods, services and related information between the point of origin and the point of consumption in order to meet customers' requirements*" (CSCMP, 2025). Or simply: "*the process of moving goods from the point of origin to customers*" (Ding et al., 2023). Historically, logistics management originated as a cost-focused function and has evolved into a means for achieving competitive advantage (Mentzer et al., 2008).

The movement of goods is global, and often obscure (Birtchell et al., 2015). As it moves across jurisdictions policy can create local variations as it intersects the path of the goods in transit (Allen et al., 2015). Hence, authorities on different levels are key stakeholders as they hold a strong position to influence the infrastructure and how it is utilized, i.e. the flows (e.g., Allen et al., 2015, p297-298; Fredriksson and Huge-Brodin, 2022) Other important influential actors are companies performing logistics services and goods receivers (Allen et al., 2015, p297-298), which in construction can be clustered into contractors and developers (Fredriksson & Huge-Brodin, 2022).

Logistical activities can be categorized in several ways. Thunberg and Fredriksson (2023) distinguish between physical and non-physical logistics activities, whereas construction logistics literature often differentiates between on-site and off-site activities (Janné, 2020). The CSCMP definition further distinguishes between inbound and outbound logistics, as well as forward and reverse flows (CSCMP, 2025). Additionally, logistics management is frequently described as encompassing transportation, warehousing, materials handling, inventory management, order fulfillment, procurement, and customer service (Mentzer et al., 2008).

2.3.3 Construction logistics management

Construction logistics management can be understood as logistics management applied within a construction context (Janné, 2020). In line with the four scenarios for SCM in construction described by Vrijhoef and Koskela (2000), construction logistics often separate between on-site (logistical activities at the construction site) and off-site logistics (e.g. what Vrijhoef and Koskela (2000) describe as the SC) (Janné, 2020). However, as shown by Sundqvist et al., 2018 on-site and off-site logistics are interdependent as reorganization in either one creates implications for the other.

From a project perspective, whether the focus is on on-site or off-site logistics depends on the initiator of the *logistical set-up*. A *construction logistical setup* can be defined as *"a governance structure for a construction project that has been agreed on to control, manage, and follow up the flow of materials, waste, machinery, and personnel to, from, and on the construction site"* (Fredriksson et al., 2021). In Sweden the initiator is usually either the main contractor, the developer or local municipality, each with varying incentives for procuring logistical services. The purpose of the set-up is central in its design (e.g. actors involved and services included) (Fredriksson et al., 2021). Thus, the services included in the set-up varies between projects and dependent on local availability of services and capabilities, though the most common service is suggested to be booking systems to manage deliveries to the project site (Ibid.).

Many construction projects are situated in dense urban areas, where the project must share space and the infrastructure with the surrounding built environment. Hence, there are similarities in the issues addressed in urban logistics, focusing on the logistical flows in the built environment, and construction logistics focusing on the flows related to construction sites as projects are temporal functions of the urban area where construction transport make up a fraction of the transport flow. Thus, besides efficient coordination of flows, other common objectives with CLS is to reduce transport emissions and mitigate congestion in urban areas (Fredriksson et al., 2021).

Urban planning has a significant impact on construction logistics in terms of space and accessibility. Studies show that integrated urban freight planning has strong potential to improve the utilization of existing infrastructure and fill-rates, thereby easing traffic movements in terms of frequency, number of vehicles, and distance travelled, and mitigating congestion and its associated environmental and social impacts, such as emissions (CO_2e, NO2, and particulate matter), noise, and accidents (Allen et al., 2015). Construction transports have been estimated to make up 30% of total urban transports (Guerlain et al., 2019), where a case study in Australia estimated that approximately 19% of the transports to a construction site were related to C&DWM (Ying et al., 2018).

To improve the flow of goods to and from construction sites, construction logistics centers (CLCs) or checkpoints are sometimes used, directing construction transport to off-site premises for unloading and storage before last-mile delivery to construction projects (Lundesjö, 2019; Janné, 2020). Similar concepts include urban consolidation centers (UCCs) and distribution centers (DCs).

DCs form part of dispersed warehouse networks where goods are kept in movement to enable a smooth flow of products from manufacturers across the globe to final customers (Allen et al., 2015; Cidell, 2015). While the main purpose of DCs is to reduce lead times and costs, UCCs aim to consolidate deliveries to optimize last-mile distribution and mitigate the negative health effects of heavy traffic and congestion, such as pollutants and noise. However, goods entering a UCC have often already passed an intra-company DC, meaning that handling at the UCC adds an additional step in the supply chain and may increase distribution costs (Allen et al., 2015).

The challenge for CLCs are similar as for UCCs, in that actors using the set-up and potentially benefiting from it are not the ones financing it and thus UCC rarely withstands without public subsidizes (Allen et al., 2015). Hence, there is a challenge of finding the right business model and policy that creates incentives where needed.

In a literature review examining how logistics and SCM have been applied in the construction industry over the past two decades, six research clusters were identified: prefabrication, procurement, supply chain integration, green construction, reverse logistics, and on-site logistics (Nguyen, 2022). In parallel, advances in technology and decreasing costs of sensors have opened new possibilities for understanding logistical flows, such as transport patterns in freight transport (Taniguchi et al., 2016). These developments have also been suggested to enable dynamic planning using real-time data (Taniguchi et al., 2016) and to support the evaluation of different transport policy measures (Kervall and Pålsson, 2022).

2.3.3 Reverse logistics and construction and demolition waste management

RL and C&DW management both address management of return flows, where C&DW constitutes a substantial part of the material flow. Both research fields have been suggested to derive from the 1980's (Kabirifar et al., 2020; Ding et al., 2023), however, from different perspectives and legal frameworks, where RL has focused on products and C&DWM on waste.

Reverse logistics has been fragmentally used in previous research (Hosseini et al., 2015). Historically it has mainly been applied to the manufacturing industry, where it has been described as a process of moving goods from the point of consumption to the point of origin (Rogers and Tibben-Lembke, 2001). Thus, early applications of reverse logistics concerned the management of product returns related to return policies and were seen as processes of moving products backwards through their original supply chains (Ding et al., 2023).

In construction supply chain management and logistics literature, RL has been identified as an emerging concept, closely related to green logistics (Nguyen, 2022). In a recent study on circular logistics in construction Ding et al. 2023 refers to RL as the *"process of planning, executing, and controlling efficient material and product flows, as well as relevant information […] from the end-of-use of projects or products to the point of resource value recapturing or* *proper disposal"*. This is similar to the definition provided in ISO 59004:2024, which describes RL as the process of moving products (including their collection and management) from their EoU through appropriate handling (including recycling) to recover or retain value, while explicitly excluding the logistics required to deliver products to a new customer.

C&DWM research has focused on mitigating the environmental burden of waste, with much emphasis directed towards waste minimization (Kabirifar et al., 2020). Objectives within C&DWM research are commonly anchored to one or more of the strategies of the waste hierarchy, where reduce, reuse and recycling are predominant (Kabirifar et al., 2020). Strategies that mirror the R-principles. However, the waste hierarchy focus on waste management whereas CE focus on reutilization (Singh and Ordoñez, 2016). Accordingly, RL has traditionally managed reverse product flows with the objective of value creation and retention. Whereas C&DW management has focused on "reverse" waste flows with the objective of risk mitigation and environmental protection (Kabirifar et al., 2020).

Both research on implementation of CE in the construction industry (Illankoon and Vithanage, 2023) and recent research on RL in construction (Ding et al., 2023) have highlighted C&DW management as a prominent theme. Whereas recent C&DW management research has positioned CE as a prominent field. Thus, suggesting a convergence of the two research fields in the light of CE opening for a more holistic perspective of reverse flows. In line with the findings of Ding et al., (2023) that even though there are similarities in approaches used in FL and RL phases respectively, little attention has been given to integrating phases between FL and RL e.g., combining networks of transports and facilities in both FL (i.e., product flows) and RL (i.e., waste flows) phases.

2.3.4 Circular Supply Chains

Circular supply chains (CSC) integrate CE principles into SCM (Farooque et al., 2019), where Geissdoerfer et al., (2017) emphasize *"the configuration and coordination of the supply chain to close,* *narrow, slow, intensify and dematerialize resource loops"*. Thus, (re-)utilization of resources is central in CSC, as opposed to its linear counterpart. As such, CSC are often depicted as a circle divided into two opposite directed flows, a forward SC (FSC) mimicking the structure of the traditional linear SC that integrates with a reverse SC (RSC) when products and materials reach EoU (Farooque et al., 2019; Chen et al., 2022; Ding et al., 2023). Hence, while the FSC focuses on slowing and narrowing strategies the RSC focuses on closing strategies, i.e., on enabling re-utilization through e.g., reuse and recycling.

Re-utilization of products and material in CSC can be divided into closed loop or open loop. Closed loop RSC integrates with the FSC from where products and materials originate prior to EoU, whereas open loop RSC can be integrated with any, and multiple, FSC independent on the product origin (Farooque et al., 2019). Nevertheless, as acknowledged in the model of a CSC by Farooque et al., (2019) CSC does not operate in a closed system.

2.3.5 Circular Construction Supply Chains

The conceptualization of circular construction supply chains (CCSC) (Abadi et al., 2025) and circular construction value chains (Dewagoda et al., 2022) has been suggested to be underdeveloped. One way to describe CCSC is through phases in which different CE strategies are applied: design, manufacturing, construction, operations and management, and end-of-life (EoL) (Chen et al., 2022). These phases can be further divided into forward logistics (FL) and reverse logistics (RL), where RL refers to operations at end-of-use (EoU), where on-site logistics comprises the logistical activities deployed at the construction site and connects FL with RL at EoU within the CCSC (Ding et al., 2023).

Different CE strategies and approaches have been identified to apply to different phases of the CCSC (Cheng et al. 2022) and in the phases related to logistics operations (Ding et al., 2023). For CCSC slowing strategies have focused on prolonging the lifetime of buildings, narrowing on efficient use of resources through design and in construction, and closing on reuse and recycling of EoL materials

(Chen et al., 2022). Examples of dimensions that have been addressed in literature related to CE in construction are the interplay between on-site and off-site logistics (Bankvall et al., 2010), the dynamics of supply-push and demand-pull in CCSC (Abadi et al., 2025), the interdependencies between actors, resources and activities (Havinga et al., 2023) and circular logistics integrations between phases in CCSC (Ding et al., 2023).

Building on the identification of CCSC as a complex adaptive system (non-linear, evolving, adaptive, self-organizing) Abadi et al., (2025) suggests the following definition of CCSC: *"a complex transformational construct, where SC actors at the macro-meso-micro levels (policy makers, NGOs, think tanks, academic institutions, clients, designers, contractors, suppliers … etc.) collaborate in non-linear patterns, self-organise their activities, and build resilience in CCSCs governance using supply-push measures to encourage demand-pull initiatives and yield emergent behaviours that prioritise circularity in construction to promote emerging circular concepts, products, or methods of working ".*

2.3.6 Circular Constructions logistics

Following the premise that construction logistics management constitutes logistics management within a construction context (Janné, 2020), and that logistics management is a sub-area of SCM (Mentzer et al., 2008), circular construction logistics can be positioned as part of circular construction supply chains (CCSC). Building on definitions of CCSC provided by Abadi et al. (2025), circular construction logistics can be described as the part of CCSC management that plans, implements, and controls the efficient and effective circular flows and storage of goods, services, and related information between actors and across multiple levels in a complex, transformational context (CSCMP, 2025; Abadi et al., 2025).

The objective of circular construction logistics is to through efficient coordination of material and information flows create value in inter-organizational constellations to promote emerging circular concepts, products, or methods of working. This definition is applicable from both a supply chain and a value chain perspective, aligning with the logistics definition proposed by Ding et al. (2023) from a supply chain perspective, as well as with the use of logistics as a value-creating activity in the construction value chain as conceptualized by Dewagoda et al. (2022).

Given that the CE emphasizes retaining materials at their highest value through reuse and recycling, and that the realization of such flows is context-dependent, this thesis defines the role of C&DWM in a CE as contributing to the highest achievable circularity rate of materials suitable for reutilization. The attainable circularity rate depends on factors such as the composition of the built environment, the regulatory framework, access to technology and infrastructure, and demand for circular materials. In this context, individual activities aim to maximize circularity potential within given constraints.

Chapter 3

Methodology

This chapter describes the research setting and my contribution to the studies included in this thesis. It presents the research design, outlines the choice of methods, discusses considerations related to validity and reliability, and concludes with a statement of the author's background and role in the research.

3.1 Descriptive overview

This thesis is a compilation of three conference papers that is a result of three studies, that conducted as a part of the research project "Construction logistics for increased material utilization and transport efficiency" (Swe: Bygglogistik för ökad resurshushållning och transporteffektivitet genom aktörssamverkan (BÖRjA))" financed by the Swedish Innovation Agency (Swe: Vinnova). The papers were, co-written in collaboration with academics with affiliation to four different Swedish Universities, see Table 3. Two of the papers were in the process of being rewritten into journal publications when this thesis was produced, Paper I, with an enhanced analysis, and Paper II, extended with four more cases.

Table 3. A brief overview of the papers included in this thesis, describing title, co-authors and the conference where the papers were presented.

	Title	**Co-authors**	**Conference**
I	Logistics: a key to increased resource utilization and transport efficiency in circular flows of construction materials	Anna Fredriksson, Linköping University	PLAN Forsknings- och tillämpningskonferens 2023. Trollhättan, 17-18 October 2023
II	Circular hubs: enablers for increasing reuse of construction products	Ahmet Anil Sezer, Halmstad University and Fredrik Nilsson, Lund University	ARCOM Conference 2024: Looking Back to Move Forward, London, 2-4 September 2024
III	Circular construction logistics for retaining value of waste material in new build projects	Nicolas Brusselares, Linköping University and Mats Johansson, Chalmers University of Technology	EurOMA 2024: TRANSFORMING PEOPLE AND PROCESSES FOR A BETTER WORLD, Barcelona, 29th of June – 4th of July 2024.

3.2 Research design

The research design of this thesis was inspired by Flyvbjerg's (2006) principle that good research design is problem-centric, where methods are curated to best address the questions at hand. The papers included in this thesis were all exploratory and aim to develop a deeper understanding of barriers and enablers related to increasing circularity in new build and renovation projects.

As the topic involves ambiguity in central concepts and includes many actors operating across multiple dimensions, from the regulatory landscape to actors' behaviour at organizational and individual levels, a qualitative research approach was considered appropriate.

Qualitative methods are well suited for studies seeking to understand complex phenomena, particularly when the subject under investigation are new, poorly studied, or complex (Bryman and Bell, 2015; Creswell and Creswell, 2023). In the case of implementing CE in the construction industry, the inherent complexity of the industry together with conceptual ambiguity motivates this approach. In addition, emerging circular logistics practices in construction remain relatively underexplored, further supporting the use of an exploratory qualitative research approach

Three qualitative research designs were developed and applied to capture different perspectives on circular construction logistics. Table 4 provides an overview of how the individual studies aligns with and address the research questions of the thesis.

Table 4. Overview of the studies included in the thesis, illustrating how each paper contributes to the research questions, empirical focus, and methods used.

Thesis RQs	Paper	Empirical focus	Method
RQ1	Paper I	Actor perspectives on circular construction logistics	Semi-structured interviews and workshops
RQ2b	Paper II	Circular construction hubs: off-site logistics activities	Multiple-case study
RQ2a	Paper III	Waste flows in new build residential construction projects	Single case study

All studies followed an abductive research approach, allowing empirical findings to inform the scope of the literature used in the analysis. Together, the three studies provide complementary perspectives on circular construction logistics by addressing actor perspectives as well as logistics activities supporting circular material flows, both off-site and on-site in construction projects. The following sections describe the design, data collection, and analytical approaches of the individual studies in more detail.

3.2.1 Study I - Actor perspectives on circular construction logistics

The first study employed an interview-based research design to examine actor perspectives on logistics and circularity (see Fig. 2). Semi-structured interviews were conducted with actors from the Swedish construction industry, with a particular focus on construction logistics. Workshops (WS) with industry actors informed the development of the interview guide and supported the discussion of preliminary findings.

A total of 16 semi-structured interviews were conducted, lasting between 35 and 60 minutes and involving one to three respondents participated in each interview. Respondents were selected based on their roles in the industry, informed by previous research on actors involved in construction logistics in Sweden. Furthermore, their participation in a research project aimed at increasing resource utilization and transport efficiency supported the selection of relevant interview candidates. An interview guide was distributed in advance (see Appendix A), allowing respondents to invite colleagues with relevant expertise if appropriate. All interviews were recorded and transcribed, and notes were taken during the interviews.

The interview material was coded and subsequently analysed using thematic analysis and pattern matching to identify, sort, and categorize challenges and enablers. Workshops with industry actors contributed to the development of the interview guide and were also used to validate and discuss preliminary findings. This study contributes to the thesis purpose by examining how actors involved in construction logistics perceive circularity, their roles, and the challenges and enablers associated with increasing circularity in construction projects.

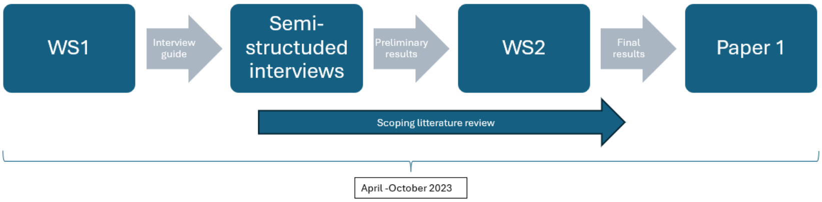

Fig 2. Research design for Study I: qualitative interview-based design.

3.2.2 Study II - Circular construction hubs

The second study applied a multiple-case study design to examine logistics activities of circular construction hubs (CCH) and their role in facilitating the reuse of construction products (see Fig. 3). Three CCH were selected as cases. The hubs shared a similar purpose of enabling reuse while differing in complementary characteristics such as market orientation and organizational structure, which enabled cross-case comparison.

Data were collected through semi-structured interviews and direct observations conducted at the hubs. Interviews were conducted with representatives responsible for hub operations (see Interview guide in Appendix A), and in one case a group interview was carried out. Observations were conducted prior to the interviews to provide contextual understanding of hub activities and logistics practices. Both interviews and observations lasted approximately 60 minutes and were documented through recordings and field notes.

The empirical material was analysed through narrative case descriptions followed by cross-case comparison to identify similarities and differences in hub practices. This study contributes to the thesis purpose by examining off-site logistics activities that support circular material flows and facilitate the reuse of construction products.

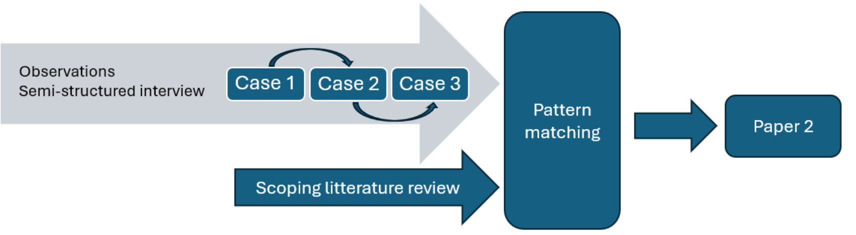

Fig 3. Research design for Study II: multiple-case study design.

3.2.3 Study III – Waste flow variation in construction projects

The third study employed a single case study design to examine variations in waste flows during different phases of new-build construction projects (see Fig. 4). The study focused on understanding how waste generation and return flows vary over time in construction projects and how this variation may influence on-site logistics practices.

The framing of the study was informed by workshops with project participants focusing on resource utilization and transport efficiency in new-build projects. These discussions highlighted that return flows vary during construction projects and that understanding this variation could support improved planning of return-flow logistics on-site.

The empirical material consisted of both primary and secondary data. Secondary data included waste collection records provided by a waste management company and project time plans from a main contractor, covering five construction projects conducted between 2016 and 2023. The dataset contained information on waste fractions, collection dates, load carrier types, and collected waste weight. Primary data were collected during two site visits to an ongoing construction project, where unstructured interviews with the site manager were conducted alongside observations of on-site sorting and material flows.

The empirical material was analysed by comparing waste flows across different project phases to identify variations in waste fractions and volumes over time. This study contributes to the thesis purpose by examining on-site material flows and waste generation patterns, providing insights into how waste flows evolve during different phases of construction projects.

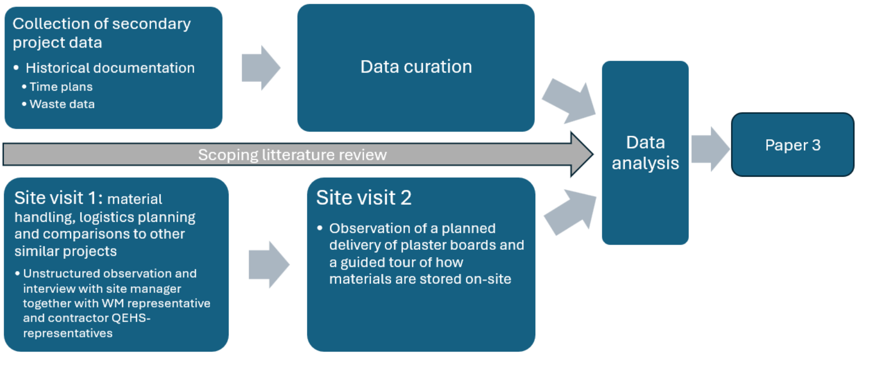

Fig 4. Research design for study III: single case study design.

3.3 Choice of methods

Methods are techniques used within a particular research design for collecting, analysing, and interpreting data (Creswell and Creswell, 2023, p. 28). While Section 3.2 described the research designs of the three studies, this section outlines the specific methods used for collecting and analysing empirical data. Table 5 provides an overview of the methods applied in the three studies. The following subsections describe these methods and their application in the research.

Table 5. Overview of methods used in the three studies.

Study	Design	Data	Analysis
I	Interview study	Semi-structured interviews	Thematic analysis, pattern matching
II	Multiple-case study	Semi-structured interviews, direct observations	Narrative, cross-case comparison
III	Single case study	Site visits, secondary datasets and time plans	Phase comparison of waste flows

3.3.1 Case study

Case studies are suitable for research addressing *how* and *why* questions and seeking a deep understanding of complex or poorly studied phenomena (Yin, 2014). Case study designs often combine multiple data sources, such as interviews, observations, and archival documentation, allowing for rich contextual analysis (Yin, 2014; Creswell and Creswell, 2023). Case studies may involve either a single case or multiple cases, allowing for in-depth analysis or cross-case comparison. Although case studies are typically associated with qualitative research and small samples, they may also incorporate quantitative data and mixed-method designs (Yin, 2014; Creswell and Creswell, 2023).

The second research question sought to identify logistics activities that support operations for circular material flows from both on-site and off-site perspectives. To address these perspectives, two case study designs were developed and applied.

To address the on-site perspective, a single case study was conducted to examine variations of waste flows during new-build construction projects and their implications for on-site logistics activities. Estimating return flows is an important prerequisite for planning on-site sorting, which in turn enables the reutilization of return-flow materials (Hosseini et al., 2017; Villoria-Sáez et al., 2020). However, construction sites are often constrained by limited space, which restricts waste-sorting layouts, for example regarding the size and placement of load carriers. Return flows from new-build projects are also assumed to have high circularity potential due to their short use phase and the potential availability of material information. Case studies are commonly used to study C&DW generation and composition at the project level, where methods such as observations, waste monitoring, truckload measurements, and surveys are often applied (Villoria-Sáez et al., 2020).

Given the aim of understanding variations in return flows during construction projects and considering the availability of historical case data and access to industry stakeholders, a single case study design was adopted. The collected data (project time plans and waste statistics) were of secondary origin and complemented with primary data from observations and unstructured interviews conducted during site visits to an ongoing construction project.

To address the off-site perspective, a multiple-case study design was developed to examine the practices of intermediate actors enabling the reutilization of materials between projects. Previous studies indicate that reuse within and between construction projects often requires intermediate storage and coordination activities that remain underexplored in the literature (Bosch et al., 2020; Ding et al., 2023). Given the limited academic documentation of reuse hubs for construction materials, the study adopted an exploratory approach to understand how such hubs operate.

Three cases were selected, each representing a circular construction hub (CCH). The cases were chosen because they shared a similar purpose of enabling reuse, while differing in complementary characteristics (e.g., market and organizational type), which allowed for cross-case comparison and identification of differences in practice. Data were collected through semi-structured interviews and direct observations, two commonly used data collection methods in case study research (Yin, 2014). Together, these methods enabled the generation of rich, in-depth insights and helped mitigate respondent bias by providing complementary perspectives.

Together, the single-case and multiple-case designs enabled the examination of logistics activities supporting circular material flows from both on-site and off-site perspectives.

3.3.2 Interviews and observations

Interviews and observations are common qualitative data collection methods and can be used independently or embedded within case study designs (Creswell and Creswell, 2023). In qualitative research, interviews are typically semi-structured or unstructured, allowing respondents to provide nuanced perspectives and insights into phenomena that cannot be directly observed (Bryman and Bell, 2015, p. 135). Interview guides are often used to maintain a line of inquiry while allowing flexibility during the conversation (Creswell and Creswell, 2023). Observations involve the researcher examining activities and behaviour within a research setting and can complement interview data by providing contextual understanding of practices and interactions (Yin, 2014; Creswell and Creswell, 2023). Observations may be participatory or direct.

In this thesis, interviews and observations were applied across the studies to capture actor perspectives and to examine logistics practices. A total of 21 interviews were conducted, including 19 semi-structured interviews that were recorded and transcribed (see interview guides in Appendix A), with supplementary notes taken during each session, and two unstructured interviews conducted during site visits, for which notes were taken. Three of the interviews were embedded within case studies. In addition, five direct observations were conducted, all of which were embedded within case studies and documented through field notes.

3.3.3 Workshops

Workshops with project participants were used to support problem framing (Studies I and III) and to validate preliminary findings and add perspectives (Study I). The workshops varied in constellation depending on the scope and interest of participants.

In the single-case study, discussions during workshops highlighted that return flows vary during construction projects and that understanding this variation could support improved planning of return-flow logistics on-site. In the interview study, workshops contributed to the development of the interview guide and were later used to discuss preliminary findings and further explore the articulated need for "hubs".

3.3.4 Secondary data

Secondary data refers to data that has not been collected specifically for the study at hand and may therefore entail limitations regarding its use. In this research, secondary data constituted the main data source for the single-case study and consisted of project time plans and waste data from five historical new-build residential projects.

Given the timeframe of the study and the accessibility of historical project data through domain representatives, this was considered the most feasible option. Collecting corresponding primary data would have required access to projects that had not yet started and fulfilled the case criteria, which would likely have required 2-5 years[1] to complete.

3.3.5 Data curation

As all interviews were recorded, they could all be transcribed. The interview guide was used to organize the transcript material. As the interviews were semi-structured the answers did not strictly follow the order of the guide. When responses did not match the guide, additional categories were created. This structuring enabled both data aggregation and cross-analysis.

The single-case study used secondary project and waste data that required the data to be structured in a way that enabled cross-comparison. Project time plans had different levels of detail and were therefore translated into generic phases. The waste data were restructured and cleaned (e.g., removal of out-of-scope data and harmonization of material names that had changed over time) to ensure quality and enable the intended analysis. The categorization of project phases was validated with the data provider, and the structuring of waste data was supported by company representatives. Familiarity with the data structure and terminology (e.g., names of

[1] Based on the project duration in the completed projects that were used (Paper III)

load carriers and vehicle types) also facilitated restructuring and interpretation.

3.4 Validity and reliability

Qualitative research typically relies on small, purposively selected samples (e.g., Yin, 2014; Creswell and Creswell, 2023). Accordingly, respondents and cases in the present studies were carefully selected to match the research questions addressed. Such sampling enables an in-depth understanding of the studied phenomena rather than statistical generalization.

In qualitative research, validity refers to the trustworthiness and accuracy of the findings, while reliability relates to the consistency of the research procedures (Creswell and Creswell, 2023). To assess the validity of the findings in Papers I–III, the eight primary strategies proposed by Creswell and Creswell (2023) were used as a guiding framework. Table 6 presents these strategies and describes how they were addressed in the present research.

Table 6. Strategies for strengthening validity in qualitative research and their application in the present studies (adapted from Creswell and Creswell, 2023).

Validity strategies	**Application**
Triangulation of multiple data sources	Multiple data sources were used to corroborate findings across the studies. **Paper I:** semi-structured interviews and a scoping literature review. **Paper II:** direct observations, semi-structured interviews, and a scoping literature review. **Paper III:** archival data from two sources and site visits (including direct observations and unstructured interviews). *See also Table 5.*
Use informants to check final reports or semi-final parts	This strategy was applied in all three studies through workshops with informants to plan studies, discuss and validate preliminary and results (see Section 3.3.3, Workshops).

Provide detailed descriptions when presenting findings	In the individual papers this strategy is partly constrained by page limitations. Therefore, Chapter 2 of the thesis provides a richer description of the research context, including key challenges, enablers, and activities.
Clarify researcher bias	Chapter 3.5 Authors statement
Provide negative or discrepant information	In line with this principle, the papers and the thesis aim to describe different aspects of the studied phenomena from multiple perspectives.
Spend prolong time in the field	Although the studies were limited in time, I have more than 10 years of professional experience in working in the field, providing familiarity with part of the context and supporting the interpretation of empirical data
Use peer debriefing	All studies included in this thesis involved multiple authors, which functioned as a mechanism for mitigating the risk of individual bias that might otherwise influence the analysis. The involvement of multiple researchers enabled continuous discussion of interpretations and analytical decisions. Furthermore, collaboration among several researchers enriched the analysis by incorporating multiple perspectives and facilitating the collection and curation of rich empirical data, which is characteristic of case study research (Eisenhardt, 1989).
External scrutiny	The research process and interpretations were discussed with supervisors and co-authors, providing external feedback on analytical decisions. Furthermore, the studies were subjected to external scrutiny at academic conferences where the papers were accepted and presented. In addition, two papers are currently being further developed for submission to peer-reviewed journals

The semi-structured interview approach enabled verification of interpretations and clarification of respondents' answers. Interview guides were used to document research procedures and disclose a chain of evidence, supporting reliability (Yin, 2014; Creswell and Creswell, 2023; Appendix A). Furthermore, all interviews were recorded and transcribed, and the transcripts were used in the analysis.

Interview-based research also entails potential limitations, as information is filtered through respondents who may differ in articulation and perception and may be influenced by the presence of the researcher. Observations complemented the interview data and supported the validation of respondents' statements, thereby strengthening the robustness of the empirical material.

In the revised version of Paper I, additional corroboration with the literature was conducted, and in Paper II additional cases were included, thereby strengthening the validity of the studies. For the study presented in Paper III, including information on inbound materials could further strengthen its validity. Similarly, collecting primary data from an ongoing project could have strengthened the study, although this would have required additional time and resources.

Finally, the studies do not allow for analysis of changes over time. This is mainly due to time limitations, as longitudinal studies require sufficient time to observe such changes.

3.5 Authors statement

I am an industrial PhD student employed by the Swedish waste management company Ragn-Sells and affiliated with Linköping University for my research education. I hold a Master of Science in Engineering in Design and Product Realization, with a specialization in Sustainable Technology, from the Royal Institute of Technology (KTH) in Sweden.

I have worked for Ragn-Sells for more than 10 years in roles including production manager for urban waste logistics services (hubs in commercial buildings), responsible for nationwide delivery coordination, and business developer focusing on circular solutions.

During my PhD studies, I also served as project manager for the Vinnova-funded research project BÖRjA, within which the studies presented in this thesis were conducted. The project ran from May 2023 to July 2025 and provided the empirical context for the research. It involved 23 partners from both industry and academia, representing a broad set of actors involved in construction logistics, as identified by Fredriksson and Huge-Brodin (2022). The project aimed to increase resource utilization and transport efficiency in construction through actor collaboration and was structured around three scenarios: new build, renovation, and demolition, reflecting differences in material flow composition, volume, and circularity potential. The project also included a policy and business model lab. Although I oversaw the project as a whole, I was primarily active in the new-build and renovation scenarios, within which the studies included in this thesis were conducted.

I am the main author of all three conference papers and was involved in all stages of the studies, from planning and execution to analysis of the results, writing the papers, and presenting them at the conferences (see Table 7 for a summary of author contributions). Although the second paper was written before the third, the third paper was presented at a conference prior to the presentation of the second paper. Project participants acted as informants and contributed to case selection, data collection and validation of preliminary results.

Table 7. Author contributions to the conducted studies.

Study	Author contributions
I	I was the main author and involved in all stages of the study, including planning, data collection, analysis, and writing. I developed the interview guide with support from my supervisor and co-author, conducted all interviews, and was responsible for transcription and thematic analysis. I also contributed to planning and moderating workshops with industry actors, which supported study design and validation of the results. The paper was co-authored with my main supervisor, who contributed logistics-related theoretical perspectives and supported the structuring, analysis, discussion, and conclusions.
II	I was the main author and contributed to the planning of the study, including case selection and development of the interview protocol, as well as to its execution through observations and semi-structured interviews. I was also involved in the thematic analysis and writing of the paper. The co-authors contributed to the planning of the study, and two of the three observations and interviews were conducted together with one of the co-authors. Interviews were transcribed using a professional transcription service, and the analysis was carried out collaboratively with the co-authors.
III	I was the main author and contributed to case selection, data collection (secondary data in the form of project time plans and waste data from completed projects), observations and unstructured interviews, data curation, analysis, and writing. The co-authors contributed to the planning of the study and to structuring the data for analysis, and acted as reviewers during the writing process, supporting improvements in scope, structure, and argumentation.

The methodological choices and procedures described in this chapter provide the foundation for the studies included in this thesis. The following chapter summarizes the three papers on which the thesis is based.

Chapter 4

Summary of appended papers

This chapter summarizes the three appended papers, highlighting their purpose, methodological approach, key findings, and contributions to the research questions. Together, the papers provide complementary perspectives on logistics-related activities, challenges, and enablers for circular material flows in construction, addressing both actor-related and operational aspects.

4.1 Paper I - Logistics: a key to increased resource utilization and transport efficiency in circular flows of construction materials

The purpose of Paper I was to explore how construction logistics can support transport- and cost-efficient circular material flows. Using an interview-based research design, the study examined how actors perceive circularity, their roles and motivations, and the challenges and enablers they encounter, thereby addressing RQ1.

The findings indicate that actors interpret circularity in different ways, with motivations ranging from perceiving it as a risk to viewing it as an opportunity. These differences are reflected in company policies as well as in how circularity is measured and monitored.

The analysis further identifies interdependencies between categories of challenges and enablers, suggesting that addressing one challenge may be associated with challenges in others. Eight interrelated categories were identified:

- praxis-related knowledge
- experience
- total cost
- business models
- matching supply and demand
- information sharing and digitalization
- policy

• design

Together, these categories suggest a self-reinforcing loop of challenges, where deficiencies in one area are associated with challenges in others (see Fig. 5).

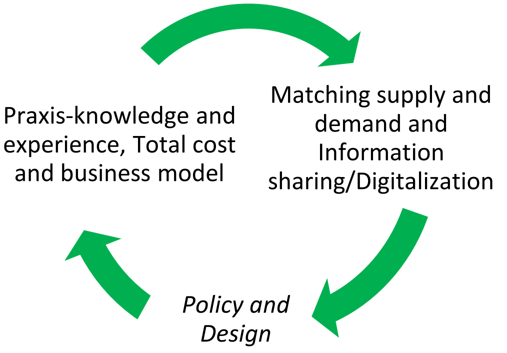

Fig. 5. Self-reinforcing loop of logistics-related challenge and enabler clusters. Deficiencies in one category are associated with challenges in others (Source: Åkerberg & Fredriksson, 2023).

Based on these findings, the study proposes a complementary research agenda aimed at addressing these dynamics. The agenda highlights the need to develop praxis-based knowledge related to matching supply and demand of circular materials across projects, which may support improved cost assessments and strengthen incentives for change.

4.2 Paper II - Circular hubs: enablers for increasing reuse of construction products

The purpose of Paper II was to examine how CCHs for construction products and materials operate, including the logistical activities through which they support off-site solutions for circular material flows, thereby addressing RQ2. Using a multiple case study research design based on semi-structured interviews and observations at three different types of CCHs, the study examined how these hubs operate, the logistical activities they perform, and the services and products they provide.

The findings indicate that reuse is technically feasible but appears to depend on active coordination between supply and demand, as both supply and demand uncertainty are associated with challenges in planning for construction projects and reverse logistics systems. The study also shows that CCHs function as more than storage facilities by performing enabling activities such as material assessment, inventory management, information documentation, marketing, sales administration, and environmental reporting, with these services evolving through iterative experimentation in an immature market.

The analysis further shows that there is a variety of hubs, differing in purpose as well as in the services and products they provide. A common trait is their intermediary function in matching supply and demand for reuse, where one of the main features is the warehouse function. Other shared features include the use of inventory protocols and related services for identifying reusable products in supplying buildings.

Based on these findings, three areas for improvement are suggested:

1. expand the market by supplying new-build construction projects
2. improve estimations of future demand to meet required quantities at the right time
3. increase transport efficiency, partly related to improved demand estimations

4.3 Paper III - Circular construction logistics for retaining value of waste material in new build projects

The purpose of Paper III was to study variations in waste fractions and volumes across construction phases to identify which materials were generated and in what quantities during different periods of a construction project. Using a single case study research design of new-build projects, the study examined how return flows vary over time in relation to construction phases, thereby contributing to RQ2 by enhancing the understanding of on-site logistics activities and constraints related to return flows and waste sorting.

The findings indicate that waste volumes and fractions vary throughout construction projects. However, current waste data appears too aggregated to evaluate improvements in sorting practices for enhanced circularity potential. The study also highlights logistical complexities, including diverse load carriers, interdependencies between load carriers and vehicle types, and different legislative frameworks governing products and waste, suggesting that improving circular outcomes is associated with the need for enhanced information sharing and coordination across actors and logistics systems.

Based on these findings, two areas for future research are suggested:

1. improve operational planning by integrating product information (e.g., bill of materials) to better understand the composition of return flows and the relationship between input and output.
2. improve the management of low-volume, low-value materials over long distances to enable aggregation into higher-quality secondary materials.

Chapter 5

Findings

This chapter synthesizes the findings of the three studies included in the thesis and answers the research questions. Section 5.1 addresses perceptions of circularity among actors involved in construction logistics. Section 5.2 presents logistics activities that support circular material flows. Section 5.3 discusses challenges and enablers identified across the studies. Finally, Section 5.4 synthesizes the findings by examining how the gap between circular supply and circular demand can be managed.

5.1 Perceptions of circularity

This section addresses the first research question concerning how actors in the construction industry perceive and interpret circularity. Drawing primarily on the findings from Paper I, it examines how the interviewed actors interpret circularity, how these interpretations relate to their roles in the construction industry, and how they influence motivations and approaches to implementation.

The interviewed generally acknowledge circularity as important and often describe it as necessary to address environmental challenges. Given that the respondents were participating in a project focused on improving resource utilization and transport efficiency, this perspective is not surprising. However, how circularity is perceived and translated into action varies across actors. For some organizations, circularity is incorporated into company strategies or environmental management systems, while others describe it as a future-oriented objective rather than an operationalized practice.

Actors' incentives for engaging in circular practices vary. Circularity may be perceived as a response to regulatory pressures or environmental risks, but it may also be seen as a business opportunity that enables new services, provides competitive advantage, or helps secure future material supply. At the same time, respondents express awareness that increasing circular flows may lead to additional transport activities, highlighting that what is circular is not always perceived as sustainable.

Perceptions of circularity are also reflected in how respondents define their scope of responsibility. For some, circularity primarily relates to the building itself, with developers and contractors focusing on the circularity of the building. Others relate circularity to their own products, equipment, or services, such as material suppliers, logistics equipment providers, consultants, or logistics service providers. A broader perspective concerns how organizations contribute to enabling circular material flows across the supply chain. This perspective raises questions regarding who is responsible for making circular material flows viable and operational.

Respondents also raise questions regarding how to measure and follow up on circular performance. The absence of widely accepted standards makes it difficult to compare and evaluate circular initiatives across projects and organizations. Questions are also raised regarding how reuse should be defined in practice. For example, uncertainty exists regarding whether reuse requires physical relocation or modification of a component, or whether continued use in its original position should also be considered reuse. Indicators mentioned by respondents include the reduction of waste measured as kilograms of waste per built area and the share of procured materials originating from secondary sources.

Perceptions of circularity are also reflected in existing roles and operational practices within the construction industry. Accordingly, strategies related to circularity often build on established performance indicators, operational routines, and available data. In addition to waste minimization, material reuse, and recycling, some respondents also associate circularity with measures such as electrification and transport efficiency. These variations in how circularity is understood are reflected in how respondents define their own scope of responsibility and the responsibilities of other actors in enabling circular material flows.

5.2 Logistics activities supporting circular material flows

This section addresses the second research question concerning logistics activities that support operations for circular material flows. Drawing on the findings from Papers I, II, and III, it describes logistics activities related to managing EoU materials on construction sites and enabling circular material flows through off-site solutions.

From a project perspective, CE extends the role of the waste producer to include that of circular material supplier, which has implications for how developers and main contractors manage materials at EoU, including activities such as deconstruction, careful relocation of materials, proper on-site storage and protection, preparation for transport, and documentation of material information. As not all products and materials can be reused, space is still required for waste sorting. These activities highlight the logistical implications of managing EoU materials on construction sites, where limited space and the need to coordinate both reuse and waste management create additional operational complexity.

Paper III shows that the circularity potential of materials cannot easily be assessed by the waste manager based on current project waste data alone. This is associated with supply uncertainty due to missing information on material origin, composition, volume, and status, which is important for off-site actors' production planning and development. Uncertainty regarding viable reutilization options also complicates the determination of requirements for on-site logistics activities.

Addressing these uncertainties highlights the importance of early involvement of actors in the main contractor's network, a point also raised in Papers I and II. Early involvement enables logistics planning that can improve materials management from inbound deliveries to on-site operations and the handling of EoU materials.

While estimating return flows can support planning of on-site activities for material reutilization at the project level, developing supporting infrastructure such as off-site services and activities depends on understanding future material flows across the built environment, including what materials, how much, when, and where they will reach EoU.

Moving materials also involves managing transactions and reporting information to authorities and clients, maintaining material and product identity, and ensuring traceability of dispersed flows that must be aggregated with materials of similar properties to meet demand. This highlights the need for information systems capable of managing a large variety of potentially unique objects. When studying the practices of CCHs (Paper II), it was found that although physical storage space is a central feature—highlighted by actors when referring to "hubs" as an enabler (Paper I)—additional services are involved in making reuse operational. These services are illustrated in Fig. 6.

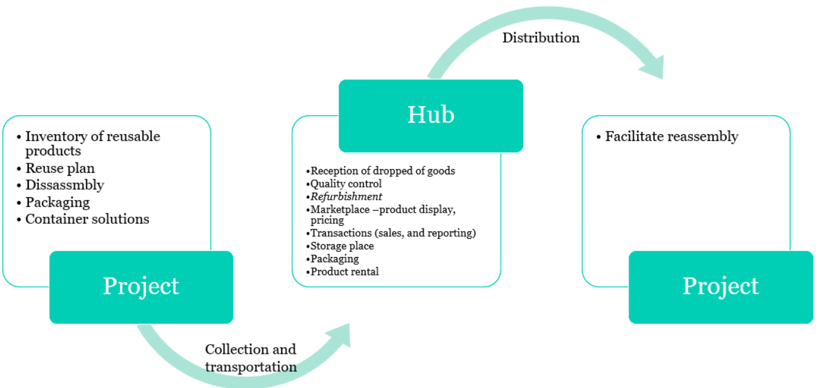

Fig 6. Activities offered by the studied CCHs for managing reuse flows. Source: Author's illustration based on Paper II.

From the off-site perspective, the practices and selection criteria applied by the CCHs provide insight into factors influencing the feasibility of reutilizing construction materials and products. These factors are reflected in the general selection criteria applied by the hubs:

- **Known demand**, as materials are generally brought into the CCHs when a potential buyer has been identified.

- **Ease of disassembly and handling**, which helps maintain material quality during deconstruction, transport, and storage.
- **Material quality**, which may allow products to be reused even when they deviate from current standards.

Meeting these criteria is associated with the need for additional product-level information. For reused products, unit-level information is recorded for each item, such as condition, classification, measurements, and origin. This information is obtained through dialogue and visual inspection and is linked to inventory systems through information carriers such as QR codes. Maintaining this information contributes to traceability and allows actors to retrieve original product specifications.

Overall, the findings indicate that reutilization involves coordination between the supplying project and intermediary actors. The intermediary serves both the supplying project and buyers of EoU products and materials, while the project can simultaneously act as both client and supplier of EoU materials. Managing these flows also involves the exchange of product-level information and maintaining traceability of materials across actors.

5.3 Challenges and enablers for increasing circularity

This section synthesizes the challenges and enablers identified across the studies in relation to the purpose of the thesis, which is to investigate logistics-related activities, challenges, and enablers related to the reutilization of construction materials and products in return flows from new-build and renovation projects. Drawing on the findings from Papers I, II, and III, the section addresses the parts of the research questions concerning the challenges and enablers for increasing circularity (RQ1) and the challenges and enablers related to logistics activities supporting circular material flows (RQ2).

The challenges and enablers related to the reutilization of construction products and materials vary across place and time and across actors' positions in the supply chain. Across the studies, several challenges and enablers for increasing circular material flows are identified.

These relate to actors' perceptions of circularity (Paper I), logistics activities associated with managing EoU materials on construction sites and through off-site solutions (Papers II and III), and coordination between actors involved in these flows. In Paper I, these factors were grouped into clusters relating to knowledge and experience, business models and total cost, matching supply and demand, information sharing and digitalization, policy, and design. Across the studies, reported challenges include uncertainties regarding material availability, composition and demand, logistics planning, coordination between actors, and how circular performance should be measured. Reported enablers include early involvement of actors, improved information sharing, and the role of intermediary actors such as CCH in facilitating the matching of supply and demand.

5.3.1 Knowledge and experience

Respondents highlight that limited practical experience with circular material flows creates uncertainty regarding how circular practices should be implemented in construction projects (Paper I). Actors describe a lack of practical examples of how to organize circular logistics and how different logistical arrangements affect costs and project performance. As a result, decisions regarding circular materials and services are often based on personal experience and existing project performance indicators such as time and cost. This lack of established practices also creates uncertainty regarding how requirements for circular materials and services should be formulated in procurement processes.

5.3.2 Business models and total cost

Incentives play an important role. Respondents highlight the need for new business models that make reutilization of materials easier and economically viable compared with current alternatives.

When studying CCHs (Paper II), it was found that initiatives related to reuse often originate from construction projects aiming to reduce waste by supplying materials for reuse. At the same time, demand for reused products remains uncertain, particularly as many hubs are recently established and lack historical data on market demand. As a result, hubs often take an intermediary role in facilitating transactions between supplying projects and potential buyers. Pricing of reused products is typically determined in relation to corresponding virgin products and may initially be set subjectively while demand patterns are still developing.

5.3.3 Matching supply and demand

A central challenge concerns matching supply and demand for circular materials. Actors managing EoU materials often lack information regarding the availability, quality, volume, and timing of reusable products and materials. At the same time, actors procuring materials may lack knowledge about the potential supply of circular materials and how such materials should be managed to enable circular applications. This results in reciprocal uncertainty between supply and demand.

The need to match supply and demand introduces coordination challenges between actors involved in circular material flows. As materials are exchanged between actors, those who traditionally operate as waste producers may also act as suppliers of materials. This introduces new interdependencies across supply chains and markets.

Several mechanisms were identified that may help reduce uncertainty regarding the availability and demand for circular materials:

- early involvement of suppliers to support logistics planning on construction sites (Papers I–III).
- inventory management systems that track material flows on-site and in buildings (Papers I–III).
- the ability to estimate return flows at the building level for on-site planning (Paper III) and at the built environment level for planning infrastructure and off-site logistics activities (Papers I–II).
- identification of standard reuse products that may simplify coordination between supply and demand (Papers I–II).

5.3.4 Information sharing and digitalization

Demand uncertainty also makes it difficult to determine what information is required for different products. In Paper II, this situation is described as characteristic of a still immature reuse market, where uncertainty regarding supply, demand, and product information leads actors to iteratively build knowledge and develop their networks. Furthermore, Paper III shows that waste data alone is not sufficient to support sorting plans aimed at enhancing the circularity potential of materials.

5.3.5 Policy and design

Policy and regulatory conditions are described by respondents as influencing the feasibility of circular material flows (Paper I). Differences between product legislation and waste legislation create uncertainty regarding when materials are considered waste and how they can be reused or transported. Respondents also mention that changing product standards and regulatory requirements, such as fire safety, noise classification, and chemical regulations, may affect the possibility of reusing certain materials. In addition, sorting and reporting requirements influence how materials are managed on construction sites and how waste flows are documented.

Design aspects are also described as affecting reuse potential. Respondents note that products may have different technical and aesthetic life cycles, which influence their suitability for reuse in future projects. Visible components may be replaced due to changing preferences or design trends, while technical components may be affected by evolving regulatory or performance requirements.

Together, these findings indicate that increasing circularity involves not only new operational practices but also mechanisms that support collaboration, information sharing, and the matching of supply and demand for EoU materials.

5.4 The gap between circular supply and circular demand

Across the studies (Papers I, II, and III), a recurring pattern concerns the gap between the supply of EoU products and materials and the demand for these at potential points of reutilization. While construction projects generate materials that may be suitable for reuse, actors seeking circular materials often lack knowledge about available supply. This pattern is reflected in the findings of Paper I, which highlight uncertainty regarding procurement of circular materials, Paper II, which shows that CCH act as intermediaries matching supply and demand, and Paper III, which indicates that available waste data provides limited information for identifying reuse opportunities.

The studies reveal a diverse set of challenges and enablers that overlap and are interdependent. Taken together, the findings suggest that circular material flows depend on several interrelated factors that vary across geographical contexts, supply chain positions, and time.

One aspect related to this gap concerns practical knowledge. Practical knowledge relates to actors' perceptions of circularity and their understanding of how circular activities are implemented in practice. This includes knowledge about how activities, resources, and actors are managed on construction sites, as well as associated costs and benefits and how circular practices interact with existing industry practices and contractual arrangements.

Second, regulations and policy are associated with incentives for circular practices. Actors highlighted that the lack of clear standards and regulatory guidance creates uncertainty regarding how circularity should be measured and implemented. At the same time, company policies responding to regulatory and market incentives were identified as enabling factors that may increase the value of buildings constructed using secondary materials.

Third, business models and market incentives are also related to the gap between circular supply and circular demand. Actors in circular construction supply chains operate across different markets. As materials move between projects and applications, actors may take on new market roles, introducing new interdependencies. A further challenge concerns a misalignment between where costs are incurred and where benefits accrue, as many benefits from material reutilization fall outside the scope of the supplying project. This situation highlights coordination challenges, since incentives at the project level may not align with circular outcomes at the system level. Similar patterns are described in the practices of CCHs. Known demand is associated with materials being brought into hubs, whereas variability in product categories and the need to aggregate heterogeneous materials complicate supply.

Nevertheless, pilot projects indicate that high circularity rates are technically achievable. Achieving such outcomes, however, involves coordination between actors across planning and operational phases.

Taken together, the findings suggest that increasing circularity is not only a matter of implementing individual logistics activities but also of aligning actors, incentives, and information flows across projects, markets, and system levels. Managing the gap between circular supply and circular demand therefore involves mechanisms that support collaboration between actors and enable circular material flows across the construction supply chain.

Chapter 6

Discussion

This chapter discusses the findings of the thesis in relation to the concepts and theories introduced in Chapter 2. Drawing on the results from Papers I, II, and III, the discussion elaborates on actor perceptions, logistics activities, and contextual conditions influencing circular material flows in construction. Particular attention is given to the reutilization of construction materials and products in return flows from new-build and renovation projects.

6.1 Perceptions of circularity in relation to challenges and enablers

The first research question addresses how actors involved in construction logistics perceive circularity, their role, and the challenges and enablers associated with increasing circular material flows. The findings presented in Paper I show that actors involved in construction logistics interpret circularity in different ways depending on their organizational roles and operational contexts. In the context of construction logistics, such variation in interpretation is reflected in how actors define their scope of responsibility, how circularity is incorporated into organizational strategies, and how circular performance is measured in practice.

Previous studies have highlighted the conceptual ambiguity of the CE (Kirchherr et al., 2017; 2023). Although a new ISO standard on CE has recently been introduced (ISO, 2024), the development of taxonomies such as that proposed by Senaratne et al. (2025) suggests that efforts to clarify and operationalize the concept are still ongoing.

Actors' perceptions of circularity appear to be closely linked to their existing roles and operational practices within the construction industry. For example, developers and contractors tend to relate circularity to the building itself, while suppliers and service providers more often associate circularity with their own products, equipment, or services. These role-based perspectives are reflected in how actors define their scope of responsibility and how circularity is incorporated into organizational strategies.

The absence of a commonly adopted standard was identified as a challenge for measuring, comparing, and following up on CE performance. This observation reflects the logic suggested by Senaratne et al. (2025), where CE strategies inform CE practices, which in turn influence how CE performance is measured, and where performance measurement feeds back into CE strategy. Different perceptions of circularity may therefore be associated with different CE strategies, which are operationalized through practices that require different performance measures. This is further related to the accessibility of relevant data.

As indicated in Paper I, perceptions of circularity are also related to actors' existing roles within the construction industry. CE strategies, their implementation, and related KPIs are therefore closely linked to current practices, performance indicators, and available data. In practice, this means that how circularity is interpreted often reflects existing organizational routines and ways of measuring performance.

Taken together, these observations suggest that CE strategy, CE practices, and performance assessment are closely interconnected in practice rather than forming a simple sequential process. CE strategy relates to actors' perceptions of circularity and existing practices. CE practices relate to strategies as well as to how performance can be assessed. Finally, CE assessment relates to reporting requirements, existing KPIs, and the availability of relevant data. These relationships are summarized in Figure 7.

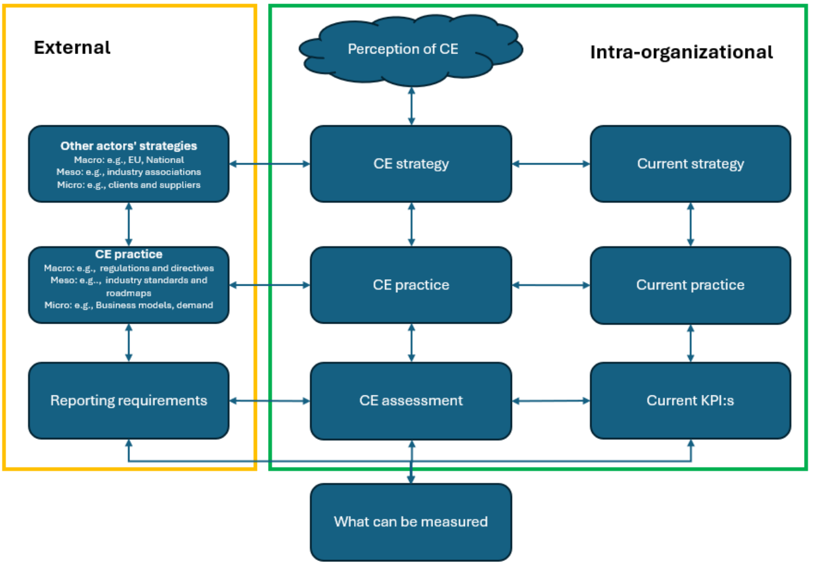

Fig. 7. Model illustrating relationships and interactions between perceptions of circularity, CE strategy, CE practices, and CE performance assessment.

Thus, conceptual ambiguity appears to be related to several of the challenges identified in the studies. Differing interpretations of circularity are reflected in uncertainty and potential friction both within organizations and between actors involved in circular material flows.

The findings of Paper I also align with previous studies suggesting that limited practical knowledge regarding how circular economy principles can be implemented constitutes a key challenge (e.g., Kirchherr et al., 2017; 2023). While actors widely recognize the importance of reducing emissions and waste, the practical implementation of circularity may appear more abstract.

Reducing emissions and waste within the scope of individual activities often involves concrete actions that actors can influence directly. In contrast, enabling circular material flows involves managing materials across longer time horizons and across multiple actors. As a result, the potential value of circularity may be difficult for actors to assess in practice, particularly when the associated business value and operational implications remain uncertain.

6.2 Operationalizing circular material flows in construction

The second research question addresses what logistics activities can support operations for circular material flows. While Section 6.1 highlighted how actors interpret circularity and the challenges associated with conceptual ambiguity, the findings of Papers II and III illustrate how circularity is translated into logistics practices within construction projects and to linked and adjacent supply chains. Enabling circular material flows requires adaptations to existing materials management practices, including activities such as deconstruction, material handling, storage, transport preparation, and information management. These activities extend traditional construction logistics practices by introducing additional requirements related to traceability, collaboration between actors, and the management of materials beyond the immediate scope of a single project.

CCSCs have been described as complex transformational constructs involving multiple actors operating across macro, meso, and micro levels interacting in non-linear ways (Abadi et al., 2025). The findings of this thesis illustrate how such complexity is reflected in practice, particularly in the coordination required between actors managing materials at EoU and actors seeking to utilize materials in circular applications. In this context, logistics activities play an important role in coordinating material flows between projects and across linked and adjacent supply chains.

Many CSC models illustrate material flows moving from one position to the next in a value chain in a circular manner. However, both the findings of this thesis and previous research suggest that implementing CE in construction supply chains is more complex than such representations imply. In practice, materials at EoU may follow several possible pathways depending on factors such as material condition, demand, regulatory requirements, and available logistics infrastructure. Figure 8 illustrates how EoU materials may circulate from a construction project perspective and how these flows connect construction projects with actors operating in linked and adjacent supply chains. Although this thesis focuses on C&DW from new build and renovation projects, several off-site actors involved in managing these flows operate across multiple markets beyond construction. In the figure, the upper part illustrates product-related flows, while the lower part illustrates waste-related flows. Together, these flows illustrate how materials at end-of-use may be categorized as products or waste depending on how they are handled and regulated.

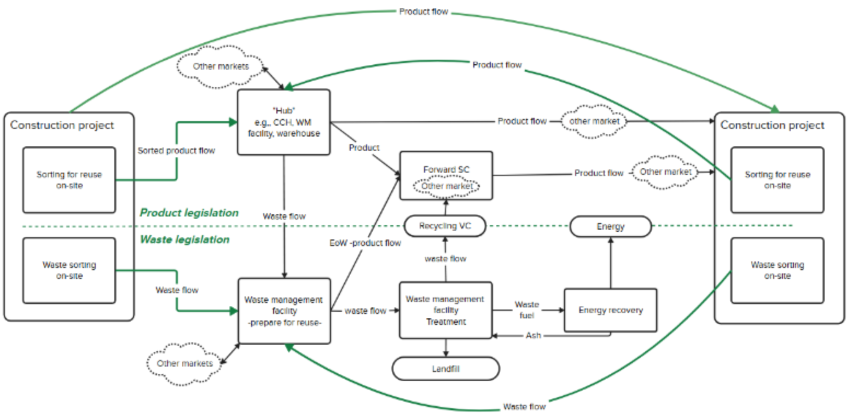

Fig 8. Conceptual illustration of possible circulation pathways for EoU materials from a construction project perspective within a CE. The illustration draws on the theoretical background in Chapter 2 and empirical findings from Papers II and III.

The product and material pathways illustrated in Figure 8 highlight that enabling circular material flows involves more than the physical movement of materials between actors. In line with Gatenholm et al. (2021) and as shown in Paper II, enabling reuse requires additional activities beyond transport and warehousing, including coordination of actors, assessment of material condition, and management of material information. These activities illustrate how circular logistics practices extend traditional construction logistics functions.

Information availability represents a central challenge in this context. Prior studies suggest that product and material information is often lost when materials are delivered to construction sites (Ghanem et al., 2018). The findings of this thesis support this observation. Paper III shows that the circularity potential of materials cannot easily be assessed by waste managers based solely on project waste data. Missing information regarding material origin, composition, volume, and status creates uncertainty regarding the potential reuse or recycling of materials.

Such information gaps contribute to both supply and demand uncertainty. From a supply perspective, actors responsible for reuse or recycling require reliable information about materials to plan their operations. From a demand perspective, uncertainty regarding the availability, quality, and timing of circular materials makes it difficult for actors to incorporate such materials into construction projects.

These findings suggest that circular material flows depend not only on physical logistics activities but also on the coordination of information and actors across supply chains. As discussed in the theoretical background (Chapter 2), the quality of recycling outcomes is influenced by how materials are handled throughout logistics processes. In particular, sorting, storage, and preparation for transport affect the ability to maintain material quality and enable higher-value recovery options. The activities identified in this thesis—such as deconstruction, careful relocation of materials, storage, and documentation of material information—illustrate how logistics practices relate to the circularity potential of materials at EoU.

Taken together, these observations suggest that operationalizing circular material flows in construction involves logistics systems that coordinate materials, information, and actors across projects and linked and adjacent supply chains. However, coordinating these flows introduces several challenges while also revealing potential enablers for increasing circular material flows in construction.

6.3 Contextual conditions influencing circular material flows

While Section 6.2 discussed how circular material flows are operationalized through logistics activities in construction projects and across linked and adjacent supply chains, the findings of this thesis also indicate that such activities occur within broader contextual conditions. These include regulatory frameworks, market structures, industry and firm practices, and the availability of information and infrastructure associated with how actors manage materials at EoU and incorporate circular materials into new applications. As outlined in the theoretical background (Chapter 2) and reflected in the findings of Papers II and III, regulatory and policy conditions form an important part of this context. Examples include reporting and documentation requirements (Paper III), rules governing the use of infrastructure (Fredriksson and Huge-Brodin, 2022), and regulations determining the status of materials and products (e.g., Naturvårdsverket, 2025c). While regulations may constrain certain logistics activities, previous research also suggests that the absence of clear regulatory frameworks can constitute a barrier to circular practices (Abadi et al., 2025).

The findings further suggest that ambiguity related to CE can be observed across several system levels and categories of challenges. Examples include existing industry (meso) and firm (micro) practices, regulatory and policy conditions (macro), market pressures (meso), and the availability of data and information across actors. Actors in circular construction supply chains often operate across several related markets, including construction, real estate, product, and waste markets. As materials move between these contexts, new interfaces and interdependencies may emerge between actors. Materials may also be classified as products or waste depending on their regulatory status and intended use, which can create coordination and information challenges across actors and jurisdictions.

The case studies (Paper I and II) illustrate how incentives and drivers for reuse appear across these levels in practice. Paper II suggests that company goals have played an important role in the development of reuse practices in some cases (Cases F and J). Respondents also noted that recent global supply disruptions have highlighted the importance of resilience in supply chains, where CCHs may function as buffers (Case F). Financial instruments such as green loans and market norms, including demand for attractive buildings, were also mentioned as factors encouraging reuse practices.

The findings also indicate that new business models and digitalization are often discussed as relevant for addressing challenges related to financial flows, incentives, and information flows. Digital tools and new organizational arrangements may facilitate the coordination of non-physical flows such as information, transactions, and responsibilities across actors. This highlights the need for coordination mechanisms that extend beyond traditional dyadic relationships between buyers and suppliers and points toward the relevance of a broader systems perspective on the coordination of CCSCs.

Taken together, these observations suggest that circular material flows in construction are shaped not only by operational logistics activities but also by broader regulatory, market, and organizational conditions. Differences in regulations, market incentives, industry practices, and access to information contribute to uncertainty regarding both the availability of circular materials and the conditions under which they can be utilized. Aligning supply and demand for circular materials therefore emerges as a key challenge in the operationalization of CCSC.

6.4 Understanding the gap between circular supply and circular demand

This section discusses the implications of the findings for understanding the challenges and enablers associated with circular material flows in construction. In particular, it interprets the findings in relation to existing categories of CE implementation challenges and enablers and examines how these are reflected in the coordination of circular supply and demand across actors, markets, and professional roles.

As outlined in the theoretical background (Chapter 2), previous research has identified several recurring categories of challenges and enablers related to CE implementation in construction (Table 2), including regulative, market, organizational, informational, technological, and product-related factors (e.g., Grafström and Aasma, 2021; Munaro and Travares, 2023 Abadi et al., 2025). The findings of this thesis suggest that the challenges and enablers identified in the empirical studies correspond to these categories at a general level. However, previous research also suggests that how these challenges and enablers manifest depends on contextual conditions that vary across places and over time. This contextual contingency motivates empirical investigation of how CE practices are implemented in specific contexts.

Within these categories, three clusters appear particularly predominant in the findings: practical knowledge, regulations and policy, and market conditions related to matching supply and demand. These clusters illustrate how challenges associated with circular material flows appear across different but interrelated dimensions of circular construction supply chains. Regulations and policy relate to the regulatory conditions surrounding circular practices, while actors' perceptions and practical knowledge relate to how circularity is interpreted and implemented in practice. Together, these dimensions are reflected in the challenge of coordinating supply and demand for circular materials across actors, markets, and professional roles.

Practical knowledge relates to how actors perceive circularity and what they consider required to carry out circular practices under given conditions. This includes understanding how activities, resources, and actors must be coordinated on-site, the associated costs and benefits, and how such practices interact with existing industry practices and contractual arrangements. As indicated in Paper I, actors interpret circularity differently, and their incentives for engaging in what they define as circular practices vary, as do their perceptions of their own and others' roles.

Regulations and policy are closely related to incentives. Prior research has highlighted the lack of regulations as a main challenge for CE implementation in construction (Abadi et al., 2025), suggesting that market incentives alone may not be sufficient to drive change. Furthermore, the perceived lack of standards for measuring and evaluating CE performance identified in Paper I illustrates how the absence or ambiguity of regulatory frameworks may create uncertainty regarding how CE practices should be implemented. At the same time, company policies driven by regulatory and market incentives were identified as enablers that may increase the market value of buildings constructed using reused materials. Additionally, regulations are reflected in construction logistics through requirements related to waste reporting and sorting, which influence how materials are managed and documented on construction sites, as illustrated in Paper III and outlined in the theoretical background (Chapter 2).

Market conditions also influence how supply and demand for circular materials are matched and coordinated. Actors in circular construction supply chains often operate across multiple markets. In a CE, actors who traditionally manage waste may also become suppliers of materials, thereby entering new market interfaces that differ from existing processes and practices. This shift introduces new interdependencies within organizations and between actors, which may require coordination mechanisms and intermediary actors to facilitate transactions between projects and markets. Matching supply and demand for circular materials is further complicated by a misalignment between where costs are borne and where benefits accrue, as many benefits from reuse fall outside the scope of the supplying project. Pilot projects demonstrate that achieving high circularity rates is technically possible but appears to require active coordination among actors from planning to operations. Incentives for developers to engage in reuse, such as green loans and evolving market norms, illustrate how regulatory and market mechanisms may stimulate demand for circular materials and related services.

Finally, the findings indicate that actors involved in circular material flows often operate under uncertain conditions regarding both supply and demand. Information about available materials, their condition, and potential applications may be incomplete, while demand for circular materials may vary across actors and over time and is also shaped by requirements related to quality, quantity, and performance in potential applications. Under such conditions, coordinating circular material flows often requires mechanisms that allow actors to navigate uncertainty and adapt to changing circumstances, for example through temporary storage, aggregation of materials across projects, and intermediary actors facilitating transactions. This suggests that enabling circular material flows requires more than traditional logistics activities such as transport or warehousing. In this sense, the gap between circular supply and circular demand can be understood as a coordination challenge involving materials, information, and incentives across actors, markets, and professional roles within circular construction supply chains.

Chapter 7

Concluding remarks

This chapter concludes the thesis by presenting the main conclusions, followed by a discussion of limitations and directions for future research, and concluding with the contributions of the study.

7.1 Conclusions

This thesis has investigated logistics-related activities, challenges, and enablers associated with the reutilization of construction materials and products in return flows from new-build and renovation projects in the Swedish construction industry. In doing so, it provides insights into how construction logistics can support the reutilization of materials through reuse and recycling.

The studies address these challenges and enablers from two perspectives: (1) actors' perspectives and (2) operational settings, with a focus on logistics activities enabling circular material flows. Together, they contribute empirical insights into how actors' perceptions of circularity relate to their motives, roles, and the challenges encountered when implementing CE practices.

In relation to RQ1, the findings show that actors involved in construction logistics perceive circularity in different ways, which is reflected in their motivations, roles, and approaches to implementation. These differences are associated with variations in company policies, as well as in how circularity is measured and monitored. The findings further indicate that challenges and enablers are interrelated, forming a self-reinforcing pattern were addressing one challenge may give rise to others.

In relation to RQ2, the findings identify a range of logistics activities that support circular material flows, both on-site and off-site. These include activities related to deconstruction, material handling, storage, transport preparation, and information management, as well as the role of intermediary actors such as CCHs. The findings also highlight that enabling such activities is closely linked to access to information, coordination between actors, and the ability to manage uncertainties related to supply and demand.

Taken together, the thesis illustrates that advancing circularity in construction is closely linked to coordination across actors, disciplines, markets, and system levels. While technological solutions exist, their implementation is influenced by factors such as fragmented knowledge, uncertainty regarding material flows, evolving markets, and regulatory differences between product and waste systems, which in turn relate to how such solutions are developed and applied. As the achievable level of circularity is contingent on place and time, the findings support the conceptualization of CE as a continuum rather than a fixed end state. Circular practices develop through iterative processes in which actors experiment, learn, and coordinate across organizational, disciplinary, and market boundaries.

Finally, a fundamental question raised in the first study remains: *who holds responsibility for making the reutilization of EoU products and materials viable and operational?*

7.2 Limitations and future research

This section reflects on the limitations of the thesis and outlines directions for future research.

7.2.1 Limitations

This thesis is subject to several limitations related to research design, scope, and context. First, the studies were conducted within a Swedish context and are therefore contingent on the regulatory and market conditions present in Sweden. Although Sweden operates within the broader regulatory framework of the EU, national implementation of directives and local market conditions may vary, which can influence how CE practices are implemented in construction.

Second, the studies are limited in empirical scope. Paper I builds on interviews with actors involved in construction logistics, while Papers II and III examine specific cases related to CCHs and waste flows in construction projects. As such, the findings reflect particular contexts and points in time. The abductive research approach allowed the studies to acknowledge broader system implications related to logistics activities, actor roles, and perceived challenges and enablers. However, the findings remain contingent on the studied cases.

Third, the thesis primarily examines circular material flows from the perspective of construction projects, focusing on new build and renovation projects. Supply chains for construction materials may extend across regional or global markets, whereas waste management practices are largely shaped by local regulations and policies. This combination complicates comparisons across contexts and limits the transferability of the findings.

Despite these limitations, the studies indicate that challenges and enablers associated with circular material flows share similar characteristics at a categorical level. This suggests that the relationships between these categories may be relevant beyond the specific contexts studied, although their specific manifestations may vary depending on regulatory, market, and industry conditions.

7.2.2 Future research

Building on these limitations, several avenues for future research emerge. First, future studies could extend the empirical scope by examining additional building types, industry contexts, and geographical settings. This could include other segments of the construction industry, such as building archetypes or industrialized construction, as well as adjacent markets and other parts of the supply chain as focal points for analysis. Comparative studies across countries or regions could provide further insight into how regulatory frameworks, market structures, and infrastructure influence circular material flows.

Second, further research could examine the development and scaling of intermediary actors such as CCHs. Expanding the number of case studies may contribute to a better understanding of hub typologies, their operational practices, and how they support the consolidation, aggregation, storage, and redistribution of reusable materials across projects.

Third, future research could explore how information from procurement processes and project planning—such as bills of materials and project time plans—can be used to support the management of EoU materials. Such studies could contribute to developing methods for anticipating return flows and improving planning of on-site logistics activities to enhance the circularity potential of materials.

Fourth, the findings highlight the importance of coordination across actors, markets, and system levels within circular construction supply chains. Future research could therefore investigate how coordination mechanisms, governance structures, and intermediary roles can support the alignment of incentives and information flows between actors managing materials at EoU and actors seeking to utilize circular materials.

In addition, longitudinal studies could examine how actors' perceptions, strategies, and practices related to circularity evolve over time. Follow-up studies with respondents from Papers I and II could provide insight into how regulatory developments, market conditions, and organizational learning influence the implementation of circular practices.

Finally, future research could further explore how policy mechanisms, market incentives, business models, and technological developments interact in shaping circular material flows. Building on the categories of challenges and enablers identified in this thesis, further studies could apply system-level perspectives—such as institutional theory or other system-oriented analytical frameworks—to better understand how changes in policy, market conditions, and technology influence the development of circular construction supply chains. Such research may benefit from interdisciplinary and boundary-spanning approaches, as circular material flows in construction involve interactions between logistics, construction practices, regulatory frameworks, market mechanisms, and technological systems.

7.3 Contributions

This thesis contributes to research on circular construction logistics by providing empirical insights into a relatively underexplored phenomenon, namely CCHs, and by examining circular material flows within a Swedish context. Given that CE implementation and C&DWM are contingent on regulatory, market, and industry conditions, the thesis adds context-specific understanding of how such conditions shape the challenges and enablers associated with circular material flows. Furthermore, the findings respond to calls from practitioners for more research on how CE principles can be implemented in practice.

Taken together, the findings contribute to an increased understanding of how circular material flows in construction are associated with actors' perceptions, logistics activities, and contextual conditions, and how these dimensions relate to coordination challenges across actors and markets. By examining these aspects from both on-site and off-site perspectives, the thesis highlights coordination challenges related to increasing the reutilization of construction materials and products.

While the studies provide insights into logistics-related challenges and enablers for circular material flows, further research is needed to understand how coordination across actors, markets, and system levels can be achieved in practice under varying contextual conditions.

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Appendix A: Interview guides

Interview guide study I

Syfte: Att fånga in alla olika projektparters perspektiv och därigenom fånga in roller, mål, utmaningar och möjligheter i olika delar av byggekosystemet samt vidga det gemensamma perspektivet och se om/var det finns samsyn och var perspektiv skiljer sig åt.

Frågor:

1) Vad är cirkularitet enligt er?
   a. Har ni någon strategi kopplat till cirkularitet?
2) Vad är er roll i byggekosystemet?
   a. Tror ni att er roll kommer att förändras när vi går mot cirkuläritet, om så hur?
3) Varför är cirkularitet viktigt?
   a. Vad hoppas ni kunna bidra med och vad hoppas ni få av det?
4) Vad är din erfarenhet i att jobba för cirkularitet?
   a. Största utmaningar
   b. Möjliggörare
5) Vad förhindrar er från att bli cirkulära?

   Exempel:
   Lagar/regler
   Logistik
   Ekonomi
   Design
   Planering
   Kunder
   Annat
6) Tror du att det finns skillnader i cirkulära materialflöden i renovering, nybyggnation eller vid rivning; om så på vilket sätt?

<u>**Interview guide study II**</u>

Interview Questions

1- What is a reuse hub? (general)
2- What is the purpose and strategy of this hub?
3- How do you do inventory in this hub?
4- Which materials/products do you get most into the hub?
    a. Do you choose which materials you accept/decline or do you accept everything? How (what are your criteria)?
5- Which materials/products are most in demand (spending least time in the hub)?
    a. Do you keep track of time different product groups spend in the hub?
6- How do the materials/products arrive to the hub? (How are they packed and carried/transported?)
    a. Do they come in the end of the project or coming throughout a project?
7- From which projects do you get the materials/products most? (Renovation, new construction, demolition etc.)
8- Which type of projects/customers buy most materials from the hub? Why?
9- What type of services do you provide in the hub?
    a. Transport to/from the hub (of materials)
    b. Refurbishment of materials/upgrade
    c. Take-backs? (golv industrierna)
    d. A digital platform/customer interface
    e. Quality assurance/guarantee period (CE label)
10- How do you manage "returns"?
    a. Do you return to the supplier (t.ex. Beijer)?
11- How is the size and layout of the hub determined? (did you determine it or were you given this much space?)
    a. What was your criteria for determining layout of the hub?
    b. Location of the hub – why is it here?
12- Who are your customers? (only internal or other external actors?)
13- What is the market perimeter of the hub? Why?
14- Do you have any reporting/quantitative data which we can access to?

Papers

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