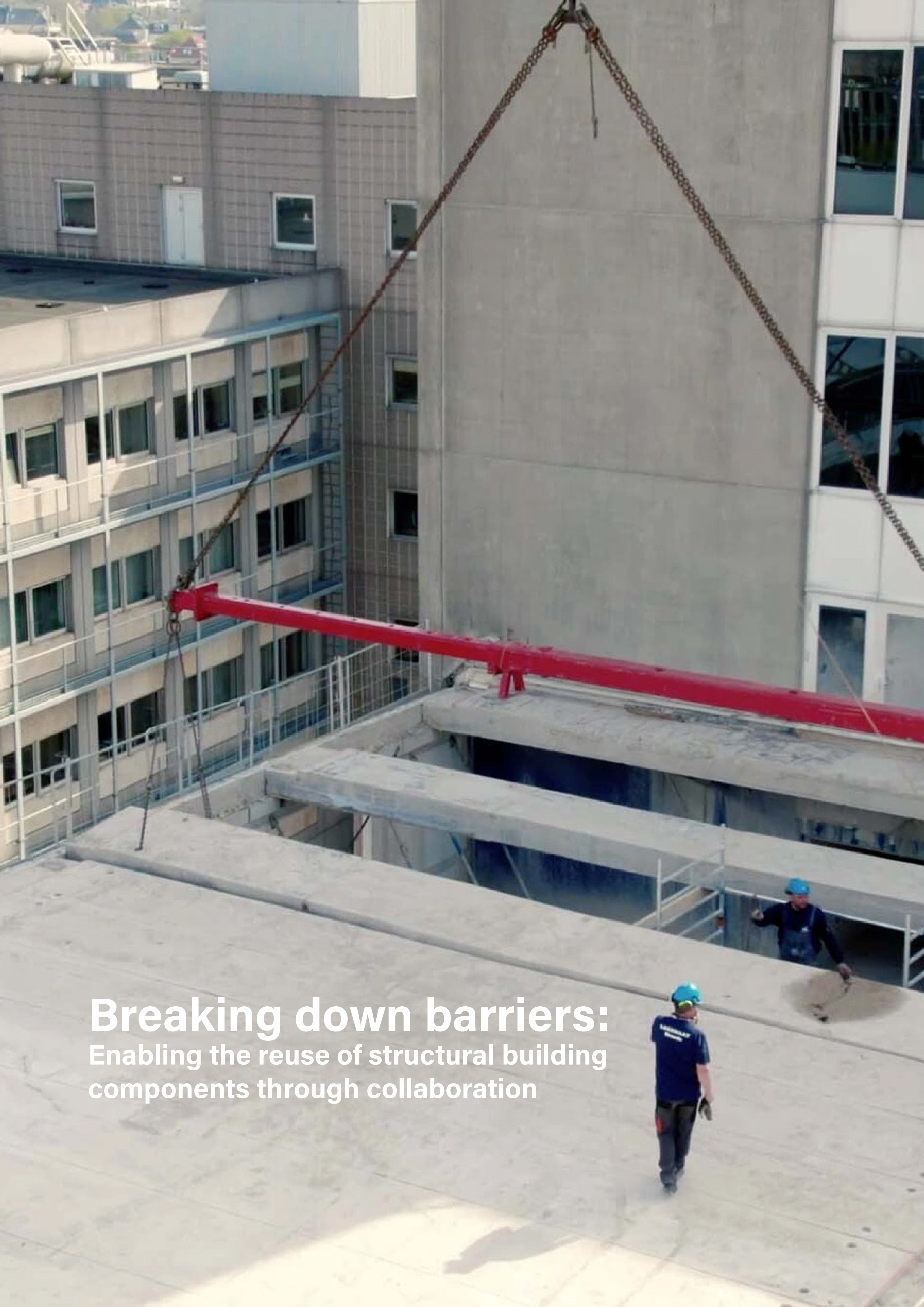

Breaking down barriers:

Enabling the reuse of structural building components through collaboration

Colophon

P4 report	Msc. Architecture, Urbanism and Building Sciences
Title	Breaking down barriers: Enabling the reuse of structural building components
Date	20-05-2025
Graduation lab	Management in the Built Environment
Graduation theme	Adaptive re-use
Organisation	Cepezed projects b.v.

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Abstract

The construction sector has a substantial impact on climate change. In the Netherlands, the construction sector accounts for nearly 35% of the Netherlands' CO_2 emissions and half of its resource use. Although Dutch recycling rates are relatively high, the use of secondary materials in new construction is still very low. Given the national ambition to achieve a fully circular economy by 2050, this represents a missed opportunity. Within buildings, structural components account for the largest share of embodied carbon and should therefore be targeted for reuse. Collaboration among key actors in the construction value chain, including actors such as developers, architects, contractors, advisors, and demolition companies, can enable this reuse, but research is limited on this topic.

This research explored how collaboration among the mentioned actors could enable the reuse of structural components from buildings reaching the end of their lifecycle. A qualitative approach was used, incorporating semi-systematic literature reviews, case studies, semi-structured interviews, and workshops. First, the study identified factors that affect the reusability structural components. After this, the study identified barriers and drivers in the reuse process, as well as the collaborative process needed such as roles, knowledge, and workflows. This was followed by a workshop that incorporated these results and identified different strategies for collaboration.

It is found that the key barriers to structural reuse are primarily economic, organizational, and social, rather than technical. Fragmented information, misaligned timelines, and unclear roles often hinder the practical implementation of structural component reuse. The resulting strategy guide addresses these barriers and proposes actionable strategies for the early project phase. The guide offers collaborative strategies that embed reuse into the routines, roles, and dynamics of construction projects.

Keywords: Structural components, Reuse, Collaboration

Preface

The process of writing this master thesis has been a challenging, insightful, but rewarding journey. It forms the final part of my studies within the Management in the Built Environment (MBE) track at the Faculty of Architecture and the Built Environment, TU Delft.

This thesis reflects my interest in sustainability and innovation within the construction sector. Throughout this research, I have had the opportunity to deepen my understanding about circular construction, material reuse, and the collaborative processes that drive reuse projects. It was interesting to explore these themes within the context of real projects and in collaboration with professionals from across the industry.

Over the past months, I have grown both academically and personally. The experience of conducting interviews and workshops, analysing real cases, and translating theory into practical insights has improved my research skills and broadened my perspective on the complexities of circular construction. I believe that the lessons I have learned through this work will continue to guide me in my future professional life.

I would like to thank my mentors, Vincent Gruis and Hans Wamelink for their guidance and critical feedback throughout this process. Their expertise in this field of research has helped to shape this research and give me direction during the process. I am also grateful to all interview participants for sharing their time, experience, and insights. Without their contributions, this thesis would not have been possible.

Finally, I would like to express my gratitude to my family and friends for their support throughout this period. Their encouragement provided me with motivation during the more challenging phases of this journey.

I hope this thesis offers a meaningful contribution to ongoing discussions about circularity and collaboration in the built environment, and inspires further research and innovation in this field.

Milan Bezem
30th June 2025

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1 Introduction

The construction sector has a substantial impact on climate change, accounting for nearly 35% of the Netherlands' CO_2 emissions and half of its resource use (Circle Economy, 2024). As the Dutch government aims for a fully circular economy by 2050, the built environment offers a critical opportunity to advance this goal (Ministerie van Infrastructuur en Waterstaat, 2024). The construction industry, especially through its use of emissions-intensive materials such as concrete and steel, contributes significantly to the Netherlands' environmental footprint.

Concrete, being the most widely used construction material globally, accounts for 30% of total mass solid waste in the EU and is responsible for 5–8% of annual global carbon emissions (Recreate, 2021). Similarly, the steel industry is responsible for 7% of the annual global carbon emissions (European Commission, 2022). With steel being the second- most used construction material globally, the steel industry contributes about 6.8% to total global solid waste generation (Biswal & Swain, 2024). Therefore, both concrete and steel, as the two most widely used materials globally, represent critical targets for improving sustainability in the construction sector.

Although the Netherlands seems to be progressive in the field of recycling, with 88% of all construction and demolition (C&D) waste being recycled, less than 8% of the materials used in new construction come from secondary sources (Circle Economy, 2022). This indicates a wide gap between recycling rates and actual material reuse.

In circular economy frameworks, reusing building components offers a more effective way to reduce emissions than recycling alone. The R-ladder represents a range of hierarchically arranged strategy options in the process towards a circular economy (Figure 1). This circular waste model shows what the most optimal waste management strategies are to reduce the environmental impact (CBS, 2020). Recycling, while important, is ranked lower in than reuse in the r-ladder due to the energy and resource-intensive processes it often entails (Hendriks & Janssen, 2003).

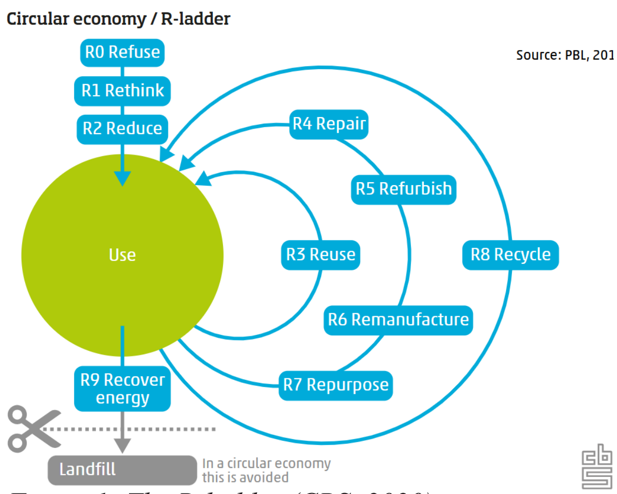

Figure 1: The R-ladder (CBS, 2020)

At the top of the hierarchy stands refuse, rethink and reduce. These strategies involve avoiding the use of new resources, utilizing resources more efficiently by sharing them or making them multifunctional, or minimizing the use of new resources by producing more efficiently (CBS,2020). For building components, this entails extending the lifespan of buildings or producing building components more efficiently. However, if building removal is unavoidable, often because of change of land-use or functional improvement rather than structural deterioration, the next best option is to deconstruct it and reuse its components (Al-Faesly & Noël, 2022).

1.1 Problem statement

Reuse is defined as 'reusing objects in the same function'(CB23,2024). Looking at a building, this can happen at six different layers according to Stewart Brand (1997). Brand (1997) shows many layers of a building that have different timeframes for renovations and can each be considered for deconstruction and reuse (Figure 2). The six layers are: stuff, space plan, services, skin, structure and site (Brand, 1997). Of these six layers, reusing structural components offers the most environmental benefits, as structural building components account for the biggest portion of a building's embodied carbon and are designed to last the lifespan of a building, often exceeding 100 years (Piccardo et al., 2024).

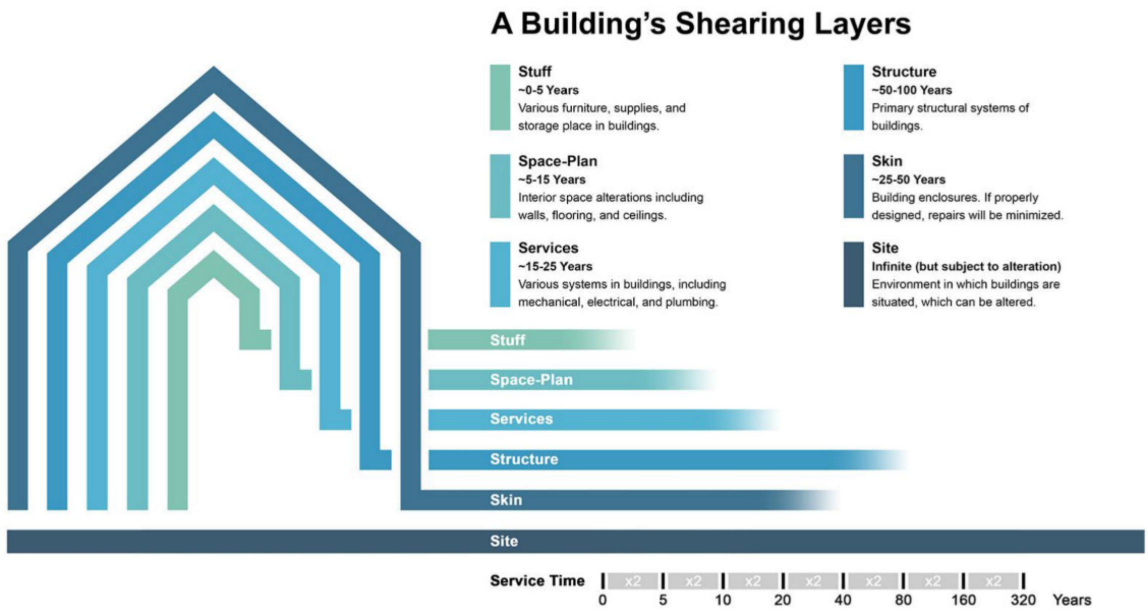

Figure 2: The six different building layers (Thai, 2024)

Ideally, structural components would be repurposed directly from one building to another, thus maintaining the material's embodied energy and extending its useful life. However, actual reuse of structural components remains limited, with the majority being downcycled for lower-grade applications such as backfilling, which reduce their value and embodied carbon (Küpfer et al., 2023).

Despite its environmental benefits, the reuse of structural building components is often hindered by different barriers. Rakhshan et al. (2020) identified different barriers and classified them into six major categories: economic, environmental, organizational, regulatory, social and technical. He indicated that addressing the economic, social and regulatory barriers should be prioritized. Gorgolewski (2008) argues that the barriers to the reuse of construction components are rarely technical or economic, but are mostly based on organizational, contractual and social structures. The stakeholders' behaviours, attitudes and social structures are crucial aspects in making the shift to a circular construction sector (Gorgolewski, 2008). Van Vooren & Galle (2024) explored the perceived challenges by stakeholders when reusing components. In addition to technical and cost-related challenges, stakeholders identified uncertainties, legal challenges, human barriers, and mismatches between supply and demand as key challenges. Hart et al. (2019) supports these arguments, as he stated that technological and regulatory developments alone will not suffice, and a shift is required in business models and stakeholders' behaviours and attitudes.

Since most companies are reluctant to change their business model, close collaboration between key actors in the construction value chain, like architects and demolition companies, can help address this barrier (Rakhshan et al., 2020). For example, collaboration between key actors of a demolition project and key actor of a new building project can facilitate the knowledge of a known list of structural components to reuse early in the design phase of the new building. However, this cooperation often never happens (Nußholz, 2019). Poor communication and isolated decision-making across actors can lead to challenges such as misaligned timelines and uncertainties about the component's performance in a new context (Gorgolewski, 2008). Addressing this issue is critical because collaboration can foster early decision-making and streamline workflows, ensuring that structural components will be reused and prioritized during the early design stages of a project. These issues represent a gap in understanding how collaboration between key actors within the value construction chain can address the key barriers to reusing structural building components and enable the reuse of structural building components.

1.2 Research objective

This study aims to address this gap by investigating how collaboration between key actors in the construction value chain can enable the reuse of structural building components. The main research question is: "How can collaboration between key actors in the construction value chain address key reuse barriers to enable the reuse of structural building components from existing buildings reaching the end of their lifecycle?" To address this question, the research first identified the general factors influencing the reusability of structural components at their end-of-life phase. After this, the barriers and enablers in reuse projects were examined. Existing collaboration processes between key actors in the construction value chain were also analysed. Lastly, a strategy guide was developed to facilitate collaboration and enable structural component reuse in future projects.

1.3 Scientific relevance

In the existing literature, there is a substantial amount of research that investigates the different barriers to the reuse of structural components. However, very little research is carried out on how to enable reuse in circular construction projects, especially on how collaboration between key actors in these circular construction projects can enable reuse. Next to that, there is little existing knowledge on practical, process-based strategies that can be implemented within such projects, to enable the reuse of structural components.

Most existing studies focus on technical or material-related aspects of reuse, such as disassembly potential or structural integrity. Other studies focus on identifying key barriers, such as organizational, social and economic barriers. While (the lack of) collaboration is frequently mentioned as a key barrier or enabler, the dynamics of collaboration such as actor roles, communication structures, and decision-making processes that can enable reuse often remain under-researched. Understanding how collaborative processes can address the barriers to reuse is essential to move from theoretical potential to practical implementation. This study contributes by proposing a strategy guide that links process-based strategies to key barriers in the reuse process, providing actionable insights for future circular construction projects.

1.4 Societal relevance

The construction sector has a big societal and environmental impact, accounting for nearly 35% of the Netherlands' CO_2 emissions and half of its resource use (Circle Economy, 2024). Despite high recycling rates in the Netherlands, only 8% of materials used in new construction currently come from secondary sources, highlighting a gap between recycling and actual reuse (Circle Economy, 2022). This gap represents a missed opportunity for the transition to a circular economy, which is one of the goals of the Dutch government, as they aim to achieve a fully circular economy by 2050 (Ministerie van Infrastructuur en Waterstaat, 2024).

Reusing structural building components, especially components made of concrete and steel, can reduce embodied carbon, as these materials are among the most emissions-intensive and waste-generating in the construction industry (Recreate, 2021; European Commission, 2022; Biswal & Swain, 2024). This study contributes by identifying collaborative strategies that can help key actors in the construction value chain in enabling reuse in construction projects and supports a broader shift towards circular thinking. In addition, the study has a societal impact by addressing the environmental and economic benefits of reuse, as it reduces carbon emissions and construction waste, and promotes resource efficiency.

1.5 Research questions

The main research question addressed in this research is:
"How can collaboration between key actors in the construction value chain address key reuse barriers to enable the reuse of structural building components from existing buildings reaching the end of their lifecycle?"
In this research, enabling is defined as "making something possible, practical, or easy" (Britannica Dictionary, 2025). This refers to how collaboration between key actors can make the process of structural component reuse more practical and achievable in real-world construction projects.

The purpose of the sub-questions is to identify and clarify the core components of the main question. Each sub-question addresses a critical component that, when combined, contributes to answering the main research question. For each subquestion, a different methodology and method is used. The outcome of the subquestion is also described. The sub-questions are as follows:

Q1. *''What technical, design and process-related factors influence the reusability of existing structural components from existing buildings reaching the end of their lifecycle?"*

Methodology: Literature review
Methods:
- Semi-systematic literature review: Conducted to identify and analyse existing knowledge on factors influencing structural component reusability, with a focus on the technical, design and process-related factors.

Outcome:
Identification and categorization of the key factors influencing reusability, focussing on technical, design and process-related factors, forming a foundational understanding that informs further research on key barriers and drivers.

Q2. *''What are the key barriers and drivers influencing the reuse of structural components from existing buildings reaching the end of their lifecycle?"*

Methodology: Literature review and case study
Methods:
- Semi-systematic literature review: review existing literature on key barriers and drivers to reuse in circular construction projects.
- Semi-structured exploratory interviews: Conduct with key actors of the case projects to identify key barriers and drivers.

Outcome:
overview of the barriers and drivers influencing structural component reuse, focussing on systematic and practical obstacles and enablers, supported by both theoretical and empirical insights, creating a foundation for the developed frameworks.

Q3. *''What roles, knowledge and processes are essential for key actors to successfully collaborate and enable the reuse of structural components?"*

Methodology: Literature review and case study
Methods:
- Semi-systematic literature review: examine existing studies on collaboration processes, including research on inter-organizational collaboration models, tools, economic structures, decision-making processes, communication strategies and roles.
- Semi-structured explanatory Interviews: Conduct with key actors of the case project to identify roles, economic structures, decision-making processes, communication processes and tools used in collaboration between key actors.
- Document analysis: analyse project reports, contracts and publications to uncover best practices and effective process structures that enabled structural component reuse.

Outcome:
A comprehensive outline of collaborative processes and workflows, detailing essential processes and specific interactions in time for case projects.

Q4. *"What strategy guide can be developed for key actors to successfully collaborate and address key barriers to enable the reuse of structural components from buildings reaching the end of their lifecycle"*

Methodology: case study
Methods:
- Workshops: Host a workshop to actively engage participants in a collaborative setting. Unlike a focus group, which centres on discussion, the workshop will encourage participants to work together on practical problem-solving exercises, in this case developing strategies for the identified challenges. The interactive format of a workshop allows for a deeper exploration of strategies, as participants can collaboratively test and refine proposed ideas in real-time.

Outcome:
A strategy guide addressing the key identified barriers, grounded in both literature and real-world feedback to maximize its relevance and applicability.

1.6 Conceptual model

The conceptual model in Figure 3 visualises the concept of the research. The 4 stages of a project lifecycle represented in the model are the design stage, the preconstruction stage, the construction stage and the demolition or deconstruction phase. In the current linear economy, these stages are followed consecutively with the design stage representing the beginning and the demolition stage representing the end. For structural components, this typically means that at the end-of-life of a building, the structure is demolished and materials are downcycled, incinerated, or sent to landfill. This research focusses on the circular economy by exploring how collaboration between key actors can enable the reuse of structural components, creating a connection between the deconstruction stage and the design stage.

To achieve this, technical, design and process-related factors influencing the reusability of structural components were examined (Q1). After this, the barriers and enablers to reuse were investigated (Q2). The research focused on how collaboration between key actors could support reuse and found that a different form of collaboration is needed compared to standard linear construction projects (Q3). The insights from the 3 subquestions formed the basis for a strategy guide developed in the final phase of the study, aimed at addressing key barriers and strengthening identified enablers through actionable strategies (Q4).

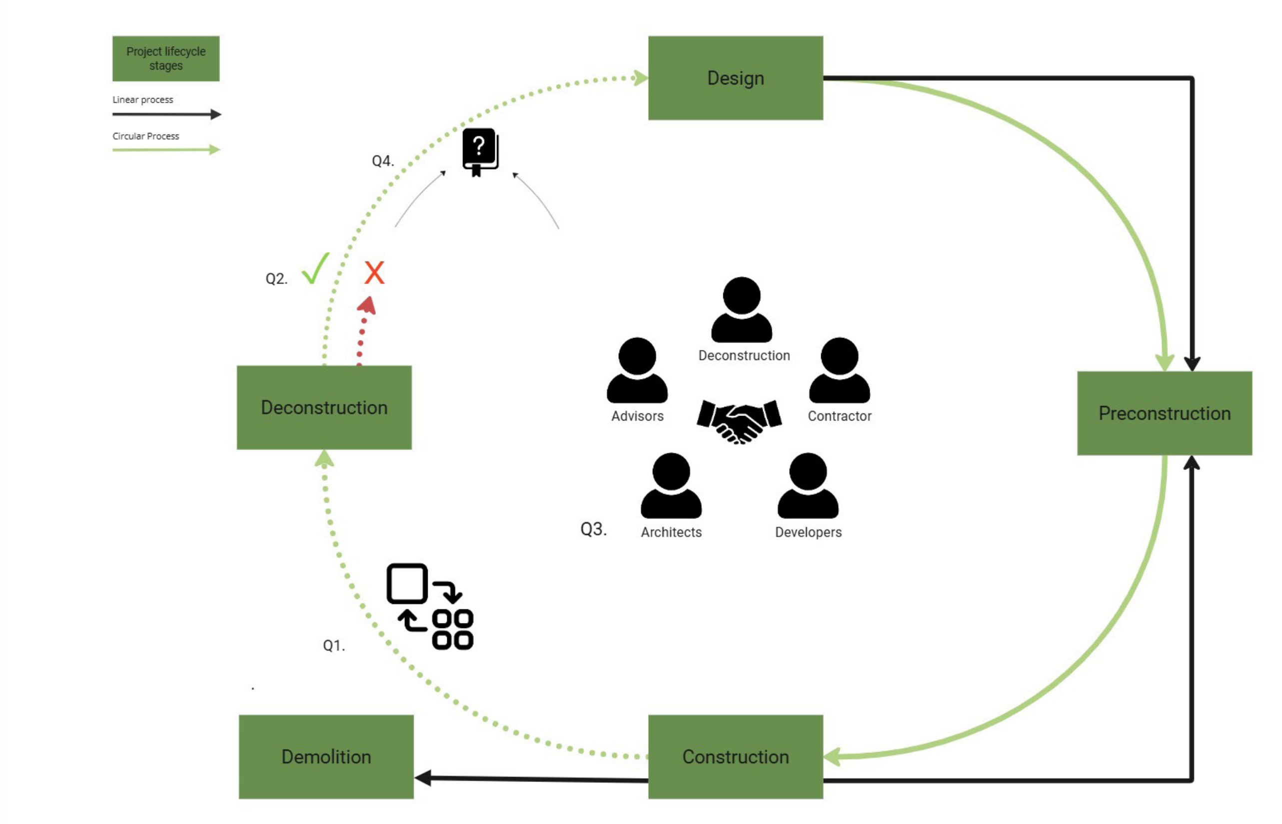

Figure 3: Conceptual model (source: author)

Research Methods

2

2.1 Type of study

This research adopted a qualitative, exploratory approach to provide valuable insights into collaboration between key actors in the value construction chain for the reuse of structural building components. The primary research question was framed as “how”, aiming to identify prescriptive strategies that enable reuse processes and address known barriers in circular construction. By examining existing practices, barriers and enablers, this research proposed feasible strategies for successful collaboration in reuse processes between key actors in the construction value chain.

This study is well-suited to qualitative research, which is optimal for understanding processes, the roles and relationships between stakeholders, and complex, context-specific phenomena common in construction. A qualitative approach allowed to explore naturally occurring behaviours and decisions within their real-world settings, reducing bias from interference. The research methodology used in this study were a literature review and a case study, providing a detailed understanding of industry practices, barriers, and areas for potential improvement in structural components reuse processes. The literature review provided a comprehensive overview of existing knowledge related to reuse practices, while a case study provided useful new insights and lesson learned from current real-world experiences (Creswell, 2013).

The case study methodology was used to answer the main research question, by investigating collaboration processes, barriers and enablers in circular construction projects involving reuse of structural components, such as structural steel or concrete. The contextual boundaries of the case study were that the project should be situated within the Netherlands and completed in the past 10 years or still in progress. The case study was used to investigate the theoretical proposition of how collaboration between key actors can enable structural component reuse. The cases used in this research were selected based on the following criteria:

1. Projects must involve the reuse of structural building components made from materials such as concrete, steel or timber.
2. Projects are situated within the Netherlands to ensure a consistent regulatory environment and market.
3. Project documentation must be accessible for analysis, including contracts, process logs, construction and demolition plans and other publications.
4. Projects must reflect diversity in the type of structural component reused (Projects with concrete components as well as projects with steel frames). This is to ensure a broader understanding of reuse practices.
5. The projects are relevant to current reuse practices and have been completed in the last 10 years or will be completed in the upcoming years.

2.2 Methods

The qualitative research methods used in this research were a semi-systematic literature review, semi-structured explanatory interviews, document analysis and a workshop. The methods are explained in the part below. Findings from these qualitative research methods were interpreted by following a theory-driven (deductive) approach, aiming to identify generalizable principles for successful collaboration and enabling reuse practices (Creswell, 2013).

Semi-Systematic Literature Review

The research started with a semi-structured literature review, to establish a solid theoretical foundation for the study. This method is structured yet flexible, allowing for a mixture of existing knowledge from different sources such as case studies, academic journals and industry reports. The aim of the semi-systematic literature review was to investigate the following three aspects:

1. Factors affecting structural component reusability, with a focus on technical, design and process-related factors.
2. Key barriers and drivers in reuse processes within circular construction, focussing on structural component reuse.
3. Collaboration processes, focussing on roles and responsibilities, knowledge and communication, decision making, tools and resources and economic structures.

This phase of the research helped address the first three subquestions by identifying existing practices and knowledge gaps. As the first three subquestions are about the practical side of the reuse process, the input came from journals, case study papers, project reports and books that analysed projects where structural components were reused. The findings of the semi-structured literature review created a foundation for the other empirical methods, such as the interviews, by identifying key themes and questions. To ensure relevance, the literature review prioritized sources after the year 2000, reflecting on more up-to date advancements in circular construction and reuse practices. The findings of the literature review were organized into thematic categories, following the aspects of the subquestions, forming a foundation for this study.

To conduct the semi-systematic literature review, the following steps were used, as proposed by Creswell (2009):

1. Identifying key words related to my research, such as ‘reuse’, ‘structural components’, ‘barriers’ ‘drivers’, ‘collaboration’ and ‘actors’
2. Searching the academic databases such as google scholar, scopus and the TU Delft library catalogue to find relevant articles, books, journals and reports. Emphasis was placed on high-quality and peer-reviewed articles and papers.
3. Selecting literature and categorise them based on the specific subquestion.
4. Do a quick scan of the literature to evaluate their contribution to the research topic. The relevant sources were separated and stored for detailed review.
5. Creating a table based on the quick scan to make a comprehensive overview of the literature by stating the aim and focus of each article, the methods used, the findings and limitations, and the scale and context.
6. Compile the literature review with a structured approach, summarizing the main findings per subquestion.

In addition, inclusion and exclusion criteria were used, as shown in table 1.

Inclusion	Exculsion
Type of sources: Literature reviews, theoretical studies, empirical studies related to reuse, collaboration, or circular construction	**Type of sources:** Testing of building materials, systems or components, and studies focused purely on research methods in the built environment
Reuse variables: Disassembly potential, technical factors, material properties, reuse barriers and enablers, structural components	**Reuse variables:** Reuse of non-structural components, recycling, non-construction contexts
Collaboration variables: roles and responsibilities, information sharing, communication structures, decision-making process, economic structures, (digital) tools and resources, circular construction projects	**Collaboration variables:** Internal company collaboration, HR collaboration, or project management outside the reuse context
Subject focus: Reuse of structural components (steel, concrete, timber), circular building case studies, collaboration processes across key actors	**Subject focus:** Adaptive reuse of entire buildings (e.g., retrofitting), product reuse, urban-scale reuse planning, non-structural components

Table 1: Inclusion and exclusion criteria (source: author)

Semi-structured explanatory interviews
Semi-structured explanatory interviews focused on the second and third sub-questions, exploring the barriers and drivers that influence the reusability of structural components, as well as the collaboration processes in a reuse project. These interviews were used to delve into specific, established topics, building on insights gained from the literature review. Explanatory interviews were used to examine not only which barriers and drivers existed, but also why certain barriers arose and how drivers could be expanded to better facilitate reuse processes.

The interviews were conducted with key stakeholders within the construction value chain, who were all present in a reuse project. Gerding et al. (2021) describe the circular construction process as a multi-actor environment typically involving clients, designers, contractors, advisors, and dismantling experts. Therefore, in this research, the key actors were divided into five main actor groups. This selection reflected the roles most directly involved in coordination and decision-making around structural component reuse. While other actors such as government authorities or end-users may influence the project context, these five groups were identified as the most central in both theory and practice:
1. Developer: This could represent the client, but also roles such as the project manager, investor, etc.
2. Architect: Represented the members of the design team.
3. Contractor: This could represent the general main contractor, but also subcontractors, site supervisors, or logistics coordinators.
4. Advisors: This could represent structural engineers, environmental consultants, material suppliers or consultants, and legal or financial advisors.
5. Demolition company: This could represent the demolition contractors, the deconstruction specialists, or waste management teams.

Different companies could represent one of the five different actors in each case study. For example, in Case 1, the following phenomenon was studied from the perspective of Company A, representing the advisor in this case.

The interviews were, where possible, conducted with all five key actors in the selected case projects to gain a better understanding of the systematic and organizational factors influencing reuse processes. The following topics were discussed in the interviews:
- What barriers hinder the reuse of structural building components?
- What drivers enable the reuse of structural building components?
- How are the roles and responsibilities defined and distributed among key actors in projects involving the reuse of structural components?
- What knowledge and expertise are essential for implementing the reuse of structural components, and how are they shared among actors?
- How do key actors communicate and coordinate at different project stages to ensure the reuse of structural components?
- What tools and resources are used during the project to ensure the reuse of structural components?
- What economic or market-related factors influence the feasibility of structural component reuse?

These topics were questioned in the context of the case project, as well as in the context of other general projects in which the participant was involved.

Document analysis

The document analysis focused on reviewing the existing documentation related to the selected case projects. This method involved examining project-specific records such as contracts, process logs, construction or demolition plans, and publications. The goal was to gain a comprehensive understanding of how structural components were reused within each project. Key topics for the document analysis included:
- Process: Step-by-step methods used in assessing, extracting, and reusing structural components.
- Roles and Responsibilities: Identify the key actors involved at each stage and their respective contributions to the reuse process.
- Tools and Resources: Evaluate the tools used to facilitate reuse and how they influenced outcomes.

The findings from this analysis complemented the insights gathered from the interviews, providing a relevant view of real-world practices. The findings from the document analysis also provided a solid foundation for some of the exploratory interviews conducted with specific actors by offering insights into the processes, roles, and tools used. This allowed the participant in the interview to explain certain insights from the document analysis. This method ensured that the research was grounded in practical, case-specific evidence.

Workshops

The workshop in this study will be conducted in the last stages of the research and will be used as input for the final strategy-based framework, developed in the last stages of the study. Workshops are an interactive research method that promotes dialogue and interaction in problem-solving and are especially applicable for complex issues like those in reuse projects (Ørngreen & Levinsen, 2017).

The workshops will serve 2 key purposes:
1. Challenge Exploration and Enrichment: The three main challenges that emerged from the analysis are presented to the participants so that they can recognise, concretise and complement them from their perspective.
2. Knowledge Sharing and Collective Problem Solving: Workshops allow participants to share their insights, thus enhancing mutual learning, while at the same time generating solutions for the challenges identified.

Workshops will follow a structured yet flexible format, comprising three segments:
- Presentation of Findings: Key insights from the literature review, interviews, and case studies will be presented, including the theoretical framework. These insights will be presented in the form of three key challenges, that were identified through the key insights of the results.
- Problem-solving: The participants have the time to come up with practical solutions, ideas and comments for the three key challenges.
- Group Discussions: The participants insights are presented to the group and discussed. This way practical solutions can be refined.

Participants will, where possible, include at least 1 representative from each of the 5 key actors. This includes representatives from developers, architects, contractors, advisors, and demolition companies. This ensures that the assessment of the framework is comprehensive across the different perspectives.

Deliverables likely to emerge from the workshops will include:
- Specific strategies on how to address barriers and successfully collaborate in reuse projects.

The workshop in this study was conducted in the final stages of the research and was used as input for the final strategy guide, developed in the last stages of the study. Workshops are an interactive research method that promote dialogue and interaction in problem-solving and are especially applicable for complex issues like those in reuse projects (Ørngreen & Levinsen, 2017).
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- Group Discussions: The participants' insights were presented to the group and discussed. In this way, practical solutions could be refined.

Participants included, where possible, at least one representative from each of the five key actor groups. This included representatives from developers, architects, contractors, advisors, and demolition companies. This ensured that the assessment of the strategy guide was comprehensive across the different perspectives. Deliverables that emerged from the workshops included specific strategies on how to address barriers and successfully collaborate in reuse projects.

2.3 Case studies

The cases used in this study were selected based on the criteria presented in the beginning of this chapter (2.1). All the selected projects are related to the company where the researcher was conducting an internship, providing easy access to project documentation, as described in selection criteria 3. Based on the selection criteria, the following cases were selected:

- Circulair Centrum Nederland (CCN)
- Cultureel Centrum Lievekamp (CCL)
- Tijdelijke rechtbank Amsterdam (TBRA)

The Tijdelijke Rechtbank Amsterdam was selected primarily due to its direct connection to the company where the researcher is conducting an internship. Although this project differs from the other two in being originally designed to be dismantled and reused, rather than involving the reuse of components from a existing building, it still provides valuable insights into the processes, collaboration, and decision-making involved in structural component reuse.
Circulair Centrum Nederland and Cultureel Centrum Lievekamp were selected because they exemplify more typical reuse scenarios, where components from existing buildings were deconstructed and integrated into new designs. Together, these three cases allow for comparative analysis between different reuse strategies and collaboration dynamics across varying project types and materials. The analysis of the three different cases is provided in appendix 1. This analysis helped clarify which actors were involved in each case, what roles they played, and how collaboration around reuse was organized. This analysis, combined with insights from the literature review, provided a solid foundation to design well-informed interview protocols.

2.4 Data collection

Data collection for this research was structured into five steps, each addressing specific subquestions. An overview of the research design is shown in Figure 4.
First, desk research involving a semi-systematic literature review built a theoretical foundation on reusability factors, barriers and enablers to reuse, collaboration processes, and industry practices. This provided essential context for the initial sub-questions.
In the second phase, a document analysis was conducted, where project reports, contracts, and publications from all case studies were used to gain a detailed understanding of the project processes and actors involved, and to identify potential barriers and enablers within each project.

The third phase included semi-structured explanatory interviews with representatives of key actor organizations in the case projects. These interviews assessed collaboration between actors, including roles, knowledge and processes, and the barriers and enablers for structural component reuse. In the next phase, the workshop served as a problem-solving exercise, discussing the main challenges identified through the interviews and literature. The workshop was conducted with actors from the construction value chain and enabled participants to develop strategies and refine them collectively in a group format. This ensured that the outcomes were practical and applicable to future projects.

The data analysis combined thematic and comparative methods to extract patterns across all data sources. Literature review findings were organized thematically to identify key topics related to reusability, collaboration, and reuse barriers and enablers. Interview data were systematically coded to reveal recurring themes within and across actor roles. Workshop data were integrated into the strategy guide, ensuring it was grounded in both theoretical and practical insights for application in the construction sector.

Figure 4: Data collection (source: author)

2.5 Data plan

This research followed the FAIR principles to ensure proper data management during and after the project (Wilkinson et al., 2016). Examples of collected data include interview recordings, project documentation, and workshop notes. The data sets provided the backbone of the study while being managed in a secure and ethical manner.

Data collection was stored on the university-provided systems throughout duration of the project. Continuous backups of data were made onto external drives. No access to raw data, such as interview recordings, was given outside the research, to protect the confidentiality of the participants. Anonymization protocols removed personal and sensitive information from the data. For each dataset, metadata were provided showing source, collection method, and relevance to the research. This documentation facilitated better understanding and reuse of the data in the future.

If the data were non-sensitive, they were made available through a public or institutional repository that allowed for compliance with FAIR principles, making them findable through standardized metadata, accessible through clear licensing, interoperable through widely accepted formats, and reusable through comprehensive documentation. Raw recordings were deleted upon publication, in accordance with ethical guidelines concerning sensitive information.

Informed consent was obtained from all participants. Participants were informed of how their information would be secured and disposed of, and they retained the right to withdraw from the study at any time. Any data associated with companies were anonymized and carefully treated with confidentiality to minimize the risk of traceability to specific organizations. No company or individual was directly named in the results to ensure confidentiality. Quotes and findings were attributed by actor group. The data plan was reassessed regularly to ensure consistency.

2.6 Ethical considerations

This research adhered to ethical guidelines to ensure participant safety and confidentially. The research therefore applied the following measures:
- Informed consent: for the interviews and workshop, the participants were informed about the purpose of the interview and workshop, and needed to write their consent.
- Right to withdraw: Participants had the right to withdraw from the study at any given time without any consequences.
- Anonymity: The identities of the companies and participants were anonymized in publications. Sensitive data was not published publicly without explicit approval.

Literature Review

3

The following literature review explores key academic and industry contributions related to structural component reuse. It aims to address the subquestions of this research by clarifying the key factors that influence the reusability of structural components, as well as the main barriers and enabling factors that shape reuse practices. In addition, the review investigates how collaboration processes between actors in the construction value chain influence these reuse dynamics. By synthesizing insights from both technical and organizational perspectives, this review provides a foundation for understanding how collaborative strategies may help overcome existing barriers and enhance the implementation of reuse in practice.

3.1 Factors influencing reusability

This section aims to explore the key factors influencing the reusability of structural buildings form existing buildings reaching the end of their lifecycle. It adresses the first subquestion: *''What technical, design and process-related factors influence the reusability of existing structural components from existing buildings reaching the end of their lifecycle?"* To answer this, key concepts such as technical , design and process-related factors are examined through a review of relevant academic literature.

Technical and design-related factors
The reusability of building components depends on a series of related factors. These include the design characteristics and the material properties of the building component. First of all, the reusability of a component is determined by the design characteristics and the extent to which they support disassembly without any damage. Durmisevic (2006) proposes a model which can help in assessing the disassembly potential of structural components. Durmisevic's (2006) model highlights two main indicators for the reuse potential of a component: independence and exchangeability. These indicators represent three domains: functional, technical and physical domain. They are further supported by eight different criteria that represent the disassembly aspects of building configuration.

Independence refers to the degree to which components can perform their original function without being connected to other components. Independence is provided through separation on function of the building level, system level and component level. Independence is represented in two design domains. The functional domain, which is defined as functional composition and separation of building layers, to prevent functional interdependencies. Next to that, the technical domain focusses on the hierarchy of components and dependence of components by number of relations and base elements. For example, a well-structured hierarchy can ensure that base elements have multiple relations, enabling disassembly without damaging interconnected parts (Van Vliet, 2018). Exchangeability is defined by the simplicity of connections between components and the number of relations between components. Minimizing the complexity of these relationships increases the chance of a component being reused. The physical domain represents exchangeability of components, defined by typology, morphology and geometry of connections and the disassembly sequences. For example, the use of reversible connections such as bolt or joints supports the long-term reuse of components (Durmisevic, 2006).

The eight criteria associated with independence and exchangeability in the model of Durmisevic's (2006) are:
- Functional independence:
Refers to how distinctly different functions within a building system can operate without relying on each other, allowing for separation and replacement without affecting the whole.
- Systematisation:
Involves grouping building parts into functional clusters or sub-assemblies based on their expected performance and lifecycle, making it easier to manage and adapt them over time.
- Relational and hierarchical pattern:
Describes how components are arranged and connected. Highly integrated systems are harder to dismantle, whereas clear hierarchical relationships allow easier intervention.
- Base element specification:
Focuses on defining a key component within a cluster that structurally and functionally organizes its surrounding parts, enabling localized adjustments without disturbing other clusters.
- Geometry:
Concerns the shape and edge design of components. Straightforward or open geometries support easy removal, while tightly interlocked forms limit disassembly options.
- Assembly sequence:
The order in which components are put together can create physical dependencies. Sequencing should support future disassembly with minimal damage or complexity.
- Type of connection:
Refers to how components are fixed to each other. Reversible connection types are preferred over permanent ones in circular construction.
- Life cycle coordination:
Ensures that materials with different lifespans are positioned in a way that avoids locking short-life components behind long-life ones, preserving flexibility for maintenance or reuse (Durmisevic, 2006).

This is in line with the factors described in report of the Dutch Green Building Council (2021) about the measurement method for disassembly potential. They described seven important factors that influence the technical aspect of the disassembly potential of a component, focussing on design characteristics that determine whether components can be physically dismantled.

The 7 factors are:
1. Type of Connection:
Dry connections like bolts and screws allow for easy separation and reuse, while chemical connections, such as adhesives, often damage components during removal.
2. Accessibility of Connections:
Easily accessible connections simplify disassembly and reduce labour costs. On the other hand, limited accessibility may require labour intensive procedures, complicating the process and reducing reuse potential.
3. Independence:
Components that can be detached independently without affecting others enhance disassembly potential.
4. Geometry of Product Edge
Open geometries ensure straightforward removal of components, whereas closed geometries require sequential disassembly, increasing the complexity and risk of damage.
5. Disassembly Sequence
Efficient disassembly follows the reverse order of assembly. Components assembled last should be the first to be removed, streamlining the process and avoiding unnecessary steps.

6. Material Compatibility:
Compatible materials at connections ensure durability and ease of separation. Incompatible materials, such as those with risk of corrosion, can weaken connections and hinder disassembly.
7. Documentation and Labelling
Clear documentation and labelling, such as material passports, provide essential information for pre-disassembly planning, reducing risks during deconstruction (Dutch Green Building Council, 2021).

Adaptability
Alongside the factors influencing the disassembly potential of a component, the Dutch Green Building Council (2024) emphasizes the importance of adaptability. Adaptability can be defined as the ability of a building or any of its elements to respond to changing functional and spatial requirements, enabling components to be reconfigured, extended, or repurposed without significant structural alterations. It reduces environmental and financial costs associated with demolition and reconstruction and supports resource efficiency in the long term. Design strategies that enhance adaptability, like the use of modular systems or reversible connections, should be integrated into the component design to achieve extension of their lifecycle (Dutch Green Building Council, 2024).

Toxicity
In addition to the disassembly potential and adaptability of a component, toxicity also has a key influence on the reusability of a component. Materials containing toxic components will have environmental and health implications on the processes of disassembly, reutilization, and final disposal. Presence of hazardous materials like lead, asbestos, or adhesives may limit the possibilities of safe reuse and increase expenses related to the handling and processing of materials Toxic components can also contaminate otherwise reusable components and lower their market value by reducing their utility. It emphasizes how non-toxic material selection during the design phase of a product development process can enable safer and more viable material reuse. Toxicity management is not only about meeting environmental regulations but also about efficiently managing the circular construction process (Verberne, 2016).

Process related factors
Van Vliet (2018) identified additional factors, such as process-based and financial factors, to the disassembly determining factors for transformation capacity, as defined by Durmisevic's (2006). Van Vliet (2018) identified the following process-based disassembly factors that can help to make disassembly easier:
1. Coding and marking:
Labelling the materials and connections will ease identification and sorting processes. Documentation of this is key during the entire development process.
2. Disassembly instructions:
Information about the used materials and (dis)assembly techniques, such as instructions, makes the process of deconstruction easier. Documentation, including changes made, is again key during the entire development process.
3. User participation:
Involving the building's owner or user throughout the process can help ensure that future maintenance decisions do not conflict with design intentions related to disassembly. Providing the building as a service, with maintenance and repairs handled by the supplier, can also enhance the potential for material reuse.
4. Disassembler expertise:
More expertise with disassembly will ease the deconstruction process.

5. Number of operations:
More operations require more time and labour, resulting in increased costs. Reducing the number of operations will increase the economic incentive for disassembly.
6. Deconstruction safety:
Safety should be guaranteed in compliance with regulations (Van Vliet, 2018).

Another process-based factor that can be seen as essential is the presence of a reliable quality assurance process, as highlighted by Räsänen and Lahdensivu (2023). It can be seen as a necessary step to confirm structural safety and compliance after technical reusability has been assumed. Räsänen and Lahdensivu (2023) discuss the several different important stages in the quality assurance process.
The process begins with a pre-deconstruction audit, where a general overview of the building and structures is established. Through the analysis of original design documentation, maintenance records, and previous inspections, the audit identifies which components can possibly be reused and advises on decision-making regarding their potential recovery.

After this stage, a structural condition investigation is conducted, playing an important role in determining technical and durability properties of components and identifying hazardous substances. This process involves destructive and non-destructive testing, the results of which need to be dependable and reflective of the component's performance. Key in this process is aligning the component condition with the current levels of performance of new buildings so that reused components can offer the same safety and durability as new manufactured components. Deconstruction design is the next phase, where the priority is the maintenance of component integrity during removal and transport, as well as occupational safety. These include careful planning of dismantling sequence, lifting techniques, and temporary support systems. It includes visual examination before, and after, deconstruction to identify pre-existing and new damage, and any damage during transport or storage must be assessed and rectified.

Once components are recovered, they must be re-designed for the new function. This involves determining whether the reused components can fulfil structural, acoustic, and fire safety requirements according to current building codes. Changes may be required due to unknown material properties or damage to joints and connections. Finally, product approval and authorization require full documentation of each stage, which provides transparency and helps designers evaluate material performance and uncertainty. While CE marking is not required for components that already exist, national authorities may nevertheless request formal approval as a way of verifying safety (Räsänen & Lahdensivu, 2023).

Next to the process-based factors, Van Vliet (2018) highlights that financial factors also play an important role in assessing the disassembly potential for building components. An economic incentive is needed to choose for disassembly at the end of life phase of a building. This financial feasibility is directly related to 2 factors:
1. Disassembly time:
The time required for deconstruction is often 3 to 8 times higher than the time required for mechanical demolition. When time is a decisive factor, deconstruction may not be feasible.
2. Disassembly costs:
Deconstruction is often perceived as more expensive than demolition. However, its costs can be offset by reduced disassembly time, the residual value of materials, and by integrating long-term lifecycle costs into early design decisions (Van Vliet, 2018).

To determine which factors are most relevant for assessing disassembly potential, Van Vliet conducted a survey with various expert groups within the construction sector. The twelve criteria that were selected are shown in Figure 5 below.

Technical disassembly factors	Process-based disassembly factors	Financial-based disassembly factors
Independency	Disassembly instructions	Disassembly costs
Type of relational pattern	Disassembler expertise	
Assembly sequence	Number of operations	
Assembly shape	Deconstruction safety	
Method of fabrication		
Type of connection		
Accessibility to connection		

Figure 5: Twelve selected criteria from Van Vliet (2018)

In conclusion, a wide range of factors influence the reusability of structural building components at the end of their lifecycle. Key among these are the component's independence and exchangeability, which determine whether it can be disassembled and reused without damage. These technical aspects are supported by additional process-related factors such as clear documentation, labelling, disassembly expertise, and safety planning, as well as financial considerations including the time and cost efficiency of deconstruction. Adaptability enhances long-term reusability by allowing components to be reconfigured for new uses, while toxicity can restrict reuse due to environmental and health-related limitations. Lastly, a comprehensive quality assurance process is necessary to verify structural performance and regulatory compliance, ensuring reused components are safe and functional in new applications. In the next section, we will dive deeper into the technical barriers and drivers associated with these factors, as well as other economic, organizational, social, and regulatory barriers and enablers that are key to realizing reuse in practice.

3.2 Barriers and enablers

This section aims to explore the key barriers and enabling conditions that influence the reuse of structural components to answer the second subquestion: *''What are the key barriers and drivers influencing the reuse of structural components from existing buildings reaching the end of their lifecycle?''* To answer this, relevant academic literature is reviewed to identify and categorize the most critical factors that hinder or support reuse practices in the construction sector.

Rakhshan et al. (2020) identified different barriers and drivers for reusing building components and classified them into six major categories: Technical, economic, environmental, organizational, regulatory, and social. In some cases, barriers and enablers are mirror images, as the barrier is the absence of the enabler and the other way around (Hart et al., 2019).

Technical

Technical barriers to reuse include the difficulty of disassembling components without damage, as well as issues related to compatibility and performance of reused components in new projects. As mentioned in chapter 5.1, negative independence and exchangeability can be a barrier to structural reuse (Durmisevic, 2006). Limited availability of tools and techniques for efficient deconstruction exacerbates these barriers (Rakhshan et al., 2020). The lack of development and use of design tools and guides, such as designing for disassembly (DFD), design for adaptability and building information tools, also plays a role in the barriers to reuse. Next to the lack of buildings being designed for disassembly or adaptation, there is also a lack of standardization in the industry

(Hart et al., 2019). Therefore, current demolition practices and disassembly procedures must be adapted, and innovative technical solutions are needed to address the barrier, ensuring that materials are reused at their highest possible value. However, most businesses are willing to spend less time on carefully deconstructing components and are often focused on quick site clearance during demolition. This often results in the downcycling of materials rather than reusing the materials (Küpfer et al., 2023).

The lack of information can be seen as a key technical barrier. Performance assessment of reclaimed materials is often needed due to a lack of technical information. These performance assessments, such as a certification process, lead to extra labour costs, higher costs for the operators and a higher final cost of the component itself. The lack of a standardized protocol or framework for conducting material assessments for the reuse of structural components exacerbates this barrier (Condotta & Zatta, 2021). Additionally, the high cost of labour in Europe compared to the low cost of new materials, often discourages circular practices like reuse. Activities that support reuse are often labour intensive, such as sourcing suitable reclaimed components or carefully dismantling buildings to preserve materials. A good quality assurance process, as mentioned in chapter 5.1, also takes time and increases costs. When labour costs are high, there is less incentive for actors to invest time in these processes, making the reuse of structural components less economically attractive during the design and construction phases (Kanters, 2020).

On the other hand, drivers for reuse can include improvements in design for disassembly and quality assessment tools that check the structural integrity of building components (Küpfer et al., 2023). The development of standardized testing and certification processes for reused components is another way to reduce technical uncertainties. Digitalisation and standardization can facilitate this. The use of digital tools such as BIM or material passports can address the barrier of the lack of information, by providing information about the characteristics, details, certificates and drawings of a recovered building component.

Economic

Economic factors heavily influence the reuse of structural components. Cost considerations, including the price of reused components and the cost of demolition versus deconstruction, act as barriers when reused materials are perceived as less cost-effective than new ones. This may be due to the low costs of virgin materials or the low end-of life values of materials (Rakhshan et al., 2020). Furthermore, extra short-term costs such as costs for coordinating the reuse process, storage costs for reclaimed components, labour costs or testing costs can also be presented as a barrier to reuse (Küpfer et al., 2023).

Additionally, the lack of a well-established market or a small market for reused components contributes to economic uncertainty (Rakhshan et al., 2020). Waste diversion to other streams can also be a barrier, as it is often cheaper to landfill the materials or refabricate the components. Prices of insurance for reclaimed components may be higher, which discourages clients and other stakeholders to invest (Hradil, 2014). The investment and business communities often operate with 'short-term blinkers', where businesses prefer transactional relationships focused on rapid return of investment rather than long-term collaborations (Hart et al., 2019). Next to that, the lack of a strong business case for reusing components and unconvincing case studies that are insufficient or incomplete often present a barrier to companies in adopting reuse practices (Hart et al., 2019).

On the driver side, reuse is may be encouraged through cost savings due to landfill fees and possible lower prices for reclaimed components (Küpfer et al., 2023). The possible lower price for reclaimed components can be attractive for developers, leading to a higher demand for reclaimed components on the market. This could, however, be counteracted if a developer has a negative perception about the reclaimed components or if the components have no clear certification (Rakhshan et al., 2020). Lacovidou and Purnell (2016) talk about how long-term economic benefits could be a driver for reuse. If the structure of a building is evaluated over its whole life, deconstruction and reuse can offer higher economic benefits than demolition and recycling. While deconstruction is more expensive than demolition, one should consider the net cost of deconstruction, including the revenues from the sale of reused components (Iacovidou & Purnell, 2016). Businesses should look at cost saving inputs, such as where designing for disassembly also means that one designs for quick assembly, leading to cost savings. Economic incentives, such as subsidies provided for circular construction or through tax benefits, may also raise reutilization by lowering starting costs (Hart et al., 2019).

A clear circular business model can be seen as an important enabler of the circular economy. This can include different types of contracts such as Design-Build-Operate-Maintain, that stimulate the practice of reuse. The increasing scale of reuse projects, whether in number or size, can act as an enabler by normalizing reuse practices, improving logistics, and strengthening the economic and market conditions needed for broader adoption. Clustering projects through collaboration can turn barriers into opportunities. In large projects, where there is an enormous scale of materials available, it can become easier to overcome the practical and regulatory challenges. Next to that, linking different demolition projects and construction projects through collaboration can enable reuse (Hart et al., 2019).

Environmental

Environmental barriers are created due to the inability to accurately estimate the environmental benefits and carry out Life Cycle Assessments (LCA) because of incomplete or inaccessible data on the reused components (Rakhshan et al., 2020). In addition, environmental contamination or degradation of materials throughout their life cycle can reduce the possibility of their reutilization. The transport and handling of the components may also have a considerable environmental impact. For example, if a component is stored and transported for a reuse project that is 200 km away from its original deconstruction site, the environmental impact of the transport should be accounted for (Hradil, 2014).

Environmental drivers include reduction in construction and demolition waste and embodied carbon through reuse, which can be seen as environmental benefits (Iacovidou & Purnell, 2016). Reuse reduces resource depletion and, consequently, water use, hence making the environmental impact from any reuse-related construction project very low (Hradil, 2014).

Organizational

Organizational barriers include a lack of coordination and communication between stakeholders, as well as resistance to change within firms (Nußholz et al., 2019). Companies often lack the infrastructure, skills, knowledge and experience needed for effective reuse (Rakhshan et al., 2020). The lack of bandwidth in the construction sector caused by a lack of a clear vision for the industry makes it difficult to make a case for reuse practices, as the sector often has overlapping and competing priorities (Hart et al., 2019).

The complexity of the construction sector can also be seen as a major barrier to reuse. There is a lack of accountability, a fragmented supply chain, and conflicting incentives. Within a reuse project, this lack of accountability and risk distribution can be presented as a key barrier (Hart et al., 2019). This also relates to the lack of ownership and control, and the lack of systems thinking, which are factors that can reduce reuse rates. For example, when a building is deconstructed, not a single actor normally takes total responsibility to ensure that the building components are reclaimed and reused. Developers may be concerned about cost and deadlines, while demolition contractors are often incentivized to remove materials as quickly as possible rather than carefully deconstructing them. Without an established organizational structure that defines ownership, responsibility, and accountability at different phases of a project, the reuse of building components often remains limited (Rose & Stegemann, 2018). Looking at contracts formed between actors in the construction chain, we can see that within the contracts formed in a typical construction project, reuse is rarely included. Gorgolewski (2008) argues that by integrating reuse in the contractual requirements, the reuse rates will increase.

Next to that, timing, logistics and storage are important barriers. The timeline is important as there must be decided when to find the materials that are going to be reused, where these materials will be stored, and when these materials are eventually being reused. It may occur that the timeline doesn't align with the project of the developer, as the timing of a deconstructed building may not align with the timing for the need of reused components in a new building (Knoth et al., 2022). This highlights the importance of matching the supply and demand of building components. According to Gorgolewski (2008) reclaimed materials are often not available at the right time, in adequate quantities, or in the required dimensions to suit the specific project. This can contribute to considerable delays or increased costs due to the redesigns needed to accommodate available components (Gorgolewski, 2008). This mismatch between supply and demand could be reduced by more efficient storage processes. However, such processes are often expensive (Kanters, 2020). Timing therefore remains a decisive factor. Especially contractors, reuse consultants and architects find that timing is a decisive factor for enabling reuse (Knoth et al., 2022).

This relates to the barriers of a lack of infrastructure that can facilitate reuse. The absence of a developed market and inventory systems makes material sourcing very difficult. Digital platforms and physical stock facilities can play an important role in bridging the gap between material availability and project timelines by cataloguing the materials in circulation and predicting their availability, thus enabling better planning. It would reduce uncertainties in the implementation of such infrastructure and would give further confidence in reuse, therefore being a more feasible option for construction projects (Knoth et al., 2022).

On the driver side, incorporating reuse into early design stages and having a dedicated reuse coordinator can significantly enhance reuse practices (Hart et al., 2019). Clear contracts that specify reuse requirements and collaborative approaches also enable organizational alignment. New business opportunities can emerge as new roles and businesses specialized in deconstruction are needed (Gorgolewski, 2008). To stimulate collaboration and integrating reuse in design, different tools can be of importance. Tools such as BIM, BAMB and material passports can help with communication between actors due to information and knowledge sharing. Next to these tools, new technologies such as sensors, controls, IoT, and other innovations can be used to stimulate the circular economy (Hart et al., 2019).

Regulatory

Regulatory frameworks often tend to act as a barrier due to strict safety standards, lack of specific policies related to reuse, and liability for reused materials (Rakhshan et al., 2020). Inconsistent or vague regulations across regions also hamper the widespread adoption of reuse practices (Hradil, 2014). Insufficient standardized documentation and certification for reused materials can make compliance with building codes challenging (Knoth et al., 2022). There is also a lack of flexibility within these building codes and regulations, as they have become very focused on energy use in the operational phase instead of focussing on the embodied energy of the building (Kanters, 2020). In addition, there is a lack of incentives for circular construction projects, such as tax incentives, public procurement, and producer responsibility (Hart et al., 2019). The rigid contracts and procurement processes represent a significant barrier (Knoth et al., 2022).

Condotta and Zatta (2021) identify two main regulatory challenges that hinder reuse: the lack of clear regulations specifically addressing reclaimed building materials and the difficult process of obtaining CE marking for reclaimed components. These issues can extend construction timelines and increase costs, especially when performance assessments and compliance with multiple legal standards is required (Condotta & Zatta, 2021).

Regulations promoting circular construction, such as mandatory construction and demolition waste (CDW) audits or incentives for compliance with reuse standards, can serve as drivers. Incentives such as public procurement or producer responsibility can stimulate the client or contractor to focus on reuse practices. Clearer and more supportive policies can provide the legal certainty required for stakeholders to embrace reuse.
If reuse is embraced by stakeholders, it can also allow for a better evidence base for policymakers, that helps stimulate regulatory changes and further increase reuse practices in the construction sector. Successful pilot projects can help with this (Hart et al., 2019).

Social and cultural
Social barriers often involve negative perceptions of reused materials, such as doubts about their quality and aesthetic value (Nußholz et al., 2019). There is also a lack of awareness among stakeholders about the environmental and economic benefits of reuse (Iacovidou & Purnell, 2016). In addition, trust in the reclaimed components and willingness to adopt the shift to a circular economy can be highlighted as social barriers to reuse (Rakhshan et al., 2020). As mentioned before, health and safety can present a barrier, as salvaged building components may contain toxicity and should therefore be tested (Hradil, 2014).

Hart et al. (2019) mention cultural and sectoral barriers that hinder circular practices such as reuse in the built environment. The overarching cultural barrier is that there is a lack of interest, knowledge and engagement throughout the construction value chain. The construction sector itself is conservative, uncollaborative and adversarial. Kanters (2020) also highlights a conservative building industry as a main barrier. Interviewees, including architects and advisors, stated that there is a lack of flexibility to do things differently because it might be considered a higher financial risk (Kanters, 2020). Kirchherr et al. (2018) align with this, as they state that the company's hesitant culture can be seen as one of the main barriers to circular economy practices. Circular economy principles are often not embedded into the core strategies of organizations, such as their mission, vision, goals, or key performance indicators. This indicates that circular economy principles are not yet fully incorporated within companies (Kirchherr et al., 2018).

In addition, delivering circular economy projects in the context of a linear economy can be seen as an important challenge. Actors trying to follow circular strategies are usually hindered by the issue of developing sustainable business cases under the lack of supporting systems, such as reverse logistics systems for the recovery and redistribution of materials (Kirchherr et al., 2018). This is exacerbated by the link between the construction sector and other linear sectors like finance, where funding methods rarely consider the residual value of materials at a building's end-of-life. Therefore, circular design methods might be less attractive from an investment perspective. Likewise, the role of real estate developers, who have short-term interests and often do not have long-term ownership, can reduce the incentive to put circular practices ahead throughout the life of a building (Kanters, 2020).

A lack of collaboration between businesses, vertically as well as horizontally in the supply chain, is described as an important barrier to circular construction practices. This lack of collaboration is often due to the competitiveness of companies. A lack of collaboration between business functions, such as finance, marketing or corporate is also highlighted. Value chain engagement, long-term collaboration and partnership between businesses were highlighted as drivers that can enable reuse practices. The main sectoral barrier is the lack of bandwidth compounded by an absence of coherent vision for the industry (Hart et al., 2019).

Knoth et al. (2022) relates to Hart et al. (2019), by emphasizing the theme of mindset and knowledge. One significant barrier to the reuse of structural components is the lack of collaboration, cooperation and communication across the construction value chain. Effective reuse requires early involvement and coordination between various stakeholders, including contractors, architects, advisors, and manufacturers. However, the current practice often delays crucial decisions, hindering reuse efficiency. Gorgolewski (2008) argues that the stakeholders' behaviour, attitudes and social structures are crucial aspects in making the shift to a circular construction sector.

Other social drivers for reuse include increasing public and professional awareness of circular economy principles, as well as fostering a culture of sustainability within construction firms. Encouraging stakeholder trust and promoting successful reuse case studies can change perceptions and build confidence. According to Hart et al. (2019), leadership can be seen as a key driver to deliver circular projects. Circular projects often cause confusion of who should lead (contractor, investor, client), and one actor taking leadership could resolve this confusion. That is why the company's environmental culture is an important enabler in circular projects. To stimulate demand for circular construction projects, collaboration with businesses and agencies, as well as early client involvement, are highlighted as key factors. Value chain engagement activities should be stimulated and the focus should be on forming long-term partnerships and relationships, rather than 'short-term blinkers' (Hart et al., 2019).

Key barriers

Rakhshan et al. (2020) state that while addressing the reuse barriers requires a holistic approach, actions to overcome the economic, regulatory and social barriers should be prioritised. Knoth et al. (2022) agree with this, as they highlight that the key themes concerning the reuse of construction materials, including barriers and success factors, are mindset and knowledge (social), reuse infrastructure (organizational), business framework (economic) and legal framework (regulatory). Gorgolewski (2008) argues that addressing the organizational and social barriers should be prioritised. He states that the barriers to reuse are rarely economical or technical, but mostly based on organisational, social and contractual structures. Hart et al. (2019) highlight that while many technical and regulatory challenges will remain, it is important to address the cultural, social and economic barriers. Kirchherr et al. (2018) ranked the technical, regulatory, economic and cultural (social) barriers, based on which barriers are the most pressing barriers that slow down the transition to the circular economy. From their large N-study, he found that cultural barriers and economic barriers are the most pressing barriers, while none of the technological and regulatory barriers ranked among the most pressing barriers (Kirchherr et al., 2018).

Next to that, the research is focused on how collaboration between key actors in the construction value chain can enable the reuse of structural components. Collaboration can be defined as the following: "Collaboration is a process in which autonomous or semiautonomous actors interact through formal and informal negotiation, jointly creating rules and structures governing their relationships and ways to act or decide on the issues that brought them together; it is a process involving shared norms and mutually beneficial interactions"(Thomson et al., 2009). Since collaboration is essentially about interactions between people, relationships between organizations, and decision-making processes, it primarily influences social, organizational, and economic barriers rather than technical, regulatory, or environmental barriers.

Social barriers, such as a lack of interest, knowledge, and engagement throughout the value chain and a lack of collaboration between businesses and business functions, can be addressed through enhanced cooperation, communication, and knowledge-sharing. For example, fostering long-term relationships and partnerships, and ensuring better cooperation and communication, can help overcome resistance and fragmentation in reuse initiatives.

Organizational barriers, such as unclear roles and ownership, and mismatched supply and demand timelines, can be mitigated by developing better contracts and collaborative procurement processes that integrate reuse considerations early in the planning phase. Additionally, the lack of infrastructure for reverse logistics can be addressed through the development of reverse logistics infrastructure that enables efficient storage, transport and reintegration of reclaimed. This can be facilitated through collaboration between different actors.

Economic barriers, including short-term financial constraints, high upfront investment costs, and a poor business case for reuse, can be influenced by circular business models and stimulating demand for secondary materials. Collaboration between developers, demolition companies, and contractors can help balance these costs through whole life costing approaches, ensuring that the long-term financial benefits of reuse are factored into decision-making. Expanding the market for reused materials through new business opportunities and market development is another key strategy that can be facilitated through cooperation among key actors.

On the other hand, technical, regulatory, and environmental barriers are less directly influenced by collaboration. Technical barriers, such as the lack of standardized design tools, insufficient information, and difficulty designing with reused components, can be addressed through drivers such as technological advancements and engineering solutions, standardization and digitalisation, and a clear reuse infrastructure (Knoth et al., 2022). Regulatory barriers, including a lack of clear policies, obstructive laws, and rigid procurement processes, are often dictated by governmental policies and legal frameworks that construction actors have limited control over. While collaboration can help provide a stronger evidence base through pilot projects to support regulatory change, it does not directly eliminate these barriers. Regulatory support from the government is needed for a wider implementation of reuse in the building industry (Rakhshan et al., 2020). Environmental barriers are also not primarily addressed by collaboration. While collaboration can raise awareness and foster alignment between stakeholders, environmental barriers, such as reducing embodied carbon or improving Life Cycle assessment (LCA) performance, are generally addressed through technical and methodological innovations. For example, a structural optimization method and Life Cycle Analysis method can be used to reduce embodied energy and CO_2 emissions by designing with reused components (Rakhshan et al., 2020).

3.3 Collaboration processes

This section aims to answer the third subquestion: ‘’What roles, knowledge and processes are essential for key actors to successfully collaborate and enable the reuse of structural components?’’ To answer this, the research builds on the barriers and drivers identified in Chapter 3.2 and focuses on collaboration as a critical mechanism for overcoming these barriers. Collaboration is widely recognized as essential for enabling circular practices in construction projects, particularly when managing complexity and coordinating across multiple actors (Knoth et al., 2022).

Knoth et al. (2022) state that the one major issue that came up during the analysis of barriers and success factors, was the need for collaboration and exchange of information in the construction value chain. Effective communication between actors in the construction value chain can lead to new opportunities, including new markets, better social values and environmental benefits. If different actors work together on innovative solutions, such as in a reuse project, it can foster continuous improvement and a better working culture. Hart et al. (2019) argue that to address the key barriers, such as the social and economic barriers, one should be looking at the approach businesses take to collaboration with the supply chain, and the impediments of presenting a strong business case for circular models. Rakhshan et al. (2020) gives examples of how collaboration can address reuse barriers. For example, the barriers at the supply chain level, such as the absence of a matured market and lack of sustainable business models, can be addressed by close cooperation between construction and demolition companies (Rakhshan et al., 2020).

Collaboration is defined as the following:
"Collaboration is a process in which autonomous or semiautonomous actors interact through formal and informal negotiation, jointly creating rules and structures governing their relationships and ways to act or decide on the issues that brought them together; it is a process involving shared norms and mutually beneficial interactions"(Thomson et al., 2009).

In the context of circular construction, these collaborative processes are essential for managing complexity and addressing reuse challenges. Matrai (2019) analysed the different elements of successful collaboration and the factors that facilitate higher learning and innovation in building material reuse projects, resulting in 9 different factors for successful collaboration:
1. A shared vision between actors in a project.
2. A mutual interest and benefits in the process: incentives are present for the actors to start a project or stay in a project.
3. Risks are shared between actors
4. There is an ability to compromise.
5. Trust is formed between actors, where actors are willing to undertake partnerships with risk of opportunism.
6. New potential partnerships are formed and affected members of the community are included.
7. Information is exchanged and is transparent and qualitative. Openness and disclosure of information are important, as well as the frequency of knowledge exchange and the presence of intermediation.
8. Joint decision-making
9. The availability of resources such as financial resources, actors' committed time or the available time for the project.

The nine factors proposed by Matrai (2019) outline the conditions that enable successful collaboration, but even when these are met, a reuse project may still fall short due to external or unforeseen challenges. Therefore, successful collaboration can be seen as a critical enabler or precondition for a reuse project's success, but not a sufficient condition on its own.

Matrai (2019) identified the nine factors based on the analysis of 5 different case studies in Danish construction on collaboration processes. First of all, the shared vision between actors in a project was seen as an important factor for successful collaboration (1.), addressing the main cultural barrier of a lack of bandwidth compounded by an absence of coherent vision for the construction industry.

New and long-term partnerships were formed in the case studies which also can be seen as a factor for successful collaboration (6.). Forming long-term partnerships and relationships, rather than 'short-term blinkers', is one of the key drivers described in chapter 3.2. Close rather than loose cooperation between suppliers were also identified in the case studies, as well as the important role of the client and the tight relationships with the client. Next to that, the actor's willingness to compromise was highlighted as important. For example, actors should be focused on optimizing the process with all the actors' interests in mind (4.). This aligns with the focus on long-term benefits and relationships rather than short-term benefits, which presents trust between actors (5.) To accommodate mutual interest and benefits in the project, incentives must be present for different actors (2.). This can come in the form of financial incentives or incentives such as producer responsibility, as described in chapter 3.2.

All cases demonstrated the importance of qualitative and transparent information exchange between actors, as well as the increased frequency of the exchanged information (7.), which align with the drivers mentioned in chapter 3.2 (Matrai, 2019). Jäger-Roschko & Petersen (2022) also highlight the importance of information sharing in the circular economy. Effective inter-organizational information sharing is critical for improving circularity. This involves sharing details on components history, material composition, and lifecycle data among manufacturers, recyclers, and remanufacturers. The lack of standardized information-sharing mechanisms can hinder this process, emphasizing the need for clear channels and technologies such as digital twins or blockchain to ensure transparency and trust (Jäger-Roschko & Petersen, 2022).

Chan et al. (2004) propose 7 significant factors for successful partnering, mostly aligning with the 9 factors of successful collaboration proposed by Matrai (2019). The first significant factor is adequate resources, as resources are often scarce and competitive, and not shared with other organizations (9.). Sharing resources such as knowledge, technology, information, skills and capital is important for successful collaboration, as well as commitment and support from top management (Chan et al., 2004).

Mutual trust towards other parties is another essential factor for successful collaboration (5.) The belief of other parties fulfilling their obligations is key. This goes hand in hand with a shared vision and commitment between parties (1.). Especially long-term commitment is important, which can be regarded as the willingness of the involved parties to integrate unanticipated problems and compromise (4.). As conflicts between parties and bound to happen in projects, it is important to implement conflict resolution techniques, such as joint problem solving. Partnering requires clear communication of information which is transparent and qualitative among all project parties (7.). Next to clear communication, collaboration requires efficient coordination, resulting in the achievement of stability and all parties fulfilling their tasks (Chan et al., 2004).

In addition, Matrai (2019) mentions the presence of intermediation as an important factor for successful collaboration. Danvers et al. (2023) supports this, as he states that the use of actors as intermediaries are important accelerators for the transition to a circular economy, as they have the capabilities to collaborate with different actors across multiple levels. Intermediaries can help organizations by distributing complex, diverse and specialized knowledge. They have important network effects and can build trust between actors (Danvers et al., 2023). Importantly, their presence can also support more effective joint decision-making between actors, which Matrai (2019) identifies as another critical factor for collaboration (8.).

Looking at the socio-technical context in which decisions are made in reuse projects, Van den Berg et al. (2020) states that the decision-making process for reusing building components is influenced by 3 necessary conditions, that determine whether components are recovered or discarded during demolition. The first condition is an identified economic demand before deconstruction. Demolition contractors are unlikely to recover components without a clear market for the components or financial incentive for their reuse. The second condition is that the demolition contractor is able and willing to adopt disassembly routines. These disassembly routines are often more disciplined and skilful than normal demolition routines, where a component is discarded to waste. The disassembly routines depend on the accessibility of the components, the type and the number of connections with other components, as described in chapter 3.1. The third necessary condition for a building component to be reused is that the demolition contractor can control the future performance of the component. The integration of a reused component in a new building plan does not depend on whether it can be recovered properly (in time) but also depends on whether storage or reparation is impractical. Controlling the performance of a component until future reintegration therefore influences the decision-making process of whether to recover or discard building components. In sum, the decision to recover building components during deconstruction depends on 3 necessary conditions; identified economic demand, distinguished disassembly routines and controlling future performance (Van den Berg et al.,2020). This highlights 3 key barriers that were also mentioned in chapter 3.2: matching the supply and demand of reused components, technical barriers such as independence and exchangeability and storage-related barriers.

Additionally, successful collaboration in structural component reuse projects requires well-defined roles, responsibilities and risk-distribution among the different actors (3.). The complexity a project can increase uncertainties, for which actors must take responsibilities which are usually not required. The restructuring of contractual relationships may also be necessary to accommodate the risks (Matrai, 2019). According to Van Vooren and Galle (2024), various traditional roles are being reorganized, with new ones being created considering new challenges presented in reuse projects. For example, circularity advisors, including material scouts and reuse coordinators, became important roles for circularity. These actors bridge the gap in supply and demand by estimating available materials and ensuring their inclusion in new projects. Material stockists and reclaimed component processors might have an important role in managing storage and processing of reclaimed materials to be readily available for subsequent uses.
New professions, such as reuse coordinators, act as generalists who help project teams navigate the complexities of circular workflows. Partnerships on reverse supply chains need to be established to make transportation and reuse of materials more efficient. These new roles reflect the collaborative nature of the work, where each actor brings specific knowledge that adds value to the reuse process (Van Vooren and Galle, 2024).

Collaboration among key actors in the construction value chain can also be enhanced by the use various tools and availability of resources designed to facilitate reuse (9.). Tools can come in many forms, including time, financial, educational and digital information tools (Matrai, 2019). Digital information tools such as material passports and Building Information Modelling (BIM) are of great importantance in the circular economy. Material passports contain detailed information on the components of a building, including origin, composition, and potential for disassembly, which gives confidence and ensures informed decision-making among stakeholders. BIM tools, support the visualization and planning of reuse processes, allowing manufacturers and designers to easily integrate reused components into new projects. These tools can enhance decision-making by providing accurate and accessible data to all stakeholders involved (Jäger-Roschko & Petersen, 2022). However, Shelbourn et al. (2007) highlights the importance of the ‘ease of use’ of different collaboration tools. Respondents from interviews with prominent leaders of project collaborations about effective collaborative working in construction projects described how many of the different available collaboration software or systems fail to address the familiarity of the tools used by participants in the collaboration (Shelbourn et al., 2007).

Next to digital collaboration tools like BIM, digital marketplaces of reclaimed materials can foster collaboration in terms of both the demand and supply for such materials. Their availability or distribution by the concerned actors becomes increasingly efficient. In addition, life-cycle assessments are a very valuable supportive system for structural reuse. (Hopkinson et al., 2018).

In conclusion, successful collaboration between actors in reuse projects depends on a range of interrelated factors. Key elements include a shared vision, mutual benefits, trust, willingness to compromise, and long-term partnerships, as identified by Matrai (2019). These are supported by transparent and frequent information exchange, joint decision-making, and the availability of resources such as time, funding, and tools. Intermediaries and newly emerging roles, such as reuse coordinators and material scouts, can play an important role in navigating circular workflows and bridging supply and demand. Decision-making around reuse is further influenced by specific conditions, including economic demand, disassembly routines, and the ability to control component performance (Van den Berg et al., 2020). Lastly, tools such as BIM, material passports, digital marketplaces, and life-cycle assessments provide essential support for collaboration, provided they are user-friendly and tailored to the actors involved. While successful collaboration can be seen as an important enabler for a successful reuse project, it does not by itself guarantee project success, as outcomes are also influenced by external or unforeseen factors. Together, these insights help to identify the collaborative structures and conditions needed to enable the reuse of structural components in practice.

3.4 Theoretical framework 1.0

To gain a better understanding of how collaboration between actors can influence the reuse of structural building components, an initial theoretical framework was developed based on a semi-structured review of academic and practical literature. This framework is grounded in the findings from the literature review and serves as a conceptual starting point for the rest of the research.

The starting point for this framework was the identification of key barriers and enablers that affect the reuse process (Chapter 3.2). These findings from the literature review were compiled into a detailed overview (Appendix 2), showing not only the type of each barrier and enabler, but also the frequency with which they were mentioned across different sources. By quantifying these occurrences, the most identified and relevant barriers and enablers were selected to form the foundation of the theoretical framework. Some of the barriers were grouped to enhance clarity and to ensure the framework remained concise. The barriers were categorized into economic, social, organizational, technical, regulatory, and environmental types. Of these, only the organizational, social, and economic barriers and enablers were included in the framework, as explained in Chapter 3.2.

To link these barriers and drivers to collaboration between key actors, a structured set of collaboration processes was developed. These processes were derived from the literature, then grouped and categorized by the researcher into five overarching themes:

1. Roles and Responsibilities
2. Tools and Resources
3. Communication and Information
4. Decision-Making
5. Economic and Market Structures

Each of these collaboration domains covers a range of processes identified in literature that could potentially influence one or more of the barriers or enablers. For each collaboration domain, two processes were highlighted. The framework is completed with a set of factors for successful collaboration, based on the work of Matrai (2019) and other scholars. The aim of the framework is to visualize and explore how these collaboration processes interact with the different barriers and enablers, and ultimately, how they contribute to the realization of factors for successful collaboration, such as trust, shared vision, joint decision-making, and stakeholder satisfaction.

This framework serves as a conceptual foundation for the empirical part of the research. Through the case studies and semi-structured interviews with actors involved in real-life reuse projects, the goal is to identify and validate different relationships between collaboration processes, barriers and enablers, which ultimately contribute to the realization of factors for successful collaboration. Based on those findings, a second framework will be developed that captures the relationships between collaboration processes, barriers, enablers and success factors. Figure 6 provides a visual impression of Theoretical Framework 1.0. A clearer, high-resolution version is included in Appendix 3.

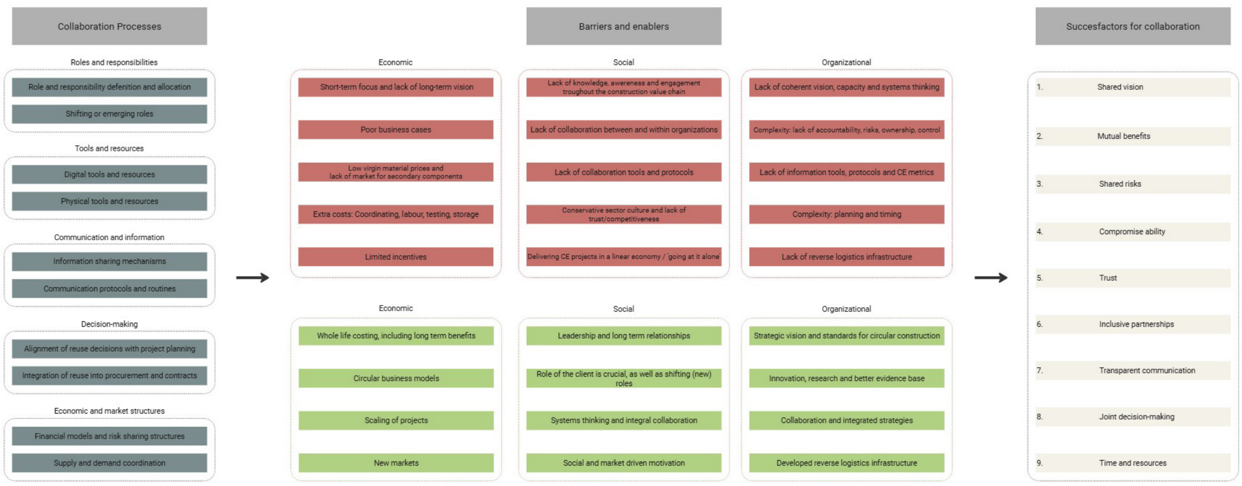

Figure 6: Theoretical framework 1.0 (source: author)

Interviews 4

This chapter presents the results of the semi-structured interviews conducted as part of the empirical phase of this research. These interviews were essential for answering the second and third sub-questions:
2. *‘’What are the key barriers and drivers influencing the reuse of structural components from existing buildings reaching the end of their lifecycle?”*
3. *“What roles, knowledge and processes are essential for key actors to successfully collaborate and enable the reuse of structural components?”*
The interviews explored the collaborative dynamics, barriers and drivers experienced by actors involved in reuse projects.

4.1 Interview participants

Participants were selected through purposive sampling, based on their involvement in the three case studies analysed in this research. For each case, five main actor types were identified: developer, architect, contractor, advisors, and demolition specialist, as mentioned in Chapter 2.2. These categories represent the key positions in the construction value chain that directly influence collaboration and reuse processes. The goal was to include at least one representative of each actor type per project, covering different perspectives across all case studies. Several companies, such as the deconstruction company, the architects and structural engineers, were involved in multiple projects. To capture different viewpoints within these organizations, the selection aimed to interview multiple individuals per case. However, this was not always feasible, which meant that some participants reflected on multiple case studies from a single professional perspective.

In total, nine semi-structured interviews were conducted with professionals who played an active role in one or more of the case projects. This included three architects, two developers, two advisors, one contractor and one deconstruction specialist. Some participants were involved in multiple cases, offering cross-case insights and comparative reflections. A summary of the participants involved is provided in Table 2.

Interview #	Actor category	Role	Cases
1	Architect	Project Leading architect	TRBA
2	Architect	Project Leading architect	CCN
3	Architect	Architect	CCL
4	Developer	Developer	CCN, CCL
5	Developer	Developer	TRBA
6	Deconstruction company	Integrated project Leader	TRBA, CNN, CCL
7	Advisor	Structural engineer	TRBA
8	Advisor	Structural engineer	CCN
9	Contractor	Project leading contractor	TRBA

Table 2: Interview participants (source: author)

The interviews were conducted in person or online via Microsoft Teams and lasted approximately 30 to 45 minutes. A semi-structured format with 15–20 open-ended questions allowed for consistent thematic coverage while enabling participants to elaborate on case-specific experiences. The collected data were analysed using ATLAS.ti, following a combination of deductive coding based on the theoretical framework 1.0 and inductive coding to capture emergent insights.

4.1.1 Interview topics and questions

The interviews were designed to explore how collaboration between key actors can address critical barriers to the reuse of structural building components. To ensure a consistent yet open-ended format, the interview protocol was structured around themes derived from the research sub-questions and theoretical framework 1.0. These topics guided the interviews while allowing flexibility for participants to elaborate on their specific project experiences.

The interviews began with two general questions regarding the interviewee's role and involvement in the respective reuse project, as well as their personal or organizational motivation to participate in reuse practices. This provided valuable contextual information and helped establish the interviewee's perspective within the construction value chain.

Following this, participants were asked to identify and explain what they considered the main barriers to the reuse of structural components. This question was intentionally posed before introducing any barriers discovered in the literature review, to allow the interviewee to speak freely and independently. After this initial input, a list of key barriers identified through the literature review was presented. This list grouped barriers under three categories that the research focusses on: organizational, social, and economic barriers. Each category presented 4 overarching barriers, which were derived from the overview presented in Appendix 1. Some of the barriers were grouped to 4 key barriers.

Interviewees were asked to reflect on these barriers, discuss which ones they recognized, and elaborate on how these manifested in their own projects.

Next, the interview questions shifted toward the collaboration processes, using five domains drawn from the theoretical framework 1.0:

- Roles and Responsibilities
- Tools and Resources
- Communication and Information
- Decision-Making
- Economic and Market Structures

The first question was a general question about how they experienced collaboration in the respective reuse project. Subsequently, two questions were posed for each domain. These questions aimed to explore how collaboration was structured within the project, how roles and responsibilities were divided, how knowledge and tools were used or shared, and how decision-making processes and market dynamics influenced reuse.

The final topic addressed success factors and enablers. Interviewees were asked to reflect on what they considered the most important drivers or success factors for reuse in their project, and which collaborative or contextual conditions had supported positive outcomes. This allowed for a holistic reflection at the end of the interview, helping to identify enabling practices and opportunities for future improvement.

All questions were open-ended, enabling participants to provide in-depth responses based on their own expertise and experience. The protocol served as a flexible guide: while most questions were covered in all interviews, deviations were allowed whenever participants introduced valuable themes or when additional probing was necessary to clarify insights. The interview questions can be found in Appendix 4.

4.1.2 Operationalization

To analyse the data collected by the interviews, the recordings were translated into written transcripts. All the interviews were transcribed verbatim to preserve the content, tone, and structure of the responses. However, some slips of the tongue or repeated words were removed to improve readability and comprehension. Nine transcripts were collected in total, one for each of the nine interviews that were conducted across the three case studies. These transcripts form the primary empirical dataset for this part of the research.

Close reading and re-reading were carried out to obtain a preliminary impression of the data. This reading cycle helped identify recurring themes and relevant segments that aligned with the theoretical model. The goal was to extract insight into collaboration dynamics, enablers and barriers encountered, and role-specific perceptions for each type of actor. The transcripts were then imported into ATLAS.ti, which is qualitative analysis software that allowed for a systematic and organized method of coding. The coding process included a deductive schema based on the collaboration domains and barrier themes of the theoretical model, while inductive elements captured newly emerging themes.

By doing this, the process allowed the analysis to be theoretically driven, but open to new perspectives that emerged directly from the interviews. Section 4.1.3 discusses the coding process in more detail.

4.1.3 Coding

To analyse the interview data in a structured and meaningful way, a combined deductive and inductive coding approach was applied. This was done using the qualitative data analysis software ATLAS.ti, which enabled systematic tagging and comparison of quotes across all interviews.
The coding process began with a deductive framework, based on the theoretical insights developed through the literature review and initial interview topics. The deductive coding framework included two primary code groups:

1.Collaboration processes: These were divided into five key domains:
- Roles and Responsibilities
- Tools and Resources
- Communication and Information
- Decision-Making
- Economic and Market structures

Each domain was operationalized with 2–3 specific codes capturing practical dimensions such as the use of digital tools, role distribution, information sharing, decision-making protocols, and business models.

2. Barriers and enablers: These were derived from the literature review in Chapter 3 and grouped under 6 main themes:
- Economic barriers and enablers
- Social barriers and enablers
- Organizational barriers and enablers

Each theme included several detailed codes reflecting the reuse barriers (e.g. lack of vision, coordination, or business case) and enabling factors (e.g. leadership, circular business models, reverse logistics systems). Regulatory, technical, and environmental barriers were only applied as individual codes when specifically relevant, as they fell outside the core focus of this research.

Once the deductive codes were fully applied across the transcripts, a second round of inductive coding was conducted. This allowed new, unexpected insights to be captured and added as codes. These inductive codes emerged directly from the interview content and included codes that were not yet present in the predefined deductive framework.

The use of both predefined and emergent codes helped ensure that the analysis was grounded in theoretical expectations while remaining open to new perspectives. Some quotations were tagged with multiple codes, reflecting the interconnected nature of collaboration processes and reuse challenges. A complete overview of the codes used in the analysis is presented in Appendix 5.

4.2 Analysis

This section presents the analysis of the interview results based on the coding process described in the previous sections. The goal of this section is to explore how the codes interact and vary across different actor perspectives and case contexts. First, an overview is provided of the most frequently mentioned barriers and success factors, structured by actor type. This allows insight into how different stakeholders perceive the reuse process and what they consider essential for its success. Next, the focus shifts towards the collaboration processes, and how they can be structured to actively address the key barriers. The findings serve as input for the development of the strategy guide in Chapter 6.

4.2.1 Results per actor: barriers and drivers

Overall, the analysis showed that the most frequently named barriers in the interviews were the organizational barriers, followed by the social and economic barriers. The same applies to the drivers mentioned. Within the organizational category (78 mentions), the most mentioned barriers were the lack of information, information tools and CE metrics (30), and the complexity of planning and timing within projects (21), concerning the timing between supply and demand, logistical processes, and working under a tight project schedule. Social barriers (43) included the lack of knowledge, awareness and engagement throughout the construction value chain (18), as well as a conservative sector culture and a competitive behaviour (13). Economic barriers (34) were mostly linked to extra costs related to coordination, storage, and certification (17), and the low price of virgin materials (10), which undermines the business case for reuse. The frequently named inductive codes will be explained throughout the chapter. Technical, regulatory, and environmental barriers were mentioned by the actors, but significantly less frequently, mainly because the research and interviews focused on the organizational, social and economic barriers only. However, it is still important to acknowledge these barriers, as they were sometimes named as a pressing by the interviewed actor.

4.2.1.1 Architects

Three architects were interviewed, each of them involved in one of the three case studies. All the architects interviewed had a more leading or directing role, often being the project leader. Two of the three architects were involved as a project leader in the early stages (VO) and one architect was involved as project leader in a later stage (DO). Not every architect had previous experience with the reuse of building components, however, they all shared a clear interest and vision regarding material reuse, such as how buildings can be designed to last indefinitely. Additionally, they all work for companies where reuse and circularity are embedded in the organizational DNA, with a design philosophy that emphasizes disassembly potential and a “kit-of-parts” approach.

Organizational barriers
One of the most frequently mentioned barriers among the architects was the lack of information, information tools and CE metrics. While standardized products or materials are relatively easy to obtain information about, architects indicated that it was far more difficult to gather accurate information on more complex components, such as prefabricated façade components. As one interviewee explained: *"A standardized product is easier to work with, but when it comes to a prefabricated façade element, it becomes much more difficult, because then the question is: has what has been drawn actually been constructed?"*
Another architect explained how the lack of information tools and CE metrics makes collaboration difficult, as *''everybody does it in their own way, uses their own preferred tools and metrics, and might prioritize different things"*.

Additionally, the architects identified the complexity of dealing with reused materials, such as dealing with guarantees, ownership, and risk, as an important barrier. Unlike new products, reused components often lack clear guarantees. Making contractors and project teams hesitant to commit. As one architect noted: *"Does the manufacturer still exist? Can they still give a guarantee? Guarantees are an important thing. Of course, if you build something, you have to be able to guarantee at some point that it has a certain safety at least. And preferably the lifespan."*
Additionally, uncertainty over ownership and responsibility for reused components increased perceived risks and costs. To manage this complexity, some projects limited reuse to components from known sources, avoiding further uncertainty.

Architects also noted the contrast between the availability of technical information on new products and the lack of equivalent data and a database for second-hand materials. In the case of reused building components, they were often forced to rely on informal searches or intermediaries, instead of accessing a central platform or database. As one architect explained: *"There was no database that we as architects could select from, so it was more a matter of throwing out an idea, like: hey, maybe you have a hollow-core slab, and then it had to be checked, who has a hollow-core slab? Hey, we want a door, who has a door? The manufacturers were not that far along yet either."*

Another architect said the following: *''It is difficult to get a grip on what we have really got in our hands. What is the supermarket we can get all our stuff from? I knew I could reuse the façade elements and floors, but what can I add to this? That cost us a lot of energy and time in the beginning, to find out the quality of the components, and if it met the requirements."*

Not only the lack of information was often mentioned as a barrier, but also the different level of information needs and detail levels between actors. For example, contractors and demolition companies often required highly specific data at the element level, such as the exact dimensions, while structural engineers were still working at a more abstract level, focusing on the overall structural integrity of floor fields to meet safety regulations. As one participant explained: *''The deconstruction company really needed to know per element: is it still there, do I need to weld extra flanges, how many new hollow-core slabs do I need to order, whereas the structural engineer was only working at the field level to guarantee structural safety"*. These mismatches in information expectations sometimes led to inefficiencies and even irritations during the design and preparation phases. One architect described it as a difficulty of matching the supply and demand of information, instead of matching the supply and demand of building components.

However, matching the supply and demand of the building components itself is also mentioned as an important barrier by the architects. In the project of the Tijdelijke Rechtbank Amsterdam, the first intention was to reuse donor hollow-core slabs from the ministry building in the Hague. However, this eventually did not go through due to problems with certification of the components. Due to the additional time pressure, they couldn't find the right donor in time, which led to the choice for building a demountable building. As one participant explained: *''The timing of matching the supply and demand of a building component is the most difficult, it should actually be available on the moment that we as architects are working with it."*

The problem of certification of reused components is also one of the technical barriers mentioned by the architects. These technical barriers, like the additional testing and research that needed to be done had a big impact on the time pressure within the project. Other technical barriers mentioned were related to building conformity, as some properties like dimensions were already fixed.

Social Barriers
The difficulty of finding a donor within the time constraint of the project of the Tijdelijke Rechtbank not only had to do with problems in the certification process, but also the way of thinking by actors, like a contractor, in the process. One architect said: *"The mindset of a contractor, but also the mindset of the people involved in such a process, is simply geared towards ordering something new from the factory. If you want to reuse materials, they don't know whether they will receive it on time, so it becomes a risk for the execution phase. As a result, sometimes the choice is made to opt for a new product."*

This is related to the social barrier of a more hesitant culture within the construction sector and a lack of trust. One architect described the hesitation that can be seen by some advisors:
"There is still a tendency among advisors to first calculate what they need, and only afterward look at what is available, instead of adjusting their concept based on existing materials."

Drivers
The architects identified several key success factors that support the integration of structural reuse into design processes. One recurring theme was the importance of shared understanding and early involvement of all project partners, especially those responsible for execution and reuse coordination. In projects where the contractor or client had direct experience with reuse, communication was easier and expectations more realistic. As one architect explained:
"They knew what kind of structure we were dealing with. If I had to explain that to someone else, they might just say: no, find another structure and start a new design."
This kind of mutual understanding helped align ambitions with the limitations of reused components, for instance, when working with fixed floor heights or widths that didn't fully match modern standards.

Another important factor was early identification of reuse constraints, such as fire safety, finishing requirements, or technical limitations. One architect noted: *"You have to identify early what becomes the Achilles' heel of the reuse, that determines whether the reuse will succeed or not."* This technical awareness within the design team was seen as essential to avoiding costly changes later in the process.

Finally, architects emphasized the value of collaborative formats, where all actors, including developers and contractors, were present from the beginning. Having the contractor at the table from day one made reuse more feasible, since practical knowledge could immediately inform the design. One participant reflected: *"The contractor was already involved from the start. That made it really easy to spar about our proposed building methods and materials."*

4.2.1.2 Advisors

Two structural engineers were interviewed, each involved in one of the three case studies. One of the advisors was primarily involved in the project of the Tijdelijke Rechtbank Amsterdam, while the other contributed mainly to the Circulair Centrum Nederland. Both advisors participated from the early stages of the projects, starting from the SO phase to the DO phase, providing structural input throughout the design and engineering process.

For the structural engineers, the Tijdelijke Rechtbank represented one of the first real experiences with circularity and the design for disassembly principle, as it was a requirement imposed by the Rijksvastgoedbedrijf in the tender. Although reuse ambitions were initially high, such as the intent to reuse hollow-core slabs, the practical implementation faced several challenges, leading to the application of mostly new materials. Both advisors emphasized that sustainability ambitions largely depend on the client's initiative, and that structural reuse remains complex within traditional cost-driven project frameworks. Nevertheless, the reuse-oriented mindset initiated during these projects has influenced their subsequent work and understanding of circular construction.

Organizational barriers

One of the most frequently mentioned barriers among the advisors was also the lack of information, information tools and CE metrics, especially concerning the reuse of structural concrete components. As one advisor explained: *"With steel, you can, even without much information, measure the profile and establish the steel quality with relatively limited testing. But with concrete, if you know nothing, you can't really do anything with the element; you have to conduct a lot of investigations."*

Another advisor highlighted the importance of detailed documentation for increasing the reuse potential: *"Actually, you would prefer the situation we have now, with a very extensive archive containing everything, so that you know precisely what you can do with it."*

In the case of the Circulair Centrum Nederland, the advisors noted that the deconstruction company organized a detailed documentation process during dismantling, which allowed components to be traced and matched back to their original specifications. Nevertheless, the interviews made clear that systematic and reliable documentation remains critical to making large-scale reuse feasible in practice.

Additionally, the advisors mentioned the lack of a database, showing which buildings are scheduled for demolition and what components they contain. This makes it difficult to design with reuse in mind. As one advisor explained: *"Right now, we are looking for something that fits what we've already designed. But it would be much better if we knew: this building will be demolished in 2025, can we design with that?"*

They emphasized that such a system should exist before demolition, not after: *"It's about unlocking which buildings are up for demolition and what they contain, so you can design with that before the demolition happens."*

However, a key issue remains: *"Who has a business model to bring all these existing buildings into view? That's the crux."*

Another barrier mentioned by the advisors was the impact of contractors making changes during the execution phase, which could undermine the reuse ambitions set earlier in the project. For instance, at the Tijdelijke Rechtbank project, the first intention in the beginning of the project was to reuse hollow-core slabs, but according to one advisor: *"That idea quickly disappeared from the table because the contractor said: I don't have them available on time, so what do you want?"*

This advisor even mentioned the role of the client and contractor as most important barrier: *"It's very important to have the client on board. We have had several projects where the ambition was very high, and we enthusiastically developed sustainable alternatives. But in the end, it often just turned into a traditional sand-lime brick structure with hollow-core slabs, because that was much cheaper."*
He further added: *"Up to and including the design development phase (DO), ambitions were high, with ideas for timber structures and circular solutions, but once the contractor came in, it was quickly abandoned. We have seen that happen multiple times."*
The advisors also highlighted that adjustments in the execution phase can introduce additional barriers: *"Executing parties often still make changes during construction. That can also create barriers, especially if changes are not properly documented."*

Another barrier mentioned by the advisors was the complexity of planning and timing within reuse projects, related to supply-demand coordination, and tight project schedules. In the Tijdelijke Rechtbank project, strict deadlines limited the possibilities for material reuse. As one advisor explained: *"There was a good tender, but there was also a planning attached to it. The temporary courthouse had to be ready on time because the real courthouse needed to be renovated. The contractors hid behind that: 'We have to meet the deadline, where are the slabs? I don't see them."*
Similar timing issues were observed in other projects. One interviewee noted: *"At another project, the contract negotiations with the contractor took so long that once it was signed, there was no time left to look for donor steel anymore. They just wanted to go full speed ahead to meet the delivery date."*

Economic Barriers
The advisors also pointed out economic barriers related to the reuse of structural components, such as the extra costs associated with testing, coordination, and labour. As one interviewee summarized: *"A sustainable building is still slightly more expensive than a new building, and that is what we also experience."*
The need for additional upfront work was seen as a major financial burden, particularly when designing with donor building components. One advisor highlighted that it is important to adapt the architectural design early on to match what is structurally feasible with reused components. This is especially true for concrete components, which require more uncertainty management than steel. As the advisor continued: *"You have to invest quite a lot of time upfront to be sure it will work, especially with concrete. Before you know it, you spend a lot of time calculating and checking, and in the end, the project may financially slip away from you."*

In addition, technical barriers were mentioned by the advisors, also influencing the economic barrier of extra costs for testing and research. At the Circulair Centrum Nederland project, the reuse of large structural components from the donor building led to design constraints and additional engineering effort. As one advisor explained: *"Existing elements limit the design flexibility at some point, both in terms of dimensions and structural capacity, which required a lot of additional investigation."*

Drivers
The structural advisors emphasized several key success factors for successfully integrating structural reuse into construction projects. One of the most important drivers they mentioned was the role of the client and having him onboard throughout the whole project. Another success factor was the early alignment between architectural design and the reuse potential of donor components. Instead of designing first and trying to fit reuse later, the advisors highlighted the importance of guiding the design based on what donor materials allow: *"You shouldn't let the architect design a*

building first and then try to fit the structure in later. The structural engineer needs to inform the architect from the start: what works and what doesn't."
This design approach was especially relevant when working with concrete donor components, which require much more research and documentation than steel. Therefore, the availability of documentation and information from the donor building was also seen as a critical factor. At the Circulair Centrum Nederland, the advisors described a successful case where reuse was facilitated by well-documented dismantling: *"There is a very extensive archive, and during dismantling by (deconstruction company), it was documented which element came from where, that allows you to match based on archival data."*

4.2.1.3 Developer

Two developers were interviewed, each involved in one or more of the case studies. One of the developers was primarily involved in the project of the Tijdelijke Rechtbank Amsterdam, while the other contributed to the early phases of the Circulair Centrum Nederland and became increasingly involved in the Cultureel Centrum Lievekamp project through the joint venture. Both developers participated in early project phases and were closely involved in tendering, design coordination, and strategic decision-making processes.

Their motivation to participate in this tender was strongly driven by their longstanding interest in circular design, the "kit-of-parts" philosophy, and the ambition to create a fully reusable building, which was a concept that at the time was still highly innovative. In the Circulair Centrum Nederland project, the developer played an advising role during the material harvesting phase, helping to assess the reuse potential of components from the 'Prinsenhof A' building. For the Cultureel Centrum Lievekamp project, their involvement was even more formalized, with the developer collaborating through a joint venture, being responsible for developing the new design after dismantling, and further applying reuse principles within the new location.

Social barriers
A social barrier mentioned by one of the developers was the lack of knowledge, awareness, and engagement across the construction value chain. While this was not considered a problem within their own consortium, it was still present in interactions with actors such as clients and municipalities. As one interviewee explained: *"We have less trouble with social or cultural barriers within the team, because as LCP we combine developer, designer, and demolisher, all already thinking in the same way. But there's still a bit of that with the client and the municipality."*
They noted that enthusiasm alone is not enough, and that experience and risk awareness are essential: *"They're enthusiastic, but less experienced. They just have to go through a learning curve. In construction, if it's a risk you're not used to, the answer is often: we don't do it. Instead of asking: how could we make it work?"*
Finally, the developer pointed out scepticism about reused materials among public officials: *"In conversations with building inspectors or people from the municipality, you often hear: second-hand materials? They must be worse."*

The developers also described a broader cultural barrier within the construction sector, characterized by hesitation to deviate from standard processes and a lack of openness to change. One interviewee reflected on the difference in mindset needed for circular design: *"Some people get frustrated and say: I'm not doing that. I want to go step by step; first this, then that, and I'm not going to revisit something we decided six months ago. But sometimes you have to if the project benefits from it."*

Another developer mentioned the difficulty of finding contractors willing to participate in circular projects, due to perceived complexity and risk: *"Normally, you ask five parties for a quote and go* *with the best one. But now, maybe four out of five would say: these requirements are too difficult, why would I even do this for you? So their quote often went up, just because of the uncertainty"* However, he also noted that once the project was successfully delivered, several of those same parties returned, curious and eager to engage, illustrating how a visible pilot project can reduce hesitation and help establish a stronger evidence base for future circular collaborations.

Organizational barriers
The developers also pointed to the complexity of planning and timing, particularly when it comes to matching the availability of reused materials with construction schedules. In the Circulair Centrum Nederland project, reused components were stored for extended periods, which led to financial and logistical challenges. As one developer explained: *"The materials are definitely going to be reused, so the match is there. But ideally, you'd want one year less of storage, that just costs money."*
He further noted that this is difficult to control: *"The building has to be gone at some point, and then maybe you're not yet fully ready with your new plan."*

Another key barrier mentioned by the developers was the lack of early integration of actors, particularly those responsible for demolition, storage, and transport. In the Tijdelijke Rechtbank project, the design team worked without early input from the deconstruction company, which led to impractical design choices: *"We designed some elements to be fully demountable, like a staircase with removable steps and handrails, but the deconstruction company later said: the bigger the better. They just lift it onto a trailer and move it."*

This lack of coordination also impacted storage strategies. The same interviewee explained: *"We thought: the smaller the parts, the easier to store, but that turns out not to be true. If you store something the wrong way, after two years it's no longer usable."*
They emphasized that late integration of reuse experts often lead to missed opportunities and rework: *"You suddenly bring in a disassembly advisor halfway through the process, but they're confronted with many decisions that have already been made."*

Economic barriers
In addition, the developers highlighted the economic barrier of extra costs, such as testing, coordination, and storage: *"You may get the materials for 'free', in quotation marks, but you still have to do a lot before you can actually use them."*
A related social barrier was the need to convince clients and users of the value of reuse when it's not necessarily cheaper, or does not align with their expectations. As the developer noted: *"Explaining that is really a barrier. In the end, we manage to ensure that the reused building is not more expensive, but you have to convince the client that, in terms of sustainability, it's important to do it, even if it's not cheaper. And it comes with a whole story, one that's difficult to express in economic terms."*

Drivers
The developers identified several clear success factors for enabling the reuse of structural components. One of the most important drivers was the role of the client, especially when they are open to innovative approaches and willing to invest in sustainability. As one developer highlights:
"A client who really wants this, who is open to a new concept and willing to spend more than on new construction, open to those kind of things."

Closely connected to this, as mentioned before by other actors, was the importance of early integration of key actors, such as contractors and deconstruction companies into the initiation phase. This integration helps avoid late-stage conflicts and creates space for better technical solutions:

"The earlier you know the target building that matches your donor, the greater the chance of success."

A third important driver was having an enthusiastic and aligned project team, where all parties share the same ambition. As one interviewee stated: *"Everyone must have the same goal in mind. If someone says it's too much trouble, it won't work. You need people who say: let's try it differently."*

Lastly, they highlighted the need for thinking in terms of long-term value, including residual value (restwaarde) and CO_2 savings. That might be the architect who does something extra regarding the disassembly potential, or the client who needs to invest in a different way. They argued that a building designed for reuse should ultimately be seen as more valuable than one built for a single use: *"Such a building becomes worth more than another building. That's what the real standard should be in a few years."*

4.2.1.4 Deconstruction company

One participant from the deconstruction company was interviewed. He was involved in all three case studies: the Tijdelijke Rechtbank Amsterdam, the Circulair Centrum Nederland, and the Cultureel Centrum Lievekamp. He had a central role in each project, ranging from strategic coordination to project-level oversight. While daily execution was handled by project leaders, he remained closely involved throughout, especially in areas such as disassembly, logistics, and remounting.

At the Tijdelijke Rechtbank, the deconstruction company was responsible for acquiring, dismantling, and relocating the building to its new site. In the Circulair Centrum Nederland, they led the project from the start, acquiring multiple donor buildings and collaborating with the architect to co-develop a new design based on harvested materials. For the Cultureel Centrum Lievekamp project, the deconstruction company operated as part of a joint venture, managing both dismantling and remounting. The company's motivation and vision are based on knowledge development and innovation in circular construction. They are convinced that we should handle the existing building environment differently, and that we are capable of doing so. Over the past decade, the company has invested in digitalisation, process optimisation, and learning-by-doing, actively reshaping the role of the deconstruction contractor into that of a key partner in circular design and reuse.

Regulatory barriers

The interviewee was one of the few participants who explicitly stated that they see law and regulations as one major barrier, especially the complexity and limitations of the current regulations. He pointed out that the new Environment and Planning Act still does not incorporate the use of secondary materials well, and the current regulatory framework still remains difficult to navigate within a circular project: *"There are openings in the law, but often the competent authority is not yet familiar with this new way of building and remounting."*

He also noted that smaller municipalities in particular often treat circular projects as regular ones, largely due to their inexperience, which can lead to mismatches and delays in processes such as permitting.

Economic barriers

The interviewee also highlighted several economic barriers that hinder the wider adoption of circular construction. An important barrier is the lack of financial models that recognise the long-term value of reused materials and buildings:

"There is still no model in the financial sector for how to finance remounted buildings, they still treat them as conventional real estate, while we see them as value-retaining materials."

He emphasized that concepts such as residual value (restwaarde) and whole-life costing are largely absent, especially among housing associations: *"In housing, everything is still written off, and demolition is expected after a certain number of years. The concept of rest value and that mindset simply don't exist there."*
The interviewee also mentioned that while circular buildings align well with sustainability goals of the financial sector, current financing practices and tools do not yet reflect this. As he put it: *"We should be able to finance these buildings differently, based on the data and value we generate, but that shift hasn't happened yet."*
In addition, he pointed out that guarantees and insurance for reused components remain difficult to manage, especially in relation to temporary storage and contract structures: *"How can you deal with guarantees, or insure stored materials? Tendering and contracts aren't designed for what we're doing, and often, people aren't even familiar with it."*

Social Barriers
While the interviewee mentioned some social barriers, he noted that organizational barriers were less of an issue for their company. He noted that the lack of knowledge, awareness, and engagement throughout the construction value chain, mainly comes from the inexperience of actors: *"The inexperience of parties is significant, people often don't know what is or isn't possible, or how it can be done. And even then, there's no immediate urgency. Everyone is aware of the 2030 and 2050 circular economy goals, but for now, it still feels like a distant concern."*

Organizational barriers
Although the deconstruction company experienced few organizational barriers within their own workflow, the interviewee mentioned that information sharing and managing different information needs still posed challenges. As he explained: *"We still mostly share IFCs, but it's a bit of a search. We need to scale this up so we can work more from the same model."*
He noted the uncertainty during design development about how far one could go in making changes: *"What do we need to pay attention to when we put things into the model? How far can we go, and when do we need to pull back if we're making too many changes during the design process?"*
He also highlighted mismatches in modelling expectations between actors: *"We often want more detailed models already at the SO phase, while an architect is still thinking in elements and structures. There's still serious room for improvement there."*
To improve collaboration, he emphasized the need for clearer BIM protocols and a better understanding of demountable design requirements within the design team.

Drivers
The participant from the deconstruction company highlighted several key success factors that enable structural reuse in practice. First, he emphasized the importance of demonstrating that reuse works through real projects. Practical realization, rather than theory, was seen as essential to building trust and momentum: *"The greatest success factor is showing that it's possible. We've reached where we are by doing, not talking."*
This practical focus also led to the accumulation of extensive knowledge and expertise, which the company actively applies and shares across projects.

Another major driver was their integrated business model, in which they take ownership of the entire reuse chain, from dismantling and documentation to storage, remounting, and even coordination with clients and architects. This allowed them to reduce complexity and control risks, helping keep reuse processes efficient and cost-effective. By streamlining these processes internally, they were also able to be in line with the market. As the interviewee explained: *"If*

we dismantle window frames and sell them directly, they're too expensive: too much labour, too much refurbishing. But if we reintegrate them directly into a new construction process, doing the transport and storage ourselves, then those extra margins disappear. That's when reuse becomes market-based."
The company also built a digital system to map and classify materials early, enabling design with specific components in mind and aligning donor and recipient buildings from the outset.

Lastly, the participant stressed the need for collaborative and long-term relationships across the value chain. They actively work to "get the peloton behind them," seeing themselves as a frontrunner tasked with inspiring and enabling others. Scaling up, in his view, depends on continued innovation, knowledge sharing, and more systemic support across the sector.

4.2.1.5 Contractor

One contractor was interviewed. This contractor was involved in the Tijdelijke Rechtbank Amsterdam project, where he was responsible for the remounting of the building at its new location in Enschede. The interviewee served as site manager, overseeing both the disassembly in Amsterdam and the reconstruction process in Enschede. His responsibilities included coordinating the dismantling, organizing transportation, and managing the on-site construction until the building was made wind- and watertight.

The company's motivation to participate in the project came from a desire to take on an innovative challenge and to contribute to proving that large-scale demountable construction is practically feasible. They saw the project as an opportunity to step into unknown territory and demonstrate their capability in circular construction, driven by curiosity and a proactive attitude toward change.

Social barriers
A hesitant company culture was mentioned again as a social barrier, as well as the complexity in the construction sector concerning accountability, risks, ownership ,and control, particularly in relation to guarantees. One important related social barrier noted by the contractor was the indecisiveness and slow, often delayed decision-making by other actors in the project. He explained that uncertainty and hesitation arose across various phases, from the early permitting stage to interior decisions during construction. As he described: *"You're using reused materials, so what about guarantees? That question keeps coming up again and again. And now we're building, and there are still choices that need to be made about the interior. If you ask me what the biggest irritation is, it's just that people don't make decisions."*

Organizational Barriers
This issue of indecisiveness is linked to another barrier identified by the contractor: the lack of clear responsibilities and authority during the project. He explained that although he had coordinated the dismantling in Amsterdam, they were unable to take on the same leading role during the remounting in Enschede due to a lack of formal command: *"We coordinated everything in Amsterdam. We're trying to do the same now, but it's not working yet, because we don't have the privileges or authority to do it."*
This lack of control caused delays and friction in the coordination of other actors, particularly in relation to the engineering and installation work. He gave an example of a tenant who was also responsible for the installation work but was not formally under their supervision:*"They have their own interests. The discussions are ongoing, but they can't make decisions because there's no layout plan yet. And again, no one is taking responsibility, even though the client could play a big role there."*

Economic barriers
Economic barriers such as extra labour costs were also mentioned as important: *"Labour is the biggest enemy in this process when it comes to cost."*
He explained that designing components to be too small for the sake of demountability can backfire, increasing time and effort during reassembly, and gave the same example of the staircase in the Tijdelijke Rechtbank Amsterdam project.

Drivers
The contractor emphasized that a key success factor in reuse projects is collaborative learning and continuous improvement between actors. He observed that parties involved were willing to reflect on what could be improved in future projects and came up with practical alternatives when challenges arose. For example, instead of designing buildings with overly fragmented components in the name of demountability, he advocated for using larger, transportable components that save time and labour during reassembly. He also underlined the importance of designing with future demounting and remounting in mind. He further explained that detailed planning, including drawing-based transport schedules and stacking logic, allowed materials to be reassembled in the correct order. As a result, reuse can even outperform new construction in terms of speed: *"If you compare rebuilding with new construction, we win 100%. I could probably rebuild it in half the time, no waiting for materials, no long transport delays."*

4.2.2 Results: collaboration processes

While the previous section identified key barriers and enabling factors in structural component reuse, this section focuses on how collaborative processes can be structured to actively address these barriers. Literature has shown that successful reuse depends not only on technical feasibility or market dynamics, but also on how well actors collaborate across organizations (Matrai, 2019). Collaboration enables better alignment, risk management and knowledge exchange, which are crucial elements in overcoming issues like mismatched planning, unclear responsibilities or fragmented data. Drawing from the interviews conducted, the following subsections explore how five main collaboration domains (roles and responsibilities, tools and resources, communication and information, decision-making, and economic structures) were structured in the case studies, and how they should be structured to address barriers in practice.

4.2.2.1 Roles and Responsibilities
Effective collaboration in circular construction projects depends on clearly defined roles and responsibilities. Unlike traditional projects where roles tend to be standardized, circular projects require more dynamic, integrated, and responsive role division due to the unpredictability of reused materials and the need for joint problem-solving.

Several interviews revealed that unclear or misaligned responsibilities hindered collaboration between actors. A recurring theme was the importance of early role allocation and alignment. In most cases, roles were not static but evolved as the project progressed. Teams that succeeded did so by jointly determining who would take the lead on reuse, who would track and test materials, and who would integrate them into the design. As one participant described: *"The contractor received a set amount for their part of the contract and were responsible for delivering it within that budget and timeframe. We assigned the design responsibility to the architecture firm, who coordinated the various expert advisors. The consortium had the end-responsibility towards the client. So everyone basically had their own responsibility within their area of expertise."*

Importantly, integral project leadership played a critical role. In many cases, the deconstruction company or joint venture acted not just as contractor or demolisher, but as an integrator, responsible

for sourcing, verifying, and preparing reused components for new construction. Their willingness to take ownership of risks, from material testing to structural performance, enabled architects and engineers to rely on their input. One architect reflected: *"That's the advantage of having a producer or contractor, in this case the joint venture, who takes responsibility for the steel structure. We ensure that it meets the required quality standards. That really takes the pressure off the design team and increases the chance that it will actually be realized."*
The data also suggests that circularity coordinators are essential. This role monitored reuse opportunities throughout the project and maintained oversight of both what was available (supply side) and what was needed (demand side). Sometimes this role was shared informally between the deconstruction company and the architect, but participants noted the need for formalizing it further: *"That matchmaking role between design and available materials is really important. You need someone to keep track of it all, but also to say at some point: this is too late, we'll try again next time."*

Another key function was the BIM coordinator, tasked with ensuring accurate digital modelling of both existing and new components. Since reused components often deviated slightly in dimensions or condition, a central role is needed to ensure consistency, avoid data fragmentation, and keep all parties aligned. One interviewee stressed: *"What's really important is the role of the BIM coordinator, the one who manages the 3D model and makes sure all the right information is attached to it."*
The interviews also highlight the importance of ownership and control. In successful cases, one party deliberately assumed full ownership of materials and the coordination process, including matching donors and receivers, validating quality, and handling storage or risk. This reduced uncertainty and fragmentation. As one interviewee noted:
"We -deconstruction company- manage the entire integrated process from A to Z, and that's intentional, to keep the process manageable and well-coordinated."
Finally, the need for cultural shift and risk acceptance was mentioned as the most important. Circular construction often introduces unfamiliar uncertainties. Teams that succeeded embraced a mindset of collective responsibility, proactivity, and learning: *"There's a culture of curiosity at the architect, the deconstruction company, and both structural engineers. Not just saying 'it won't work', but asking: how can it work?"*

These examples highlight how unclear responsibility allocation and the absence of a coordinating reuse role are closely tied to organizational barriers such as fragmentation and lack of accountability. However, when strategic vision and leadership are present, they enable trust and shared responsibility, which represent two critical success factors for integrated collaboration.

4.2.2.2 Tools and Resources
The integration of the right tools and resources, both digital and physical, are essential for effective collaboration in circular construction projects. These tools can help overcome practical challenges related to traceability, material compatibility, information sharing, and logistical complexity.
A recurring theme in the interviews was the lack of shared tools and structured data systems. Multiple actors, especially architects and the deconstruction company, highlighted the absence of a centralised database for reused materials.

A key enabler across all cases was the use of Building Information Modelling (BIM). BIM was often the central platform where data about reused components (structural dimensions, origin, condition) was visualized, updated, and coordinated between disciplines. As one architect explained: *"We created a harvest model showing where the elements were in the existing building, and then a new structural model where we translated them to a new position. With a script, we* *could check which elements were already used, from which location, and what was still available. That was a really cool thing."*

In addition to design coordination, BIM models were also used for demolition planning, logistics, and inventory management. To support this, reused components should be labelled early on and directly linked to the model for precise coordination. As one participant noted: *"We now already attach codes at the assembly stage. So during disassembly, we don't have to search again which slab is which. That prevents a lot of mistakes."*
The contractor emphasised the need to plan backwards from reassembly: *"The trick, I've learned, is to think carefully about how you want to build it back up before you start dismantling."*
All materials were uniquely numbered and registered: *"I divided everything on drawings into a freight schedule, just like we'd get from a manufacturer."*
This allowed for structured transport and site storage: *"Each pallet has a list, every item is labeled, and we know exactly what's where. That way, we can pick everything in the right order for rebuilding."*

Maintaining the BIM model during execution and beyond can support long-term use and reuse. As one participant explained: *"In this project, our BIM model stopped after the design phase and wasn't continued during execution."*
To change this, responsibilities need to be formalized early on: *"The client really needs to make sure it's in the contract, because for contractors it's often more work, and the intention isn't always there."*

To enable greater reuse, actors emphasized that reuse platforms should be structured to provide relevant data early in the project: *"Ideally, you want a database showing which buildings are set for demolition. Not after, but before. So you can design with them,"* one interviewee explained.
This enables project teams to align donor material supply with the project's timeline and technical needs: *"Then you're not looking for a donor that fits your design, but designing directly with your donor."*
Public clients like the Rijksvastgoedbedrijf are already experimenting with this approach, requiring contractors to provide material passports and making donor lists available during the design phase: *"We could already check in the donor list what they had available from other projects."*

Some actors envisioned scaling reuse beyond individual components. In the context of demountable buildings, structures designed to be fully dismantled and relocated, one participant envisioned a national portfolio of reusable buildings that could be matched to future spatial demands. *"You end up with a kind of basket of buildings across the Netherlands. If there's a demand, you already know, this one becomes available in two years and fits perfectly on that site."*
By standardizing design and documentation, these buildings could effectively function like modular building products, ready to be disassembled, relocated, and reassembled with known specifications.

It's also important that the coordination around tools is structured well enough to avoid fragmentation. One barrier mentioned across cases was that, without a shared process and clear responsibilities, digital models and data systems become fragmented. This highlights the importance of early BIM coordination, frequent feedback sessions, and collaborative workflows. In one project, an interviewee emphasized: *"You need to organize feedback moments. Otherwise everyone just does their own thing. You have to sit down together and ask: What worked? What didn't?"*

4.2.2.3 Communication and Information

Clear and well-structured communication processes are essential for successful collaboration in circular construction. As explained earlier, in the analysed cases, communication barriers often stemmed from mismatched information needs, incomplete data, or a lack of shared protocols. One architect explained: *"I think it has more to do with matching the supply and demand of information, instead of matching the supply and demand of building components."*
This especially became an issue when actors had to provide overly detailed data early on:
"We had to provide such detailed information, down to the cubic decimetres of new concrete, the number of bolts and nuts. For a few connections that's fine, but for the whole project, it's almost impossible. It's hard to keep oversight."

To address these mismatches, teams developed various strategies. As explained earlier, tools like BIM were implemented to coordinate information. Yet without a shared BIM protocol, data fragmentation remained a challenge: *"In hindsight, we should have developed a joint BIM protocol at the start. At the Zuiderstrandtheater, information came from all sides. Some files were outdated, others incomplete or incorrect. So, the chances of making a mistake were higher."*
The advisors highlighted the development of a protocol within the European RECREATE project to guide how reused components should be tested and assessed under varying levels of available information. As they explained: *"Suppose you know nothing, what should you do? Suppose you have all the information, what should you do? And everything in between. So it's really a protocol that can be used later on."*

Structured meetings and evaluation sessions were also essential for aligning information needs across disciplines. *''Essential is a lot of sessions, just sitting around the table together and discussing: what are you running into? Reflections. However, it needs to be properly organized, because otherwise everyone just does their own thing and it never comes back together."*
These evaluation sessions after key phases, such as dismantling, were found to be highly valuable:
"We asked: What did we run into? How did our assumptions hold up in execution? That session brought up very valuable lessons, like the staircase, which hadn't been planned well."
Contractors also emphasized proactive communication with subcontractors, to select enthusiastic and subcontractors. One contractor noted: *"We held a lot of introductory conversations with subcontractors, to explain the project's ambition and check if they saw it as an opportunity or a burden. That helped us choose the right partners."*
Ultimately, the interviews suggest that collaboration around communication should be structured through shared BIM environments, clear protocols from the outset, and recurring moments of reflection and exchange. These measures ensure alignment across changing project phases and prevent information fragmentation.

4.2.2.4 Decision-Making

Delayed or indecisive decision-making was a significant issue, particularly when it came to guarantees, layout decisions, and material choices. As explained earlier, the contractor expressed frustration that "people don't make decisions," even during execution. Early integration of parties like clients and end-users into the reuse strategy was seen as a way to reduce this issue. Developers pointed out that setting reuse ambitions and aligning all design decisions from the beginning helped steer projects consistently.

In the initiation phase, reuse ambitions must be clearly defined and operationalised into measurable goals. In several projects, this was done by setting targets for CO_2 savings or reuse percentages, which were then used as a reference point for evaluating decisions throughout the design and execution process. As one participant explained: *"Those are the kinds of ambitions you formulate at*

the beginning. You need to build a structure so that throughout the process every decision you make is tested against those principles. You don't always have to follow them 100%, but the point is that you made the decision consciously."
To manage complex reuse trade-offs, teams often worked with decision matrices. One interviewee described this process as follows: *"We just listed all the options, and then each discipline had a column to list the pros and cons from their own perspective. That way, we could weigh what the best course of action was."*
This collective tool was used for comparing, for example, different reuse scenarios for façade components or floor systems.

Flexibility was another essential component. Reuse projects often required actors to make decisions in non-linear ways. Unlike traditional projects, decisions about specific components could not always be postponed to later phases. In some cases, donor components even became available during a late stage and had to be quickly integrated into the design. As one architect reflected: *"Sometimes in technical design (TO) you're suddenly doing sketch design (SO) level things again. But the type of decision doesn't change, only now they happen throughout the whole process"*.
This demands a cultural shift, as he explained: *"Some people go crazy thinking: I'm not going back to something we decided six months ago. But if it improves the project, you have to."*

Finally, participants also highlighted the potential of digital and contractual tools to support better decisions. As one participant explained: *"If you could already tag all building elements with a code in your model, and then in execution you have QR codes attached, then a contractor could walk around with a scanner and immediately know: this is this component, from this manufacturer, with these specifications."*
This would help ensure traceability and informed choices throughout the building's lifecycle.

4.2.2.5 Economic and Market Structures
Economic viability was often mentioned as an important driver for reuse. Several interviewees highlighted the need for new financial models that recognize residual value and lifecycle benefits of reused materials. Developers and advisors also highlighted that even though reuse can be cost-neutral or beneficial, the uncertainty around costs, storage, and logistics makes clients hesitant. Transparent cost-benefit communication and early planning were suggested to help build trust in the process and convince clients. As one architect explained: *"In the end, the difference between construction costs and residual value determined what the consortium's profit would be,"* highlighting how residual value should be a shared economic lever, rather than an afterthought. However, as stated earlier, convincing clients of this remains difficult.

As mentioned earlier, having a receiver building identified before dismantling the donor structure increases the chance of reuse success. However, in order to match donor components with future projects at the right moment, the reuse market needs to mature. This includes the development of digital marketplaces or material banks that can make supply and demand visible before demolition takes place. As one developer explained: *"The second-hand materials market is still very small and undeveloped. Nobody really knows yet how to include things like CO_2 savings in the economic calculations, so right now it mostly only works if a destination building is already known."*
However, as the advisor highlighted, it remains difficult to bring the supply of donor buildings into view: *"Who has a business model to bring all these existing buildings into view? That's the crux."*

The interviewed participant from the deconstruction company gave a good example of how to adapt a business model to address this issue. Unlike traditional linear processes, the deconstruction company positions itself as a "building broker," actively matching material supply and demand

across projects. As the interviewee explained: *"We get questions from clients who want to build and from those who want to demolish. We match those using digital inventories. In a way, we are building brokers."*
This model allows them to design buildings around available materials and seek reuse destinations for dismantled components. Their process is digitally driven: materials are scanned, classified, and stored in a depot, forming the basis for new design projects. *"From that depot, we coordinate and assemble new buildings, which in turn become depots themselves,"* he explained.
This circular logic is central to their operations and allows them to integrate dismantling, design, logistics, and remounting under one company, enabling cost control and planning reliability. *"We are owners. We manage the integral process from A to Z. That's intentional, to keep the process manageable and well-coordinated."*
Having a single actor responsible for an entire process phase was also seen as a strength in other cases. It reduced miscommunication and created clearer accountability. As one contractor noted, *"I personally organized all the transport myself, and that's exactly what I think is good about it, that one person handles it all."*

4.2 Analysis

The analysis showed that the most frequently identified barriers by interviewees were organizational, followed by social and economic barriers. Organizational barriers often included fragmented information and lack of information tools, unclear roles and planning mismatches. Social barriers often related to limited awareness and a hesitant sectoral culture, while economic barriers often related to extra costs for labour, coordination and storage. Although technical and regulatory barriers were mentioned less frequently, they were still seen as pressing in some cases.

4.3.1 Empirical framework 2.0

In addition, the analysis revealed clear connections between the five collaboration processes and how barriers and enablers shape both their functioning and overall project outcomes. These relationships were visualized in the initial theoretical framework, which served as a basis for identifying how collaboration dynamics shape reuse practices. This has now evolved into an updated empirical framework, informed not only by theoretical insights but also by findings from the interviews. The relationships are briefly described below, and the full empirical framework can be found in Appendix 6.

The findings illustrated how collaboration around roles and responsibilities is mainly influenced by organizational and social barriers, such as complexity with unclear roles, responsibilities and ownership, as well as limited systems thinking. A hesitant sectoral culture and lack of awareness across the value chain further complicated this. At the same time, the presence of a strategic vision, leadership, and new coordinating roles (such as reuse coordinators or BIM managers) acted as key enablers to address this complexity. Particularly in cases where roles were clearly defined and actors took ownership across the reuse process, success factors such as trust, shared risks, and a shared vision were more likely to emerge.

The use of tools and resources for collaboration is mostly influenced by organizational and economic barriers, such as the lack of shared digital tools, fragmented data systems, and the absence of infrastructure for reverse logistics. Additional cost-related challenges, such as testing, coordination, and storage costs, further complicated tool implementation and information sharing. At the same time, the integration of systems thinking, long-term value considerations (eg., whole life costing), and the proactive use of digital platforms like BIM acted as key enablers. Particularly in cases where digital tools were implemented early and physical logistics were centrally coordinated, success factors for collaboration such as inclusive partnerships, mutual benefits, and efficient resource use emerged more often.

Communication and information processes were often hindered by organizational and social barriers, such as the lack of shared tools, unclear protocols, and a sectoral culture of hesitation or competitiveness. These barriers often led to fragmented information flows, mismatched information needs, and inefficiencies in coordination. However, strategic vision, systems thinking, and the use of shared digital environments, such as BIM protocols, acted as important enablers. In cases where communication was supported by structured routines, feedback sessions, and early engagement with all actors, success factors such as transparent communication, trust, and a shared vision were more likely to be achieved.

Decision-making processes were often hindered by organizational and cultural barriers, including the complexity of planning, unclear ownership, and a lack of early alignment across actors. These issues made it difficult to coordinate reuse decisions with tight project schedules and changing material availability. Moreover, hesitation and limited awareness across the value chain hampered the integration of reuse ambitions into procurement and contractual procedures. At the same time, enablers such as clearly defined reuse goals, strong client leadership, and collaborative strategies supported more timely and consistent decision-making. When actors remained flexible and jointly developed decision frameworks, success factors such as shared vision, joint decision making and trust were more likely to emerge.

Collaboration around economic and market structures was mainly influenced by financial and organizational barriers, such as a poor business case for reuse, limited economic incentives, and the complexity of planning across long product lifecycles. Additional challenges included the lack of reverse logistics infrastructure and uncertainty around cost, ownership, and risk allocation. These barriers often made clients hesitant and reuse efforts difficult to scale. At the same time, drivers such as circular business models, lifecycle valuation, and emerging reuse markets provided opportunities to better align material supply with project demand. In cases where reuse was integrated into the business strategy and supported by clear coordination mechanisms, success factors such as mutual benefits, shared risks, and the availability of resources were more likely to be achieved.

Figure 7: Challenge 1 highlighted in emperical framework 2.0 (source: author)

4.3.2 Key challenges

Based on these findings from the interviews, three overarching challenges were identified. These challenges reflect recurring patterns in the relationships between collaboration processes, barriers, and enablers discussed in the previous section. These challenges were the most frequently mentioned and most significant across all actors, and represent the most critical barriers in reuse projects. Each challenge is rooted in several underlying barriers that emerged throughout the results. All three key challenges are highlighted in the empirical framework, which can be found in Appendix 6. Figure 7 provides a visual impression of challenges highlighted in the empirical Framework 2.0. A clearer, high-resolution version is included in Appendix 6.

Challenge 1: Mismatch of Information

One of the most frequently mentioned challenges across projects was the fragmented and uncoordinated flow of information about reusable components. Actors often operated with different expectations and at different levels of detail, both during design and after handovers between project phases. For instance, deconstruction companies required precise, component-level data early in the process, while design teams were still working at a more abstract level. This mismatch in information needs and levels of detail made it difficult to effectively assess feasibility or match available components to design intentions.

In addition, the absence of (shared) databases made it difficult for actors to know what materials existed, in what condition, and when they would be available. Similarly, the lack of shared information models, such as a centrally coordinated and maintained BIM model, often resulted in outdated or fragmented information across actors. This lack of reliable and accessible data contributed directly to increased testing requirements, and therefore additional costs during design and execution. In conclusion, this mismatch of information added complexity throughout the reuse process.

Challenge 2: Unclear Roles, Responsibilities and Ownership

A second overarching challenge was the lack of clarity around who was responsible for which parts of the reuse process. This included uncertainty about ownership, risk allocation, quality control, and decision-making authority, especially as projects progressed through different phases. In several cases, actors delayed or avoided decisions because responsibilities were not clearly assigned. This was particularly problematic during handovers, when changes introduced during execution were not properly documented or communicated back to the design team.

This aligns with the role of both the client and the contractor proved critical. Reuse was sometimes abandoned when components were unavailable or perceived as risky, and in many cases, circular ambitions were scaled back due to limited commitment, lack of leadership, or difficulty convincing the actors of the added value. This reflects a broader mindset issue in the whole construction sector, where hesitant company cultures, limited awareness, and risk aversion prevented actors from taking initiative or stepping away from traditional processes.

Additionally, contractual frameworks were often not suited to circular goals. Reuse ambitions were not embedded sufficiently in tenders or contracts, and there was a lack of financial models, such as those incorporating residual value, that support long-term thinking. The absence of early integration of key actors, such as demolition companies and reuse coordinators, further increased uncertainty and reduced the feasibility of reuse planning. Together, these challenges resulted in more complexity and uncertainty throughout the reuse process.

Challenge 3: Mismatch Between Material Supply and Project Planning
A third overarching challenge was the mismatch between when reused materials became available and the demands of linear project planning. In several projects, intended reuse had to be abandoned because components were not available in time or because there was no system in place to match available stock with project demands. Even when components were successfully harvested, they often had to be stored for long periods, which led to financial and logistical burdens. Projects lacked reliable insight into upcoming demolitions or available donor stock, limiting the ability to design with reuse in mind. As a result, reuse often remains reactive and opportunity-based, rather than being planned from the start. Without tools to forecast material flows or integrate reuse into early-stage project planning, many teams defaulted to using new materials simply to maintain certainty and meet deadlines.

Together, these three challenges represent the most pressing and frequently observed barriers across the case studies. In the next chapter, they serve as the foundation for a workshop in which professionals explore concrete strategies to address each challenge.

Workshop 5

5.1 Workshop participants

To develop strategies for enabling reuse in construction projects and answer the fourth subquestion: "What strategy guide can be developed for key actors to successfully collaborate and address key barriers to enable the reuse of structural components from buildings reaching the end of their lifecycle?", a co-creation workshop was conducted. This workshop followed the interview phase and aimed to explore practical strategies with key actors who were directly involved in the analysed case studies.

The workshop brought together three professionals representing the key actor categories identified in the study. Each participant had direct experience with one or more of the case projects. The group included:

- An architect who was involved in the Cultureel Centrum Lievekamp project (also interviewed).
- A developer who was involved in the Tijdelijke Rechtbank project (also interviewed).
- A deconstruction specialist, not previously interviewed, and representing the deconstruction perspective.

This mix of participants allowed for rich dialogue from different perspectives in the value chain, while keeping the group small enough to enable in-depth discussion and co-creation.

5.1.1 Workshop topics

The workshop focused on identifying actionable strategies, specifically during the early (initiation) phase, to address the overarching challenges identified in chapter 4.3.2. The focus on the initiation phase was deliberate, as this is the stage where project ambitions are defined, key actors are selected, and foundational decisions are made that shape the feasibility of reuse. Many of the identified challenges, such as unclear roles, lack of information, and mismatches in planning, can be mitigated more effectively if addressed early, before later decisions limit flexibility.

Based on the interview analysis, three key challenges, as defined in chapter 4.3.2., were presented:

1. Mismatch of Information
2. Unclear Roles, Responsibilities and Ownership:
3. Mismatch Between Material Supply and Project Planning

Each challenge was introduced with illustrative quotes and examples from the case studies. Participants were asked to respond to these by identifying what actions could be taken from the start of a project to avoid or address these challenges.

The aim was not to validate the challenges, but to collaboratively explore strategy directions, concrete ideas, improvements, and tools that could strengthen collaboration and reuse outcomes. The emphasis was on actions that could be taken during the early project stages, such as design and demolition.

5.1.2 Operationalization

The workshop was conducted online using the Miro platform, allowing for interactive co-creation using digital post-its and collaborative canvases (Figure 8). It lasted approximately 70 minutes and followed a structured yet flexible format.

The workshop was structured in three rounds, each focusing on one of the key challenges:

• First, the challenge was presented, along with quotes from literature or earlier interviews.
• Then, participants were given time to write their own ideas or experiences on digital post-its.

• This was followed by a plenary discussion in which ideas were shared, discussed, and refined collaboratively.
Participants were encouraged to write down:
• What can be done differently during the initiation phase to prevent this problem?
• Which actor(s) should be involved or take the lead?
• What tools, formats, or agreements are needed?
• Concrete practical strategies or examples based on experience.
Ideas could include improvements to current practices, creative alternatives, new roles or processes, or technical tools.
The workshop was audio-recorded (with consent), and all notes and post-its were saved in Miro for analysis. The full layout for the workshop can be found in appendix 7. The outcomes are used to refine and finalise the strategy guide in Chapter 6.

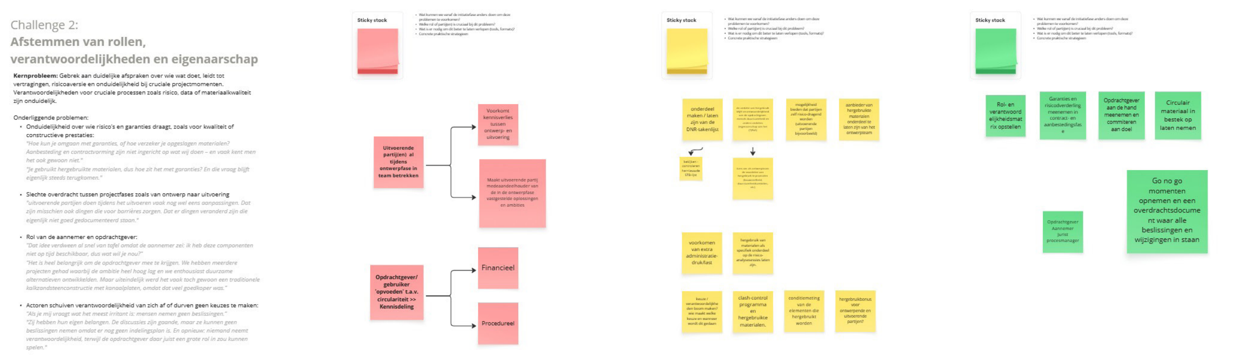

Figure 8: Using the collaborative miro platform (source: author)

5.2 Workshop results

Challenge 1: Mismatch of Information
Participants unanimously acknowledged the challenge of fragmented or mismatched information in reuse projects. To address this challenge, participants proposed:
• Early alignment on information needs and LOD (Level of Detail) across all disciplines at project start. This can be facilitated by improved start-ups and a clearer protocol.
• Immediate creation of a shared digital model, ideally hosted in a central BIM environment, together with a better BIM protocol that specifies how to add and code information and the desired LOD.
• Use of standardized building scans and labelling protocols to ensure that as-built conditions are accurately captured and linked to digital 3D models.
• Incorporating reuse ambition and scope into the program of requirements and task lists of each actor from the outset.
• Selecting advisors and partners based on their experience with and commitment to circularity.
The demolition expert particularly emphasized the need for a shared BIM protocol, a uniform labelling system, and a centrally accessible model to reduce fragmentation and improve coordination. All parties stressed the value of a joint kick-off session to define information goals, tooling, and responsibilities at the outset of the project.

Challenge 2: Unclear Roles, Responsibilities and Ownership
The participants acknowledged that circular projects often lack predefined structures for determining who is responsible for what, especially regarding reused components.
Proposed strategies included:
• Developing a clear role and responsibility matrix, outlining who makes which decisions at which moment.
• Including reuse-specific issues such as material warranties and storage risk in contract and tender documentation.
• Involving executing parties early, during the design phase, to avoid loss of knowledge and improve feasibility.
• Committing the client to circular ambitions and clarifying their ownership of reuse goals throughout the project.
• Using decision logs and handover documents to ensure clarity during phase transitions.
• Integrating material reuse into risk analysis sessions and assigning ownership to parties best suited to manage those risks.
The architect suggested linking responsibility to the DNR task lists and offering incentives for actors who successfully integrate reuse into their scope, either through financial incentives or by allocating more time. The demolition expert emphasized the importance of early client engagement and the role of legal advisors and process managers in formalizing responsibilities. Overall, the need for clear governance structures tailored to circular workflows emerged as a shared conclusion among participants.

Challenge 3: Mismatch Between Material Supply and Project Planning
Participants agreed that reuse success depends heavily on aligning donor material availability with the design and construction timeline.
Proposed strategies included:
• Involving the demolition company earlier in the process to provide insights into available materials and expected release dates.
• Making reuse potential a formal part of the program of requirements, allowing design to respond to real material constraints.
• Allocating planning and budget space for storage and logistics of harvested components
• Establishing centralized material platforms or databases that allow design teams to anticipate material availability before demolition.
• Exploring standardization of material passports or inventories, potentially even mandating them as part of building permits.
The architect noted that reuse is more feasible when components are standardized or sourced from multiple donors. The demolition expert underlined that without transparency in upcoming demolitions and available stock, reuse will remain opportunistic rather than strategic.

The strategies developed during the workshop, combined with the enablers and success factors identified earlier in this research, provided essential input for developing the strategy guide. This guide integrates the findings from the interviews (Chapter 4), including key barriers and enablers, with the results of the workshop, which provided practical strategies (Chapter 5). The strategy guide presents actionable measures to address the three key challenges and strengthen collaboration between actors. This guide is further elaborated and reflected upon in the next chapter, where it serves as a direct response to the fourth sub-question of this thesis.

Strategy Guide

6

This chapter presents a set of strategies developed to address the fourth subquestion: *"What strategy guide can be developed for key actors to successfully collaborate and address key barriers to enable the reuse of structural components from buildings reaching the end of their lifecycle?"* The strategies respond directly to the three key challenges identified in chapter 4.3.2. These challenges emerged from the empirical framework (Appendix 6), which outlined the relationships between collaboration processes, barriers, enablers, and success factors in reuse projects. The strategies respond directly to these recurring patterns by offering actionable approaches to overcome barriers hindering integration of structural component reuse in construction projects. They are grounded in empirical findings from the interviews and workshop, as well as theoretical insights from the literature review. The goal of this strategy guide is to support professionals in enabling the integration of structural component reuse within construction projects. In the following sections, each challenge is addressed through a set of four strategies. Together, these strategies respond to the underlying barriers associated with each key challenge. The strategy guide is shown below in figure 9.

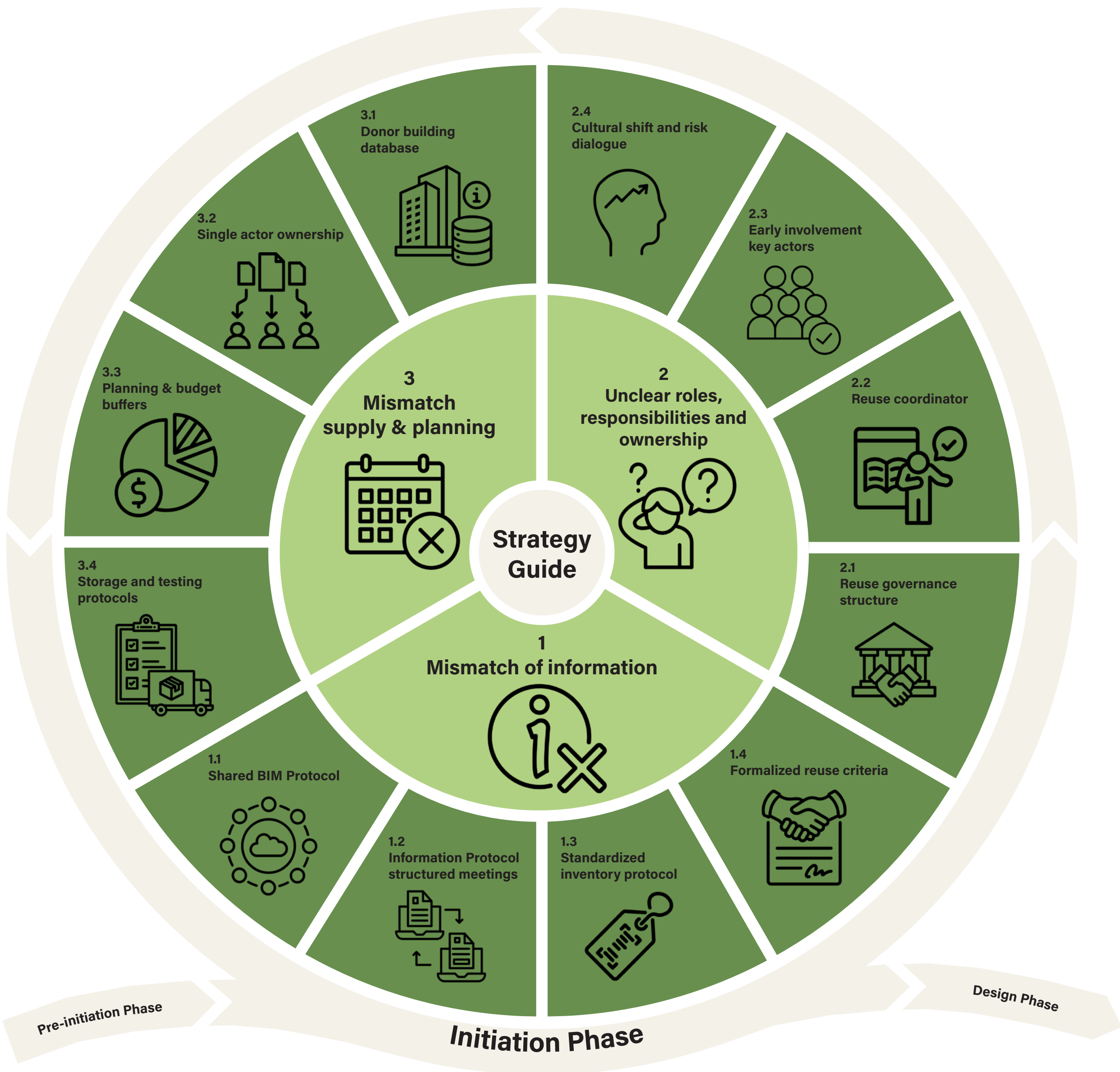

Figure 9: Strategy guide (source: author)

6.1 Mismatch of Information

This section outlines four strategies aimed at addressing the mismatch of information in reuse projects.

Strategy 1.1: Shared BIM Protocol and Digital Environment
One of the key barriers contributing to information mismatch is the absence of a coordinated and continuously updated shared digital environment, such as a shared BIM model. This strategy proposes the development of a shared BIM protocol that is co-created by all relevant actors at the project outset. The protocol should define responsibilities for modelling, updating cycles, levels of detail per phase, and rules for information handovers. The goal is to establish and maintain one shared BIM model that is continuously updated and accessible to all actors. By formalizing this shared BIM protocol, the BIM environment becomes a more reliable and traceable source of information, reducing information fragmentation and miscommunication throughout the reuse process. It addresses the challenge of fragmented and unaligned information needs, gaps between expected and actual information, and the absence of shared and up-to-date databases.

Strategy 1.2: Reuse-Driven Kick-Off Meetings and Information Agreement
To align actors around reuse goals and information expectations, this strategy recommends improved structured kick-off meetings focused on. These meetings should clarify data needs per actor, coordination responsibilities, and how reuse ambitions are translated into measurable actions. This can be done in the form of agreements. This agreement may take the form of a documented “information protocol” or shared reuse action plan that outlines what data is needed, by whom, and when. Such early agreements prevent miscommunication later, particularly across project phases. This strategy addresses fragmented and unaligned information needs and reduces gaps between actors’ expectations about information and the actual available information.

Strategy 1.3: Standardized Building Scan, Component Labelling and Documentation
This strategy proposes a standardized approach to scanning donor buildings and labelling reusable components. This can include a well-defined protocol for measuring component dimensions and conditions, assigning unique identifiers to each element, and systematically documenting all this information in a format that is directly linked to the project’s BIM model. This ensures that as-built conditions are accurately captured and components can be traced throughout the entire reuse process, from disassembly to reassembly. This structured documentation process reduces the need for repeated testing and verification by capturing component information early and consistently. It responds to the underlying challenges of poor data quality and the extra labour and verification costs it causes.

Strategy 1.4: Embed Reuse Ambitions in Contracts, Selection, and Handover Requirements
In addition to addressing unclear roles, responsibilities, and ownership (Challenge 2), this strategy strengthens information continuity by formally embedding reuse ambitions into project documentation. This includes specifying measurable reuse targets in the program of requirements, specifying reuse-related deliverables and responsibilities in contracts, and integrating reuse performance criteria into procurement selection processes. For example, tenders should reward bidders based on the percentage of reused materials proposed, or actors should be selected based on their experience with and commitment to circularity. At the project handover stage, formal documentation of reused components such as origin, condition, and future reuse potential should be submitted. These contractual mechanisms make reuse ambitions binding and ensure accountability across project phases. By embedding reuse requirements into formal procedures, the strategy directly responds to gaps between expected and actual information and addresses the lack of clarity around roles and reuse responsibilities across phases.

6.2 Unclear roles, Responsibilities and Ownership

This section outlines four strategies aimed at addressing the unclear roles, responsibilities and ownership in reuse projects.

Strategy 2.1: Formalized Governance Structures for Reuse Integration

This strategy proposes embedding reuse responsibilities directly into the formal governance structure of the project. It involves the development of a role and responsibility matrix that outlines clear task division and decision-making authority for all reuse-related activities, such as material sourcing, testing, documentation, and integration into the design. By identifying key decision moments and including reuse actions in official task lists and risk plans, the strategy targets ambiguity around responsibilities, risks, and ownership. This approach supports a more structured and coordinated implementation of reuse throughout the project, preventing reuse remains an informal ambition without clear follow-up actions.

Strategy 2.2: Appointing a Reuse Coordinator

To ensure continuity and accountability throughout the project, this strategy involves the appointment of a dedicated reuse coordinator. While this does not necessarily mean creating an entirely new role, it does require assigning clear reuse responsibilities to one actor, often through expanding or adapting an existing role. Acting as a central role across project phases, the reuse coordinator is responsible for tracking reuse opportunities, aligning material supply with project demand, and facilitating communication between key actors. The reuse coordinator helps in reducing information fragmentation and ensures that reuse ambitions are consistently pursued. This strategy directly addresses several barriers: the lack of early actor integration, and ambiguity in roles, responsibilities, risk ownership, and decision-making authority.

Strategy 2.3: Early Involvement of Execution and logistics actors

This strategy proposes the structured involvement of key execution partners, including contractors, deconstruction specialists, and logistics providers, at the early stages of the project. In traditional linear construction, these actors are often involved only in later phases. However, in reuse-oriented projects, their early insights into technical feasibility, material logistics, and sequencing are crucial, as seen in the case studies discussed earlier. Involving them during the initiation phase and early design phase (SO and VO) helps with identifying technical issues early, matching reuse goals with what's realistically possible, and avoids delays or changes later on. The strategy directly addresses the challenge of insufficient early integration of actors, as well as the hesitant sectoral culture stemming from risk aversion. It also helps all involved actors take more responsibility for reuse by making sure they are informed and involved early on.

Strategy 2.4: Cultural Shift and Risk Dialogue

Finally, this strategy targets the broader cultural barriers that were repeatedly identified in the interviews, including sector-wide risk aversion and hesitation toward reuse. It proposes more evaluation sessions, recurring feedback loops, and structured risk dialogue across all project stages. These sessions encourage open reflection on challenges and uncertainties, helping actors to move beyond risk-averse and hesitant behaviour. In addition, it is important that the client formally supports the reuse ambitions, both in procedures and in financial terms. To help secure this commitment, project teams should actively engage the client early on, through workshops, targeted information sessions, and by sharing examples and data that show the added value of reuse. It is important to guide the client through the reuse process and make their ambitions tangible, as this helps to shift mindsets and build trust. When this commitment is secured early on, it helps make reuse a real priority in both design and procurement decisions. By addressing the lack of initiative and commitment that often holds actors back, this strategy encourages a more open mindset focused on learning, adapting, and dealing with risks together.

6.3 Mismatch Between Material Supply and Project Planning

This section outlines four strategies aimed at addressing the mismatch between material and project planning in reuse projects.

Strategy 3.1: Donor-Driven Design Enabled by Early Demolition Insights

One of the main reasons reuse fails to be integrated into construction projects is the lack of early visibility into available donor buildings. This strategy proposes the creation and use of a national or regional demolition database that allows actors to anticipate the availability of reusable components before design work begins. Components identified early through demolition insights can be included in the specifications and program of requirements, ensuring that reused materials are delivered directly by the client and are not left for the contractor to decide or replace with new materials.

This directly addresses timing conflicts between material availability and design needs, and the absence of a structured system to match supply and demand. To make this system effective, a viable business model is needed to bring upcoming demolitions into view. This can include incentives for building owners to register demolitions early, public funding for digital material platforms, and business models in which demolition companies actively match supply and demand. These companies can act as building brokers who scan, store, and reuse components across projects. Such models allow reuse to become part of the design strategy, not just a leftover opportunity.

Strategy 3.2: Assign Single-Actor Ownership Across the Reuse Chain

This strategy addresses fragmentation and unclear accountability that often arises when reuse responsibilities, such as disassembly, testing, storage, and reassembly, are distributed across different project actors. In linear construction projects, responsibilities are typically split per phase and actor, with limited incentive to coordinate beyond the actor's scope. However, reuse requires alignment across phases and domains, as delays or information fragmentation at any point can hinder the process. By assigning full ownership of the reuse chain to a single actor, continuity, accountability, and planning efficiency are improved. This single actor, typically a contractor or consortium partner, is contractually responsible for the full process from disassembly to reassembly and is supported by a reuse coordinator. Centralizing responsibility in this way improves coordination of logistics and ensures consistent quality control and testing. This strategy directly addresses the challenge of aligning supply with project timelines and managing the complexity of reuse across phases.

Strategy 3.3: Integrate Planning and Budget Buffers and Long-Term Financial Models

This strategy addresses the risk that reuse plans are dropped due to time pressure or unexpected extra costs. It proposes that reuse-related costs such as transport, storage, labour and testing costs are included early in the project budget. In addition, specific time buffers should be built into the planning schedule to absorb delays related to reuse logistics. Tools such as whole-life costing, including residual value calculations, can be used to support this early financial planning. By allowing more flexibility in time and money, these measures help project teams handle changes during the process and strengthen the long-term business case for reuse.

Strategy 3.4: Pre-Defined Storage and Testing Protocols

Finally, this strategy focuses on reducing technical risk and logistical uncertainty by creating standardized procedures for storage, testing, and certification of reused components. Without clear protocols, materials might be stored under poor conditions, which lead to degradation, additional testing, or complete abandonment of reuse plans. This strategy proposes that storage and testing protocols are predefined during the design phase and implemented during execution, ensuring material quality and project safety. For example, testing protocols can include decision rules based on available information: when certain data about a component's history or properties is already available, only a limited set of tests may still be required. This avoids unnecessary testing and improves efficiency throughout the process. The strategy directly addresses the barrier of unplanned logistics requirements and adds predictability to reuse workflows.

Discussion 7

This chapter reflects on the findings of this research in relation to the main research question: *"How can collaboration between key actors in the construction value chain address key reuse barriers to enable the reuse of structural building components from existing buildings reaching the end of their lifecycle?"*

7.1 Strategy guide

While the strategy guide represents a practice-oriented contribution, it must be acknowledged that it does not answer the main research question in a comprehensive way. Much of the research focused on identifying barriers, and only a small portion explored actionable collaborative strategies or long-term implementation outcomes. This means the research uncovers *where* the reuse process breaks down and *why*, particularly in relation to collaboration, but less so *how* to enable successful reuse at scale. The strategies presented offer promising starting points but remain early conceptualizations that require further validation. In addition, the workshop only involved three participants, meaning the strategy development process lacked a wide range of perspectives.

In addition, a critical consideration is the generalisability of these strategies across different contexts. In the studied cases, project teams were relatively experienced in circular construction and integrated workflows. Therefore, applying the same strategies in other contexts with less experienced teams would not directly lead to similar outcomes. Moreover, the relevance of specific strategies may vary depending on project scale, actor type, or regulatory setting. The successful implementation of reuse strategies appears to depend not only on having the right tools, but also on the organisational culture, willingness to experiment, and the existing collaboration practices between the involved actors.

However, the strategy guide developed through this research still provides a strong foundation for enhancing collaboration in circular construction projects. It synthesizes both theoretical insights and real-world experiences into practical, actionable strategies that address specific barriers encountered by actors in the reuse process. While not comprehensive, the strategy guide offers a practical approach for early-phase collaboration that can support future experimentation, validation, and adaptation across diverse project settings.

7.2 Limitations

Several limitations influenced the depth and generalizability of the research outcomes:

- Organizational limitation: All three case studies were affiliated with the same overarching organization (the internship company of the researcher), limiting organizational variety in the approach.
- Interview bias: Five out of nine interview participants worked within one company's ecosystem, meaning responses may be aligned to shared work cultures or visions. This could limit the diversity of perspectives.
- Sample size: Only nine interviews were conducted, and just three stakeholders participated in the workshop. This limited sample constrains the representativeness and depth of certain findings and cannot be used to generalise the outcomes for the entire construction sector.

• Assumptions: The research assumes that the presence of certain collaborative processes or enablers lead to successful collaboration and reuse outcomes. While plausible, these causal assumptions were not empirically tested or evaluated through performance indicators.
• Temporal limitations: The research reflects a specific moment in time, but reuse practices, rules, and ways of working together are changing quickly, especially in the Netherlands.
• Interpretation bias: The qualitative data were analysed through thematic coding, a method that relies on the researcher's ability to identify and group patterns. This involves subjective judgement, meaning the findings reflect the researcher's interpretation of the data.

7.3 Broader context and contribution

Despite these limitations, the research contributes to a growing body of knowledge about collaboration in circular construction, particularly regarding structural reuse. It highlights that collaboration is not only about formal role division or contractual alignment, but also about shared vision, timing, information integration, and cultural mindset shifts.
It offers practitioners, especially public clients, developers, and design teams, insight into the practical building blocks of circular collaboration. These findings can serve as the foundation for future reuse projects and help inform public procurement criteria and design tender formats.

Conclusion 8

This chapter presents the main conclusions derived from the research. The findings are based on the results of the literature review, case studies, interviews, and workshop. It begins with an overview of the conclusions for each sub-question, followed by a conclusion that addresses the main research question. The chapter then outlines recommendations for professional practice and suggestions for future research.

8.1 Research conclusion

Q1: *''What technical, design and process-related factors influence the reusability of existing structural components from existing buildings reaching the end of their lifecycle?"*

The reusability of structural components depends mainly on their design characteristics and material properties, particularly in relation to their potential for disassembly without damage. Durmisevic (2006) identifies independence and exchangeability as key indicators of reuse potential. These are evaluated across functional, technical, and physical domains and supported by eight disassembly-related criteria including type of connection, geometry, and assembly sequence. This is supported by the Dutch Green Building Council (2021), which highlights the importance of dry, accessible connections, material compatibility, and clear documentation to simplify disassembly. Van Vliet (2018) adds that process-based factors such as disassembly expertise, instructions, and user involvement, as well as economic factors such as time and cost, strongly influence practical feasibility.

In addition, adaptability increases reuse potential by allowing components to respond to future spatial or functional changes, while toxicity can be a limiting factor if materials pose environmental or health risks. Lastly, a robust quality assurance process, including condition assessments and documentation, is necessary to ensure that reused components comply with safety and performance standards. All these factors combined influence the reusability of structural components.

Q2: *''What are the key barriers and enablers influencing the reuse of structural components from existing buildings reaching the end of their lifecycle?"*

Based on both literature and empirical findings, this research identified a range of interrelated barriers and enablers that influence the reuse of structural components. The literature review categorized these into six main domains: technical, economic, environmental, organizational, regulatory, and social. While all six categories play a role, the literature proved that organizational, social, and economic barriers should be prioritized, as they are often the most pressing and responsive to collaborative strategies (Kirchherr et al., 2018; Hart et al., 2019).
Key organizational barriers identified include complexity in terms of accountability and risks, a lack of information tools and CE metrics, and challenges in planning, logistics, and storage. Key social barriers involve a conservative sector culture, lack of awareness, and a lack of engagement and trust across the construction value chain. Key economic barriers relate to the higher upfront costs of reuse, such as testing, documentation, and storage, as well as a weak business case compared to new construction due to low material prices and insufficient financial incentives. Although technical and regulatory barriers, such as issues with certification and rigid procurement processes, were also present, these were considered less important to focus on.

The interview data supported these findings. Across all stakeholder groups, organizational barriers were most frequently mentioned, particularly the lack of reliable information as well as information asymmetry, unclear responsibilities, and mismatched supply-demand timelines. Interviewees emphasized the complexity introduced by tight schedules, the absence of reuse infrastructure, and late involvement of key actors. Social barriers such as sectoral hesitation, trust issues, and risk aversion were frequently cited, especially by architects and contractors. Meanwhile, economic barriers such as additional labour and coordination costs were seen as key constraints by contractors and advisors.

Several enablers were consistently highlighted. These include early involvement of key actors, availability of reuse documentation, supportive clients, and shared reuse ambitions across the team. Digital tools such as BIM, clear contracts, and demonstrated project successes were seen as enablers of both trust and feasibility. Notably, actors agreed that collaboration, particularly early and integrated collaboration, was essential in overcoming organizational and social barriers.
It can be concluded that while the reuse of structural components is constrained by various technical and regulatory conditions, this research confirms that the most decisive barriers are organizational, social, and economic in nature. These are also the domains where collaboration between key actors in the construction value chain can make the most significant impact.

Q3. *"What roles, knowledge and processes are essential for key actors to successfully collaborate and enable the reuse of structural components?"*

This research shows that the successful collaboration of key actors in reuse-oriented construction projects depends mainly on clearly defined roles, shared knowledge, and structured processes. The literature emphasizes collaboration is a key enabler for overcoming social, organizational, and economic barriers to reuse, particularly in complex and multi-actor settings. Frameworks by Matrai (2019), Chan et al. (2004), and others identify factors for successful collaboration such as a shared vision, mutual trust, transparent communication, and joint decision-making. These are supported by resources such as financial capacity, available time, and collaborative tools such as BIM.

The interviews confirmed these insights and provided further detail across key collaboration domains. First, in terms of roles and responsibilities, early role definition and clear allocation of responsibilities were seen as critical to prevent uncertainty and foster alignment. New or shifting roles such as reuse coordinators, integrated BIM coordinators, and other intermediaries were seen as essential in managing information flows, bridging supply and demand, and coordinating reuse logistics. Looking at the tools and resources used, digital instruments such as BIM and material passports can play an important role in organizing reuse data, coordinating actors, and enabling traceability. However, their impact depended heavily on early implementation and shared protocols to prevent data fragmentation. In addition, continuous communication, shared feedback sessions, and evaluation moments were repeatedly highlighted as necessary to deal with uncertainties around timing, guarantees, and material availability. Interviewees also emphasized the importance of a proactive attitude and flexible mindset to deal with uncertainties and prevent mismatched expectations.

Interviews further demonstrated that decision-making must be adaptive and continuous, often revisiting earlier choices based on new material inputs or logistical shifts. This requires a cultural shift in the sector and a different mindset from the actors. Finally, enabling economic structures, such as residual value recognition, reuse-based procurement, and circular business models, can further support reuse. The presence of a single actor managing the whole process, such as a deconstruction company that takes ownership from dismantling to remounting, was seen as highly

effective for reducing friction and ensuring planning reliability.
It can be concluded that successful collaboration in reuse projects depends not only on good project coordination and the use of digital tools, but also on a proactive attitude from actors and a culture shift in the sector, as well as clear communication protocols, shared decision-making, and enabling economic structures. These elements are key to making structural component reuse work in practice and applying it more often in future projects.

Q4. *"What strategy guide can be developed for key actors to successfully collaborate and address key barriers to enable the reuse of structural components from buildings reaching the end of their lifecycle"*

This research resulted in a strategy that outlines twelve practical strategies to succesfully collaborate and enable the reuse of structural components in construction projects. The guide directly responds to three key challenges identified through both theoretical insights and empirical findings: (1) mismatch of information, (2) unclear roles and responsibilities, and (3) mismatch between material supply and project planning. Drawing from workshop insights and enablers mentioned in both literature and interviews, the strategy guide focuses on structured coordination in the initiation phase.

For Challenge 1, the strategies aim to align information flows through shared BIM protocols, early reuse-driven kick-offs, standardized inventory protocols, and embedding reuse ambitions into contracts and selection criteria. For Challenge 2, the strategy guide proposes governance strategies that are reuse-specific, formal appointment of reuse coordinators, and early involvement of key actors such as logistical partners. It promotes a cultural shift through feedback loops and client-led ambition, fostering trust and shared risks. For Challenge 3, the strategy guide proposes aligning reuse supply with project timelines via a national demolition database, assigning single-party ownership across the reuse chain, budgeting for storage and delays, and predefining storage and testing protocols. Together, the strategies provide a foundational guide that supports improved early-phase collaboration between key actors, thereby enabling the reuse of structural components in circular construction projects.

Main research question: *"How can collaboration between key actors in the construction value chain address key reuse barriers to enable the reuse of structural building components from existing buildings reaching the end of their lifecycle?"*

This research aimed to understand how collaboration between key actors can enable the reuse of structural componentsfrom existing building reaching the end of their lifecycle, particularly by addressing the organizational, social, and economic barriers that often stand in the way of circular practices. Through a combination of literature analysis, three empirical case studies, nine semi-structured interviews, and a workshop, the study uncovered three key process-level challenges: mismatches in information, unclear responsibilities, and a mismatch between material supply and project planning.

These findings were synthesized into a strategy guide that provides twelve actionable, actor-specific strategies aimed at supporting collaboration in the initiation phase of reuse-oriented construction projects, ultimately enabling the reuse of structural components. The strategies, ranging from shared BIM coordination and reuse-focused kick-off sessions to assigning single-party ownership of reuse logistics and the development of a national demolition database, represent a practical foundation for addressing known reuse barriers. While the strategy guide is not a one-size-fits-all solution, it offers a replicable structure that public clients, developers, and design teams can apply and adapt to strengthen early-phase collaboration and make reuse a more practical and achievable practice in the construction sector.

By combining insights from theory with real-world project experiences, this research fills a gap in the circular construction discourse: providing concrete guidance on how actors can enable reuse practices through collaboration. Further validation is encouraged, but the groundwork has been laid for translating circular principles into practical project action.

8.2 Recommendations for practice

Based on the findings, the following practical steps are recommended to enable structural reuse in construction projects through collaboration:

- Involve key actors early:
Formally include demolition, logistics, and reuse coordinators at the initiation phase to ensure feasibility and reduce late-stage changes.
- Appoint a reuse coordinator:
A dedicated reuse coordinator ensures continuity, tracks reuse ambitions, and manages supply-demand alignment throughout the process.
- Integrate reuse into contracts and selection:
Translate reuse goals into contractual requirements and use selection criteria that prioritize experience with reuse and circular design.
- Establish shared BIM protocols:
Develop a joint BIM protocol and shared model environment to prevent data fragmentation and support coordination across actors.
- Enable donor-informed design:
Develop national or regional demolition databases to design with available components, aligning supply with design timelines.
- Plan for reuse-specific logistics:
Reserve time and budget for testing, storage, and transport early in the project, and use long-term value models to support investment in reuse.

8.3 Recommendations for future research

Based on the limitations, findings, and exploratory nature of this research, several directions for future studies are proposed:

- Further development and validation of the strategy guide:
The proposed strategies offer a starting point but require testing across a broader range of project types, actor types, and contract models. Future research should investigate how these strategies can be operationalized in different contexts and further developed into actionable tools.
- Focus on national reuse databases and enabling business models:
Challenge 3 highlighted the need for systemic reuse planning. Further research is recommended into the technical design, governance, and business models behind national demolition databases or donor material platforms. This includes exploring ownership structures, data-sharing incentives, and policy and procurement systems.
- Linking reuse to quantifiable impact:
Research is needed into how reuse strategies can be connected to measurable performance outcomes, such as CO_2 reduction, cost savings over time, or material productivity. This can help clients and policymakers make evidence-based decisions in favour of reuse.

- Client-driven perspectives and long-term adoption:

As the client plays a key role in setting and maintaining reuse ambitions, more research should focus on how public and private clients can embed reuse in a structural way, both in project delivery and portfolio strategies. This could include comparative studies between client types and their organizational readiness for circular procurement.

- Legal frameworks and risk governance:

To address perceived uncertainties and hesitations around liability, research should explore how legal tools can support confidence in reused components and enable collaboration under more flexible contractual conditions.

Reflection 9

This graduation project, developed within the MBE track of the MSc AUBS programme, investigates how collaboration between key actors in the construction value chain can enable the reuse of structural components. The topic aligns closely with the MBE focus on process management, stakeholder alignment, and sustainable development, while also contributing to the broader ambition of circular construction practices. It aligns with the MBE focus by not only addressing technical barriers but also proposing process-oriented strategies that strengthen cross-actor collaboration and sustainable development, which is a key focus in both the MBE track and the MSc AUBS program.

Initially, the research aimed to explore both the barriers to reuse and the strategies to overcome them. However, the balance between these two goals was not optimal. A large part of the research focused on identifying and understanding barriers, particularly organizational, which provided a strong foundation but left limited time to fully develop or validate practical strategies. As a result, while the strategy guide offers relevant insights, it could have been more detailed in terms of implementation, especially regarding tools, timing, and actor responsibilities across project phases.

The research findings on actor roles, supply-planning mismatches, and information asymmetries directly informed the formulation of the strategies in the strategy guide. On the other hand, translating these findings into practical strategies revealed the importance of prioritizing early-phase collaboration and clarified which types of knowledge are most critical in practice.

Throughout the process, I found it challenging to structure the research output and define what the final deliverable would look like. This often led to uncertainty and inefficiency in planning. However, the feedback sessions with my mentors were crucial in providing more direction and clarity, and helping me maintain progress. Their guidance helped me refine my problem statement and focus on actor collaboration, and better connect theoretical input with empirical findings. This iterative process also taught me how to deal with ambiguity during research.

The methodology, a combination of literature review, case studies, semi-structured interviews, and a workshop, worked well in capturing diverse perspectives and practical constraints. The combination was chosen to bridge theoretical knowledge with practice-based insights. For example, practice-based insights were used to validate theoretical findings. While the sample size was limited, the qualitative data provided valuable input for the development of strategies. However, earlier clarity on the framework's scope and intended output could have helped in creating more actionable and detailed strategies from the start. In addition, conducting follow-up interviews or validating findings with actors after the workshop could have added more depth to the research, but this was not pursued due to time constraints.

Academically, the research contributes to the discussion on collaborative governance in circular construction, particularly regarding structural reuse. It addresses the gap in the literature concerning how reuse can be enabled through collaboration. The findings offer practical insights and directions for professionals in this field of research. Societally, the topic is highly relevant as reuse remains underutilized despite its environmental benefits. However, the translation of insights into practice still requires further development, particularly concerning system-level tools like national demolition databases or performance-based reuse contracts. Dedicating more time to concrete tool development or practical strategies could have enhanced the societal value and transferability of the results.

The research is grounded in the Dutch context, particularly in projects involving actors with more experience in reuse. However, the strategies developed are also relevant to reuse projects in other contexts. It should be noted that transferability may be limited in regions with less formalized collaboration structures or where reuse practices are not yet institutionalized.

* It is important to note that to improve clarity and ensure fluency, selected sentences in this research were rephrased using AI (ChatGPT), based on my own content and intentions. All analytical interpretations and academic arguments remain my own.

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Appendices 11

Appendix 1. Case studies

This Appendix presents the three case studies used in this research. A document analysis in combination with interviews were conducted to gain insight into each project's structure, timeline, reuse scope, and key characteristics. The analysis also helped clarify who was involved, what roles actors played, and how collaboration around reuse was organized.

1.1 The Tijdelijke Rechtbank Amsterdam

The Tijdelijke Rechtbank Amsterdam was conceived as a temporary courthouse located on in Amsterdam. Developed by the Rijksvastgoedbedrijf, it served as an temporary solution during the construction of a new permanent court building. What distinguishes this project is its circular design approach: the building was specifically designed for disassembly, reuse, and reassembly in a different context. This made it one of the Netherlands' pioneering examples of large-scale demountable construction.

Timeline and Project Development

The Tijdelijke Rechtbank Amsterdam (TRBA) was built as a response to the temporary housing needs of the Dutch judiciary during the development of a new courthouse in amsterdam. The project was initiated through a Design, Build, Maintain and Remove (DBMR) tender by the Rijksvastgoedbedrijf in early 2014. A consortium formed by CepezedProjects and duPrie bouw & ontwikkeling (DPCP), with partnering companies IMd raadgevende ingenieurs and Cepezed, won the tender with a design that emphasized reusability and circular construction principles. In early 2015, the consortium officially received the commission. The subsequent period encompassed design, engineering, permitting, and construction, all conducted under a tightly managed timeline. The building was delivered to the judiciary in 2016 and served its initial function as a courthouse until mid-2021. Notably, the TRBA remained in use longer than initially planned due to delays in the development of the permanent courthouse (Cepezedprojects, 2025).

In line with its DBMR contract and circular design ambitions, the building was not demolished but disassembled after use. In 2021, the structure was carefully dismantled, stored, and transported to its new location in Enschede. There, it is being reassembled under the name TechBank to serve as a knowledge-intensive office and educational building at Kennispark Twente. The building's new function is significantly different from its original purpose, showcasing the versatility of its design. This planned second life was embedded in the project's DNA from the outset. The design accounted for future disassembly, including reversible connections, modular structural components, and separable building layers. The success of the TRBA project illustrates the potential of circular construction not only as a theoretical ambition but as a viable, scalable and repeatable building practice (Cepezedprojects, 2025).

Project Characteristics and Structure

The building comprises a steel skeleton frame with demountable concrete floors and modular façades. Structural principles and joints were designed to allow the building to be disassembled with minimal material damage. The design team, led by cepezed, collaborated with IMd raadgevende ingenieurs (structural engineer), ingenieursburo linssen (installation advisor), Cepezedinterieur (interior) and lbp sight(acoustic, safety). The construction and maintance team, led by duprie bouw &ontwikkeling, collaborated with schoonderbeek installatietechniek (e-installation) and putman installaties (w-installaties). The consortium of DPCP carried final responsibility.

One of the key innovations in this project was the extensive use of dry connections, including bolted joints, for both structural and façade components. Floors were laid using prefab concrete slabs, connected without poured-in-place concrete, allowing for reversibility. The façade was constructed with prefabricated timber-frame elements with aluminium cladding and glazing, all designed for intact disassembly (Cepezedprojects, 2025).

Material Reuse

According to the disassembly evaluation and project documentation, over 90% of the primary structural components of the Temporary Courthouse were successfully dismantled and prepared for reuse. This included the complete steel frame, hollow-core concrete floor slabs, interior partition walls, curtain wall elements, and aluminium-framed windows. The dismantling process was supported by the use of dry, reversible connections, which enabled components to be removed without damage.

Smaller elements such as raised floor systems, ceilings, and interior finishes, were dismantled based on their physical condition and future applicability. Components were taken down in reverse order of their original installation, following a reverse-engineering logic. This process was facilitated by the structured documentation and the Building Information Model (BIM), which captured both the assembly sequences and the design intentions, supporting the planning and coordination of the deconstruction and reassembly phases (Cepezedprojects, 2025).

Roles and Responsibilities

The Rijksvastgoedbedrijf took the role of commissioning body, while the consortium DPCP was the contracted party, ultimately responsible for the project. Parts of the responsibility were divided in the design team, led by cepezed, and the construction team, led by Duprie bouw & ontwikkeling. Demolition and reassembly were later managed by Lagemaat, a specialist in circular demolition, and Groothuis, who is responsible for the reconstruction of the building.

Tools and Resources

Building Information Modelling (BIM) played an important role in the design and planning phase of the project. It enabled the design team to precisely coordinate the structure's demountability by digitally modelling joints, sequences, and logistics. Although no formal material passports were used, the BIM model essentially the showed all the material properties, functioning as a material passport, the model captured the specifications, assembly logic, and intended disassembly strategy of the components.

Communication and Information

Communication within the TRBA project was characterized by a structured meeting schedule and an open exchange of information between consortium members. Monthly steering and project group meetings were held, with the DPCP project leader acting as the single point of contact. Information Modelling (BIM) played a crucial role in aligning design and construction information, especially concerning disassembly. Throughout the project, from design to dismantling, the BIM model functioned as the building's digital memory, capturing assembly logic and material specifications. In addition, construction photos, scans, and video recordings helped create a well-documented archive that proved valuable both internally and externally. This digital documentation enabled efficient planning of the disassembly and now supports preparations for reconstruction in Enschede.

Decision-Making

Several key decisions regarding demountability and component selection were made at the beginning of the project. The design team collectively opted for exclusively demountable building systems, even when alternatives would have been cheaper or easier to implement. For example, poured-in-place concrete floor connections were rejected in favour of dry joint hollow-core slabs. These early design choices required trust and alignment between client and design-build partners and were guided by the long-term vision of reusing the building in a different context. The choice to document every step of the design and construction process was also a strategic decision to support future disassembly and reuse.

Economic and Market Structures

The project was procured through a Design-Build-Maintain (DBM) contract, which incentivised long-term thinking, quality in execution, and cost efficiency over the full lifecycle. An important economic consideration was the residual value (restwaarde) of the building. Unlike traditional projects where the building depreciates to zero, the Tijdelijke Rechtbank was designed as a value-retaining asset. The ability to reuse the structure in a second location (Enschede) was part of the initial business case. By including the estimated future value of the dismantled components in financial planning, the project team was able to justify higher initial investments in demountable construction. In the long term, this approach was considered more cost-effective than demolishing and building new (Cepezedprojects, 2025).

1.2 Circulair Centrum Nederland

The Circulair Centrum nederland was an project initiated by the company Lagemaat. Located in Heerde, the project embodies a shift from traditional demolition and construction towards a model of reuse, remountability, and inclusivity. The structure is primarily composed of components harvested from the former provincial office “Prinsenhof A” in Arnhem. The project is a Dutch pilot within the EU-funded ReCreate program, which aims to standardize and scale reuse practices for precast concrete components across Europe. This pilot project serves not only as a knowledge and innovation hub but also as a demonstration of how building components can be given a second life in a structurally sound and economically viable way.

Timeline and Project Development

The deconstruction of the Prinsenhof building (approx. 7,400 m²) was completed in 2022 by Lagemaat. This large office building, originally not designed for disassembly, delivered over 8000 m² of reusable precast components including hollow-core slabs and façade panels. These were transported to Heerde for reuse in a new development of the Circulair Centrum Nederland.
The project entered the design phase in parallel with deconstruction. The architectural and structural teams, including Cepezed and IMd Raadgevende Ingenieurs, adopted a reverse design approach, starting not with a blank canvas but with the inventory of available components. This dynamic and iterative process relied on digital modelling and close interdisciplinary collaboration. As of early 2025, the project is nearing the Definitive Design (DO) phase. A mock-up will precede full-scale construction to test fit and tolerances of the reclaimed components. Construction of the Circulair Centrum Nederland is scheduled to start later in 2025 (Cepezedprojects, 2025).

Project Characteristics and Structure

The building’s structure is designed entirely around reclaimed components, particularly from Prinsenhof A. The reused materials include hollow-core floor slabs with in-situ structural topping and large concrete façade panels. Due to the original wet connections between the components, all joints had to be sawn during deconstruction. Lagemaat coordinated the dismantling and storage of these components, using a labeling and tracking system to maintain full material traceability throughout the process (Cepezedprojects, 2025).

Material Reuse

The project has a reuse rate of 92% for the original Prinsenhof building materials, making it one of the most comprehensive examples of reuse-driven construction in the Netherlands. Precast concrete floor and façade components were assessed, tested, and approved for reuse. Compression tests revealed that the hollow-core slabs from Prinsenhof were still more than twice as strong as originally required by code. These outcomes not only proved the structural reliability of reused components but also highlighted the carbon savings compared to producing new materials (Cepezedprojects, 2025).

Roles and Responsibilities

Lagemaat acts as client, deconstruction company, and logistics coordinator. The architectural design was led by Cepezed, with IMd Raadgevende Ingenieurs (structural engineer), Galjema Technisch Adviesbureau (installations), and LBP|SIGHT (building physics) as key engineering partners. From the outset, the team collaborated on a dynamic and iterative design process, where the final building concept evolved in parallel with material harvesting. This reverse workflow, designing based on available “building blocks”, required high levels of flexibility, technical creativity, and open communication across the consortium.

Tools and Resources

Lagemaat relied heavily on digital tools, including BIM modelling and 3D scans, to assess the as-built conditions of donor buildings and track materials. Each harvested element was classified according to the R-ladder (Figure 1) to map circular potential and CO_2 savings. A labelling and storage system ensured traceability throughout the process, enabling components to be delivered in the correct sequence and condition for remounting.

Communication and Information

The project was characterized by early and close cooperation between client, architect, and structural engineer. The design began before all donor components were harvested, requiring constant coordination and iterative updates. Questions such as "What kind of blocks are these? What can we do with them?" guided ongoing material investigations and testing. External partners like TNO and TU Eindhoven supported material assessments, including structural loading tests. Transparent documentation, shared understanding, and flexible workflows are essential in this type of project.

Decision-Making

One of the project's key decisions was to build entirely with reused components, even when this meant greater uncertainty or complexity. Design adaptations were made around the geometry and properties of the harvested components, rather than reshaping or overengineering them. This required trust between stakeholders and a shared commitment to circularity. Decisions about documentation, testing, and traceability were made early to ensure feasibility and replicability of the process.

Economic and Market Structures

The Circulair Centrum Nederland is grounded in a long-term business model that sees buildings not as disposable assets, but as future material banks. By reusing high-value components and reducing material input, the project aligns economic goals with sustainability. Although higher upfront investments were needed for testing and logistics, the reuse of major structural components drastically reduced material costs and embodied CO_2. The resulting structure is a scalable and competitive model, demonstrating how circular construction can be both financially and environmentally sound (Cepezedprojects, 2025).

4.3 Cultureel Centrum Lievekamp

The Zuiderstrandtheater was originally conceived as a temporary venue in Scheveningen to house the Nederlands Dans Theater and Residentie Orkest during the construction of the Amare cultural complex in The Hague. After its closure in 2021, the building entered a new phase: it is currently being deconstructed, stored and remounted in Oss, as part of a major redevelopment of Cultureel Centrum Lievekamp.

Timeline and Project Development

The Zuiderstrandtheater was completed in 2014 and functioned until 2021. In 2022, the building was sold by the Municipality of The Hague to the Municipality of Oss for €1.1 million. Starting in early 2023, it was dismantled by LCP, a joint-venture between Cepezedprojects and circular demolition specialist Lagemaat. The new cultural complex in Oss, designed by Cepezed in collaboration with PBTA (Theatre consultancy), Aronsohn (structural engineer) and Nelissen (installations), integrates the reused building into a completely reimagined cultural venue. Construction is expected to begin in 2026, with completion scheduled for 2029 (Cepezedprojects, 2025).

Project Characteristics and Structure

The original building consisted of a steel skeleton with hollow-core concrete floors and heavy concrete façade panels designed for high acoustic performance. About 80% of the original building, including all structural components, is being reused in Oss. The reconstruction includes a large theater hall (former zuiderstrandtheater) with 900 seats, a smaller 350-seat hall (former main hall of De Lievekamp), and a new 100-seat "vestzakzaal" for intimate performances. The entire structure is being reassembled on a new foundation system and partially integrated with components of the original De Lievekamp building (Cepezedprojects, 2025).

Material Reuse

The Zuiderstrandtheater was carefully dismantled in Scheveningen and transported to a storage near Oss. To get an idea of the operation, around 85 truckloads of floor components and 47 truckloads of wall panels were transported from Scheveningen to Oss. These components are reused one-to-one where possible. Adjustments are made only when necessary for programmatic changes, acoustic requirements, or structural safety. For example, floor heights were adjusted in response to new insulation and performance needs. In some cases, existing components required stripping or cutting to remove additional layers, such as bonded top coatings on the hollow-core slabs. Each element is re-evaluated for its load-bearing capacity and integration in the new structural system.

Roles and Responsibilities

The Municipality of Oss is the client, with LCP Circulair responsible for deconstruction, transport, and remounting. Cepezed leads the design in collaboration with Aronsohn (structure), PBTA (theatre consultancy), and Nelissen (installations). Collaboration began in the early VO phase and was driven by a shared ambition for circularity. Cepezed ensured circular ambitions were embedded in the design, while Lagemaat coordinated the logistics of dismantling and remounting. The reuse strategy centered on the available "Lego pieces" from the original theater, which dictated both structural and spatial solutions.

Tools and Resources

A 3D model of the steel structure, created by the original steel fabricator, was reused and integrated into the BIM model to plan remounting. This model was critical in assessing the compatibility between available components and the new design. While no formal material passports were used, detailed visual and technical inspection, labelling, and field testing provided the necessary information for remounting. The reuse strategy was constrained to components from the Zuiderstrandtheater to limit complexity.

Communication and Information
In the Cultureel Centrum Lievekamp project, early collaboration between the developer and the deconstruction company enabled coordination around available components and reuse ambitions. While the use of shared BIM environments was not emphasized, feedback loops and early integration of key partners supported decision-making and reduced some of the uncertainties around reused material logistics.

Decision-Making
The decision to reuse the Zuiderstrandtheater was made at the highest level as a core principle of the project. Cepezed and LCP committed early to working within the constraints of the available structure, adjusting only where technically or functionally necessary. Decisions regarding additional elements, such as new balconies or soundproofing, were made in collaboration with structural engineers to avoid overloading the reused frame. The reuse of building components was not only a design choice but also embedded in the broader political, cultural, and financial vision of the project.

Economic and Market Structures
Although the reuse strategy helped avoid rising material costs and reduced embodied carbon, the overall project cost remains high (ca. €75 million). Reuse did not reduce costs per se but added value by shortening lead times and showcasing circular innovation. The reused materials were treated as assets, not waste, and cost modelling took into account the labour-intensive nature of adaptation and verification (Cepezedprojects, 2025).

Appendix 2. Literature barriers and enablers overview

Barriers		Enablers		Literatuur: Hart el al (2019)	Hradil (2014)	Knoth et al (2022)	Rhakshan et al. (2020)	Gorgolewski (2008)	Lacovidou, purnell (2016)	Condotta en zatta (2021)	Kupfer et al(2023)	Kircherr et al. (2018)	Kanters (2020)
Hard Factors													
Technical / manufacturing / designing		**Technical / manufacturing / designing**											
A1	Downcycling / quick site clearance	A2	Digitalisation and standardisation	X		X					X		
A2	Lacking standardization / lack of information	A6	Responsability for documentation: certification agencies	X	X	X	X	X	X		X	X	
A3	Insufficient use and development of design tools	A7	Being flexible and willing to adapt	X				X	X		X		
A4	Technical challenges regarding material recovery (independence and exchangebility)	A4	Using similar layout / original functions	X	X			X - X	X				
A5	Lack of storage facilities	A2	Labelling components			X			X				
A6	Lack of testing framework/ certifcation process	A2	Accesible information for all actors			X	X		X	X	X		
A7	Difficulty of design with reused components (flexibility etc.)	A2, A6	Quality assesment tools								X - X	X	
A8	Too few large scale demonstration projects											X	
Regulatory / legislation/ policy		**Regulatory / legislation/ policy**											
B1	Lack of a consistent regulatory framework	B1	Policy support & public procurement	X - X			X						
B2	Obstructing laws and regulations	B2	Regulatory reform	X - X		X	X				X	X	
B3	Lack of incentives for CE.	B3	Fiscal support (incentive)	X - X		X	X					X	X
B4	Lack of regulations	B3	Producer responsibility (incentive contractor)	X	X	X	X						X
B5	Rigid contract / procurement process	B5	Reuse focused collaborative procurement process			X - X	X						
							X						
Economic and market		**Economic**											
C1	Short-term blinkers' , rapid ROI. Transactional relation > long term collaboration	C1, E3	Whole life costing	X - X			X						
C2	Short term costs: High upfront investment	C4, C2	Take the easy wins	X - X	X				X			X	
C3	Low virgin material prices and lower EOL values	C5	Circular business models	X - X		X			X			X	
C4	Poor business case and unconvincing case studies	C4	Scale of projects	X - X									
C5	Limited funding	C7	New markets	X			X					X	
C6	Long term costs: social, economic, environmental costs	C6	Long-term economic benefits		X	X			X	X			
C7	Small market for second hand elements/ lack of market		Job creation		X	X	X		X	X			
C8	Short-term costs: Coordinating costs, extra labour costs, testing, storage costs				X		X		X	X	X		X
C9	Diversion to other waste streams is cheaper				X								
C10	Insurance				X								
Environmental		**Environmental**											
D1	Life-cycle performance is not studied		Conservation of embodied energy and GHG		X		X		X	X			
D2	Transport may have considerable impact		Preservation of raw materials		X		X			X			
D3	Environmental contamination or degradation		Compliance with Paris accord and national goals		X								
Soft factors													
Organizational / sectoral / business models		**Organizational / sectoral / business models**											
E1	Lack of bandwidth compounded by an absence of coherent vision for the industry.	E1	Clearer vision for CE in the built environment	X - X		X							
E2	Complexity (lack of accountability, risks, ownership, control), confused incentives	B1, C5	Better evidence base / pilot projects	X - X		X	X - X	X			X		
E3	Long product lifecycles (complexity)	A3, F3	Collaboration and design tools and strategies	X - X		X							
E4	Lack of information tools and CE metrics	F1, A4	R&D, innovation	X - X		X					X		
E5	Timeline : matching supply and demand, timing storage	A2	Develop standards and assurance schemes	X		X	X - X	X			X		X
E6	Lack of early planning	C2, A4, D2, E9	Develop reverse logistics infrastructure	X		X	X						
E7	Lack of skills and experience	B5	Better contracts				X - X						
E8	Lack of systems thinking	E2	Management				X						
E9	Lack of reverse logistics infrastructure								X				
E10	extra time and effort needed for deconstruction and tight project schedule						X		X	X			
E11	Lack of collaboration tools			X									
E12	Limited circular procurement											X	
Social / cultural / sectoral		**Social / cultural / sectoral**											
F1	Lack of interest, knowledge/skills and engagement throughout the value chain	E1, F6	Leadership	X - X	X	X							
F2	Delivering CE projects in a linear economy / 'going at it alone'	E1	Sustainability/environmental drivers	X - X		X						X	
F3	Lack of (horizon. and vert.) collaboration between businesses (competitiveness)	C4	Stimulate demand	X - X		X						X	
F4	Lack of collaboration between business functions	C1	Value chain engagement	X - X									
F5	Hesitant company culture	C1	Longer term relationships and partnerships	X								X	
F6	Sector itself is conservative, uncollaborative, adversarial	E2, B6	Systems thinking	X - X									X
F7	Awareness and understanding (and interest)	F3, F4	Cooperation and communication		X	X - X	X					X	
F8	Perception		Including reuse experts in value chain/ new roles		X	X	X			X			
F9	Health and safety	F1,6,7	Role of the client is crucial		X		X	X					X
F10	Lack of trust/ competitiveness						X						
F11	Tight connection to other linear sectors												X

Interesting for research
semi-interesting for research
Not interesting for research

Appendix 3. Theoretical framework 1.0

Appendix 4. Interview questions

Introductie
1. Kun je je rol beschrijven binnen het project en je ervaring met projecten binnen het thema hergebruik? Vanaf welke fase ben je betrokken geweest bij het project? Waar ben je nu mee bezig binnen het project?
2. Wat waren voor jullie organisatie de belangrijkste drijfveren om deel te nemen aan dit project en het hergebruik van structurele componenten te integreren?

Barriers
3. Wat waren volgens jou de belangrijkste barrieres of knelpunten bij het realiseren van hergebruik van structurele componenten in dit project?
4. Gevonden barrieres literatuur presenteren:
-Organizational: 4 key barriers
- Social: 4 key barriers
- Economic: 4 Key Barreiers

Collaboration
7. Kun je iets vertellen over de samenwerking met andere partijen?
- Met welke partijen werkten jullie nauw samen binnen het project?
- Hoe verliep deze samenwerking en hoe verschilde deze t.o.v. van een standaard project?
- Hoe heeft de samenwerking met andere partijen bijgedragen aan het aanpakken van barrieres rondom en het realiseren van hergebuik?
- Waren er conflicten tussen bepaalde partijen?

Roles and Responsibilities
8. Hoe werden rollen en verantwoordelijkheden rondom hergebruik verdeeld in dit project? Waren deze rollen vanaf het begin duidelijk en formeel vastgelegd?
9. Zijn er nieuwe rollen of taken ontstaan gecreëerd binnen dit project om hergebruik beter te faciliteren, zoals een materiaalverkenner of circulair coördinator? Welke invloed hadden deze rollen?

Tools and Resources
10. Hoe werden digitale hulpmiddelen zoals BIM, materiaalpaspoorten of databases gebruikt om hergebruik in dit project te faciliteren? Hoe effectief waren deze voor het delen van informatie en samenwerking tussen partijen?
11. Hoe werd er in het project omgegaan met de opslag, transport en kwaliteitscontrole van herbruikbare materialen? Waren er fysieke systemen of processen die hierbij hielpen?
Was er een centrale partij die dit coördineerde?

Communication and Information
12. Hoe werd informatie over beschikbare herbruikbare materialen gedeeld tussen de verschillende betrokken partijen? Was er sprake van ontbrekende kennis of informatie die het faciliteren van het hergebruik bemoeilijkte?
13. Hoe werd de samenwerking en kennisdeling tussen actoren bevorderd? Zijn er binnen dit project specifieke afspraken of structuren opgezet voor overleg, zoals gecoördineerde meetings of feedbackloops?

Decision-Making
14. Hoe werd binnen dit project gezamenlijk besloten over het toepassen van hergebruik? Welke

partijen waren hierbij betrokken en hoe verliep de samenwerking in dit proces? Hoe werd bepaald welke materialen hergebruikt konden worden en welke niet? Waren hier vaste criteria voor?
15.Hoe werden beslissingen afgestemd op andere projectfactoren zoals budget, planning en functionele eisen? Waren er momenten waarop hergebruik onder druk kwam te staan door andere projectprioriteiten?

Economic and Market Factors
16. Hoe hebben financiële overwegingen (zoals kosten, financiering of businessmodellen) invloed gehad op de beslissingen rondom hergebruik in dit project?
17. Hoe werd de beschikbaarheid en sourcing van herbruikbare materialen gecoördineerd? Speelde de markt voor tweedehands materialen een rol in de ontwerpfase of uitvoering?

Success Factors / Enablers
18. Wat waren volgens jou de belangrijkste enablers of succesfactoren die het realiseren van hergebruik van structurele componenten mogelijk maken in dit project?

Appendix 5. Interview codes

Deductive codes
- Social Barriers
Social barriers: Lack of knowledge, awereness and engagement troughout the construction value chain
Social barriers: Lack of collaboration between and within organizations
Social barriers: Lack of collaboration tools
Social barriers: Conservative sector culture and lack of trust/competitiveness
Social barriers: Delivering CE projects in a linear economy / 'going at it alone'

- Social Drivers
social drivers: Leadership and long term relationships
social drivers: Role of the client is crucial, as well as (new) experts
social drivers: Systems thinking and integral collaboration
social drivers: social and market driven motivation

- Organizational Barriers
Organizational Barriers: Lack of coherent vision, capacity and systems thinking
Organizational Barriers: Complexity (long product lifecycles and lack of accountability, risks, ownership, control)
Organizational Barriers: Lack of information, information tools and CE metrics
Organizational Barriers: Complexity of planning and timing within a project (storage, supply and demand, tight schedule)
Organizational Barriers: Lack of reverse logistics infrastructure

- Organizational Drivers
Organizational drivers: Strategic vision and standards for circular construction
Organizational drivers: Innovation, research and better evidence base
Organizational drivers: Collaboration and integrated strategies
Organizational drivers: Develop reverse logistics infrastructure

- Economic Barriers
Economic barriers: Short-term focus and lack of long-term vision
Economic barriers: Poor business case and limited incentives
Economic barriers: Low virgin material prices and lack of market for secondary components
Economic barriers: Extra costs: Coordinating, labour costs, testing costs, storage costs

- Economic Drivers
economic drivers: Whole life costing, including long term benefits
economic drivers: Circular business models
economic drivers: Scaling of projects
economic drivers: New markets

- Technical Barriers
Technical barriers: Technical barriers
- Technical Drivers
technical drivers: Technical drivers

- Regulatory Barriers

Regulatory barriers: regulatory barriers

- Roles and Responsibilities
Roles and responsibilities: Risk, ownership, accountability and responibility distribution
Roles and responsibilities: Roles / new roles

- Tools and Resources
Tools and resources: Using digital tools, databases, planning tools
Tools and resources: Using physical resources, reverse logistics infrastructure (opslag, transport etc.)
Tools and resources: Using testing and certification processes, LCAs and impact tools.

- Communication and Information
Communication and information: Information sharing between actors (communication channels, intermediaries)
Communication and information: Establishing communication protocols / procedures for information sharing
Communication and information: Monitoring processes/ performance tracking

- Decision-Making
Decision-making: Defining procedures decision-making
Decision-making: Aligning project schedules to coordinate demolition and construction timelines
Decision-making: Integrating reuse considerations into contracts, procurement and tender processes
Decision-making: Developing shared criteria for selecting reusable components.

- Economic & Market Structures
economic & market: Financial considerations: Cost-sharing/risks agreements, investments, developing business models within the project
economic & market: Coordinating supply-demand matching within and between projects

Inductive Codes
- Organizational drivers:
Organizational drivers: architect having important role
Organizational drivers: documentatie
Organizational drivers: Directie leveringen
Organizational drivers: experience
Organizational drivers: Market conformity
Organizational drivers: One operating actor
Organizational drivers: specificeren

- Technical barriers:
Technical barriers: building conformity / designing with donor
Technical barriers: Lack of standardization

- Regulatory barriers:
Regulatory barriers: Building special requirements

- Organizational barriers:
Organizational Barriers: Changes in uitvoering / Aanemer changes
Organizational Barriers: Different information level needs

Organizational Barriers: lack of early integration actors
Organizational Barriers: Long contracting process

- Social barriers:
Social barriers: convince user and client, supplier
Social barriers: Making decisions slowly
Social drivers:
social drivers: enthousiasm
social drivers: Open to challenges
social drivers: Showing practical impact
social drivers: Unpredictable events (covid etc.)

- Economic drivers:
economic drivers: economic incentives (subsidies, funds)
Economic barriers: Guarantees

- Cross-cutting:
dynamic process

Appendix 6. Empirical framework 2.0

Challenge 1: Mismatch of information

Challenge 2: Unclear roles, responsibilities and ownership

Challenge 3: Mismatch material supply and project planning

Appendix 7. Workshop structure

Introductie:
- Hoofdvraag onderzoek:
"How can collaboration between key actors in the construction value chain address key reuse barriers to enable the reuse of structural building components from existing buildings reaching the end of their lifecycle?"

Interviews:
Gekeken naar Barieres, drijfveren en samenwerkingsprocessen.
10 personen geinterviewd uit 5 groepen:
- Architect
- Demontage bedrijf
- Ontwikkelaar
- Adviseur (structureel engineer)
- Aannemer

Hieruit 3 veelvoorkomende challenges

Doel van de workshop:
Wat kunnen we in de initiatiefase van een circulair bouwproject organiseren of afspreken om deze 3 challenges te voorkomen in een latere fase, en daarmee samenwerking en het hergebruik van structurele componenten te verbeteren?
gericht op ontwikkelen van praktische strategieen

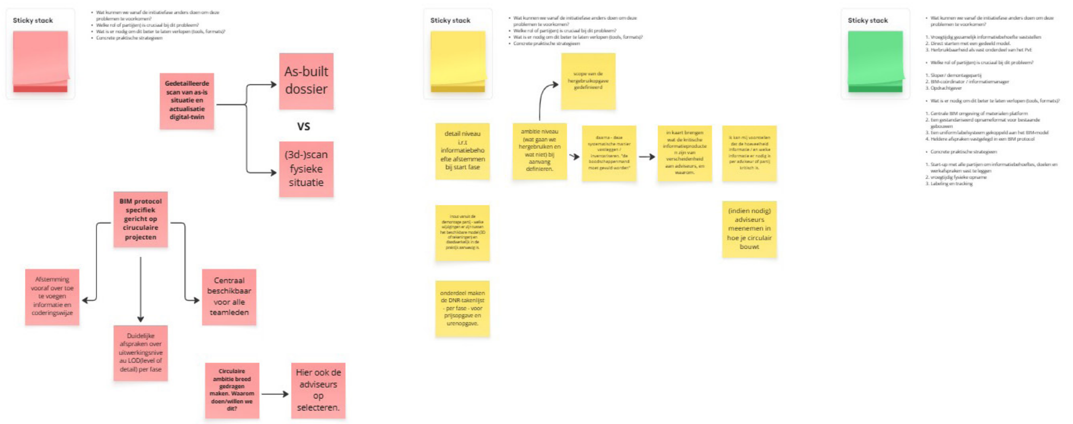
Context
Initiatiefase van een circulair project:
- Publieke opdrachtgever wil een nieuw gebouw realiseren
- Er is al een programma van eisen, en de ambitie om hergebruik toe te passen is uitgesproken.
- Er is nog géén volledige match met een donorgebouw, maar er zijn wel één of twee potentiële gebouwen in beeld.

Challenge 1:
Mismatch aan informatie
Kernprobleem: Informatie over herbruikbare elementen is versnipperd, onvolledig of ontoegankelijk voor ontwerp- en bouwpartners, wat leidt tot inefficiënties, misverstanden en gemiste reuse-kansen. Dit gaat zowel over informatieniveaus als informatiebehoefte.

Onderliggende problemen:
- Mismatch tussen beschikbare informatie en daadwerkelijke situatie:
"Het is natuurlijk de vraag: is hetgeen wat getekend is, ook daadwerkelijk hetgeen wat je in handen hebt? Dus daarmee zit een soort van verschil in aanname."
- Verschillende informatiebehoefte en niet afgestemde detailniveaus:
"Wij willen bij de start van het project (al in de SO-fase) exact weten wat de afmetingen van bijvoorbeeld kanaalplaten zijn. Terwijl een architect dan nog veel globaler denkt: in volumes en structuren. Daardoor kunnen wij die materiaalmatching nog niet goed doen." (Deconstructeur)
''LCP had een andere informatievraag dan de constructeur. Lagemaat wilde echt per element weten, zit deze er nog wel? Moet ik flenzen aanlassen? Terwijl die constructeur die was echt nog alleen maar bezig op veldniveau, om constructieve veiligheid te garanderen." (architect)
- Werken vanuit verschillende modellen (BIM), geen centraal gedeeld model of BIM-protocol:
''Binnen het Circulair Centrum en bij oss was het vaak nog even zoeken. Waar moeten we nu op

letten als wij dingen erin zetten? Tot hoe ver kunnen we dan gaan, wanneer moeten we nog wel trekken Als we teveel gaan muteren in een ontwerpproces?”
“Je wil uiteindelijk wel weten: deze ligger of kolom komt uit die plek. Dat vraagt dus om een labelsysteem dat idealiter gekoppeld is aan het BIM-model.”

post its:



Challenge 2:
Afstemmen van rollen, verantwoordelijkheden en eigenaarschap
Kernprobleem: Gebrek aan duidelijke afspraken over wie wat doet, leidt tot vertragingen, risicoaversie en onduidelijkheid bij cruciale projectmomenten. Verantwoordelijkheden voor cruciale processen zoals risico, data of materiaalkwaliteit zijn onduidelijk.

Onderliggende problemen:
- Onduidelijkheid over wie risico’s en garanties draagt, zoals voor kwaliteit of constructieve prestaties:
“Hoe kun je omgaan met garanties, of hoe verzeker je opgeslagen materialen? Aanbesteding en contractvorming zijn niet ingericht op wat wij doen – en vaak kent men het ook gewoon niet.”
“Je gebruikt hergebruikte materialen, dus hoe zit het met garanties? En die vraag blijft eigenlijk steeds terugkomen.”
- Slechte overdracht tussen projectfases zoals van ontwerp naar uitvoering
“uitvoerende partijen doen tijdens het uitvoeren vaak nog wel eens aanpassingen. Dat zijn misschien ook dingen die voor barrières zorgen. Dat er dingen veranderd zijn die eigenlijk niet goed gedocumenteerd staan.”
- Rol van de aannemer en opdrachtgever:
“Dat idee verdween al snel van tafel omdat de aannemer zei: ik heb deze componenten niet op tijd beschikbaar, dus wat wil je nou?”
“Het is heel belangrijk om de opdrachtgever mee te krijgen. We hebben meerdere projecten gehad waarbij de ambitie heel hoog lag en we enthousiast duurzame alternatieven ontwikkelden. Maar uiteindelijk werd het vaak toch gewoon een traditionele kalkzandsteenconstructie met kanaalplaten, omdat dat veel goedkoper was.”
- Actoren schuiven verantwoordelijkheid van zich af of durven geen keuzes te maken:
“Als je mij vraagt wat het meest irritant is: mensen nemen geen beslissingen.”
“Zij hebben hun eigen belangen. De discussies zijn gaande, maar ze kunnen geen beslissingen nemen omdat er nog geen indelingsplan is. En opnieuw: niemand neemt verantwoordelijkheid, terwijl de opdrachtgever daar juist een grote rol in zou kunnen spelen.”
Post its:

Challenge 3:

Mismatch vraag en aanbod

Kernprobleem: De beschikbaarheid van herbruikbare componenten sluit vaak niet aan bij het traditionele lineaire planningsproces van ontwerp en uitvoering. Hierdoor ontstaan knelpunten in timing, opslag en logistiek, en worden reuse-opties niet of te laat benut.

Onderliggende problemen:

- Onvoldoende integratie van ontwerpproces met materiaalbeschikbaarheid:
“De timing van matching vraag en aanbod van een bouwcomponent is het moeilijkste. Het moet eigenlijk beschikbaar zijn op het moment dat wij als architect ermee werken.”
- Tijdsdruk zorgt voor onzekerheden rondom hergebruik. Daardoor worden vaak toch nieuwe materialen gekozen:
“Het tijdelijke gebouw moest op tijd klaar zijn want de echte rechtbank moest verbouwd worden. De aannemer zei: ‘Ik zie de kanaalplaten niet, dus ik ga gewoon verder.’”
“Bij een ander project duurde het contracteren zo lang dat er geen tijd meer was om donorstaal te zoeken.”
- Zodra componenten geoogst zijn maar nog niet gebruikt kunnen worden, ontstaan logistieke en financiële problemen:
“De materialen gaan zeker hergebruikt worden, dus de match is er. Maar liever had je een jaar minder opslag gehad — dat kost gewoon geld.”
“Als je het verkeerd opslaat, is het na twee jaar niet meer bruikbaar.”
“Voor echt goede materialen die je echt binnen wilt opslaan, zoals glas, daar zal in de toekomst wel structureel wat voor moeten komen.”
- Er is geen systeem waarmee tijdig zichtbaar is welke gebouwen binnenkort vrijkomen en welke materialen beschikbaar zijn, wat planning en ontwerpkeuzes beperkt:
“Je wil een database: dit gebouw wordt in 2025 gesloopt — kunnen we daarmee ontwerpen?”
“Er is nog geen businessmodel voor om alle bestaande gebouwen in kaart te brengen, dat is precies de crux.”

Post its (Via mail):

- Kennisdeling met bijvoorbeeld een open-source platform. (veel geprobeerd, toch erg ingewikkeld omdat je met concurrentie in aanbod / afname zit).

- Hoe meer integraal het element onderdeel is van het gebouw hoe lastiger de (latere) integratie. Met constructie (bijna) als lastigste onderdeel. (het gebouw wordt er namelijk mee / omheen gebouwd).
- Standaard producten (zoals plafondpanelen, haspels, binnenwandsystemen etc), zijn het makkelijkste toepasbaar, omdat deze ook vaak uit andere bronnen te oogsten zijn. De risico-spreiding is daar makkelijker mee.
- Sloper-Koper-Advisieurs-Bouwer actief aan elkaar koppelen
- Optie zou zijn, net zoals dat een gebouw bij verkoop een energielabel nodig heeft, ook het verplicht maken van een materiaalinventarisatie? Maar dat is wellicht heel ambiteus.

- Als demontagebedrijf herkennen we dit probleem duidelijk.
- Circulair bouwen vraagt in tegenstelling tot het lineaire proces om flexibiliteit en vroegtijdige samenwerking.
- Wij zien dat hergebruik alleen kan slagen als materiaalbeschikbaarheid al in de ontwerpfase wordt meegenomen.Dat betekent dat wij als demontagepartij veel eerder betrokken moeten worden in het proces, zodat we tijdig inzicht kunnen geven in wat er vrijkomt en wanneer.
-Daarnaast is het belangrijk dat er ruimte wordt gemaakt in planning en budget voor opslag en logistiek.
- Tot slot zouden centrale systemen of platforms om materiaalstromen inzichtelijk te maken enorm helpen.Daarmee kunnen ontwerpers en aannemers eerder en beter inspelen op beschikbare componenten.