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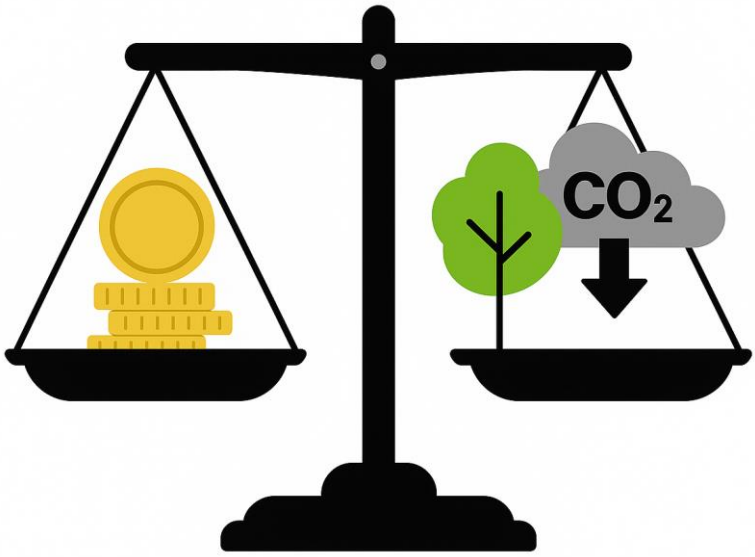

Optimizing Reuse Decisions: Visualizing Profitability and CO_2 Savings

Master's thesis in the Master's Programme Design and Construction Project Management

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CHALMERS UNIVERSITY OF TECHNOLOGY
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ABSTRACT

The construction sector is under growing pressure to reduce its environmental impact, particularly in terms of CO_2 emissions and material waste. This master's thesis explores how to enhance reuse decision-making in renovation projects by applying structured decision-making models that strike a balance between environmental responsibility and economic viability. By combining a systematic literature review with qualitative interviews with professionals in the Swedish real estate sector, the study highlights key factors that influence reuse choices, such as CO_2 reduction, economic factors and technical lifespan. A decision-support framework using the TOPSIS model is created, offering a clear method for comparing and prioritizing reuse alternatives using multiple weighted criteria. The results underscore the critical role of internal expertise, consistent use of standardized indicators and effective data visualization in facilitating a more systematic approach to reuse. Although organizations recognize the value of reuse as part of their long-term climate goals, challenges such as unclear responsibilities and high labour costs persist. This study contributes to the field by showing how practical tools and organizational strategies can work together to make sustainable reuse a more attainable objective in the construction industry.

Key words: Circular economy, Reuse, TOPSIS, Visualization, Decision-making, Sustainability, Multi-criteria analysis, Life Cycle Assessment (LCA), Life Cycle Cost (LCC) , Renovation projects, Construction sector.

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Gothenburg, May 2025

Abdalle Ali & Sadjad Hussein

1. Introduction

1.1 Background

As the global community increases efforts to prevent climate change, optimizing reuse in construction has become a top priority in the industry. The construction industry accounts for almost 40% of worldwide CO_2 emissions, making it one of the most significant contributors to total carbon emissions, including operational and embodied carbon (Isuri Amarasinghe et al., 2024). Approximately 80% of the climate impact during the construction phase comes from the production of new materials (McNamee et al., 2023), highlighting the importance of reuse as a strategy to reduce the environmental footprint of construction. Reusing materials has the potential to greatly increase economic efficiency while lowering the need for raw resources and embodied carbon emissions.

Reducing carbon emissions is critical for mitigating the negative effects of climate change, such as extreme weather, rising sea levels, and ecological damage (SMHI, 2022). Meeting carbon reduction targets requires a complex balance between economic development and environmental sustainability (Casey & Galor, 2017). Maintaining this balance in the construction industry can be challenging due to the tension between cost-effectiveness and lowering the environmental impact of building projects.

Eberhardt et al. (2019) mention that reusing materials holds great potential, it still faces several hurdles, such as complicated supply chains, weak collaboration within the industry, and no universally agreed upon definition of a circular economy. To overcome these challenges flexible strategies tailored to different types of buildings and materials need to be developed. Bertin et al. (2022) notes that reusing materials in construction, especially structural concrete elements, can significantly cut down on environmental impact, including greenhouse gas emissions and resource use. Designing structures for disassembly and long-term durability, particularly when utilizing high-performance concrete, enhances the potential for material reuse. Government support is also crucial for driving sustainable economic growth and fostering innovation in achieving effective carbon reduction strategies (Niu, 2021).

Y. Takva et al. (2023) mentions the importance of integrating contemporary additions while preserving a building's historical context in its role as a more sustainable

alternative to demolition, as it minimizes material consumption, energy consumption and environmental impact. There is also a historical trend of inadequate climate action, creating obstacles in transitioning toward a low carbon economy and the fulfilment of the Paris Agreement (Santos et al., 2022). Implementing sustainable practices now is essential for ensuring a thriving and flourishing environment for future generations (Hansen, 2013).

1.2 Problem Formulation

The push for sustainability has brought material reuse to reduce CO_2 emissions. However, demonstrating its economic feasibility remains a challenge, as decision-makers struggle to justify the cost without clear evaluation frameworks (Kim & Kim, 2020). Existing models for CO_2 reduction and sustainable supply chains emphasize the importance of incorporating both social and financial costs to improve decision-making (Guinée et al., 2018).

While interest in material reuse as a sustainability strategy is growing, current understanding remains limited regarding the precise ways in which investments in reuse infrastructure and practices lead to tangible economic benefits and carbon emission reduction (Rydberg et al., 2022). This study examines how improved visualization techniques and structured indicators can support more balanced reuse decisions.

1.3 Aim and Research Question

The study aims to construct a decision-making model to assess the impact of reuse investments on profitability and CO_2 reduction. Furthermore, it intends to provide stakeholders with a systematic and data-driven strategy for making long-term and profitable investment decisions by assessing visualization tools and developing key criteria. To address the research aim, the following research questions were developed:

1. "How can a decision-making model be developed to evaluate the trade-off between economic profitability and CO_2 reduction in reuse projects?"
2. "What are the key criteria and indicators needed to effectively visualize the impact of reuse investments on financial and environmental outcomes?"
3. "How can improved visualization techniques help justify investments in reuse?"

1.4 Scope and Limitations

The study was conducted in collaboration with a large real estate company based in Gothenburg, Sweden. The empirical data has been collected through interviews with relevant professionals across multiple roles, including project managers, site managers and environmental coordinators.

The study focuses specifically on fixed building materials and visible interior elements that are commonly found in housing renovation projects. Technical installations, loose furnishings or non-structural parts of a building fall outside the study's scope. Instead, it puts emphasis on materials that are already known to have beneficial reuse potential, such as interior doors and windows.

Geographically, the study is limited to the Gothenburg region, which makes it possible to take a deep dive into the specific challenges of reuse in urban settings. However, this geographic focus may limit the extent to which the findings can be applied to other regions. The study also mainly reflects the perspectives of one organization and its internal process. Stakeholders, such as tenants, external suppliers, and government agencies, are not included in the interview sample, though their influence is acknowledged.

2 Theory

This chapter establishes the theoretical foundation for the master thesis. It begins with a description of circular economy and Life Cycle Sustainability Assessment, offering insight into their mechanisms and implications. This section also explores the principles of circular economy, such as reuse, remanufacturing and recycling. Subsequently, the chapter delves into the concept of Life Cycle Sustainability Assessment, which integrates social, economic and environmental dimensions to the impacts of processes, products or systems throughout their entire life cycle. The theory section also explores the interplay between the circular economy and Life Cycle Sustainability Assessment, highlighting how Life Cycle Sustainability Assessment can serve as a key tool for evaluating the effectiveness of circular strategies. In conclusion, the chapter lays the groundwork for the rest of the thesis, which will delve deeper into these themes through empirical analysis.

2.1 Circular Economy

Cervantes Puma et al. (2024) explains that the circular economy is an economic model that focuses on prolonging the life of resources, minimizing waste and pollution, while opening new growth opportunities. Riuttala et al. (2024) describes the circular economy as a model that prioritizes sustainability by utilizing resources efficiently and supports closed-loop production. Collaboration among stakeholders is crucial to maximise the value of reused materials, which not only reduces waste but also improves the environment and economic outcomes. According to the Ellen MacArthur Foundation (n.d.), the circular economy is a sustainable system making sure that nothing goes to waste and finding ways to keep materials in use. It keeps materials and products in use through processes such as reusing, repairing, recycling and composting.

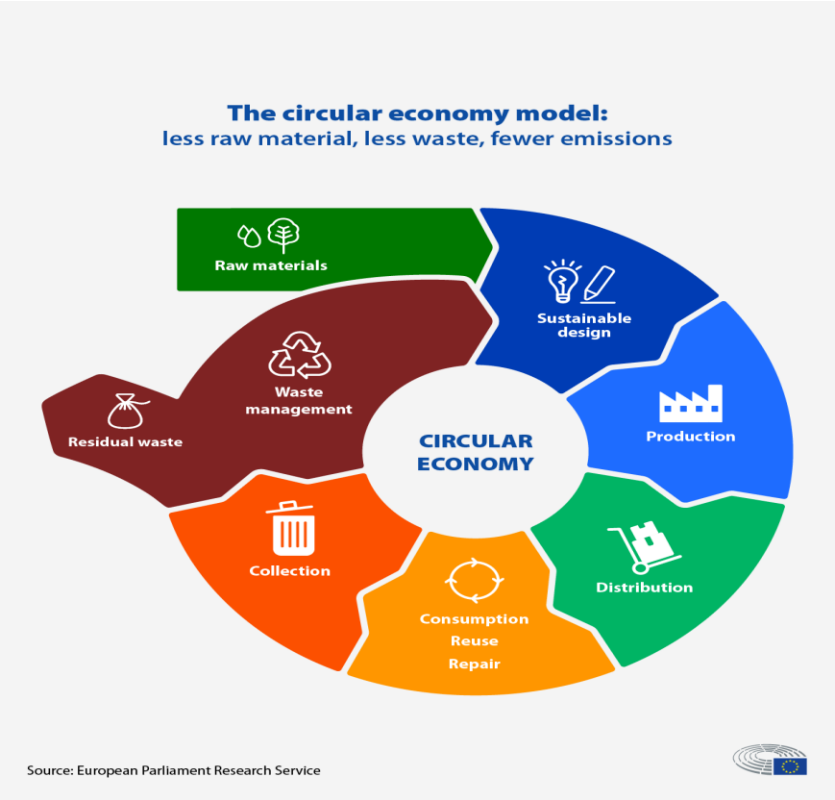

Figure 1: The circular economy model (European Parliament Research Service, n.d.).

2.2 Life Cycle Sustainability Assessment

Life cycle sustainability assessment (LSCA) is a comprehensive method for assessing the sustainability of products and processes that considers environmental, economic, and social factors. LSCA incorporates three primary methods: Life Cycle Assessment (LCA), Life Cycle Costing (LCC), and Social Life Cycle Assessment (SLCA) (Nikolic et al., 2019).

This method expands the traditional LCA, focusing primarily on environmental consequences, adding social and economic factors (Schramm, Richter, & Götze, 2020). As decision-makers strive to balance environmental sustainability objectives with economic viability, LSCA has become increasingly relevant. UNEP/SETAC defines LSCA as a methodology for making more sustainable choices throughout the life cycle, by assessing negative and positive environmental, social and economic impacts in decision-making (UNEP/SETAC, 2011). LSCA is methodologically based on the four phases of the ISO 14040 standards: interpretation, life cycle inventory, life cycle impact assessment, and goal and scope definition, allowing for a structured and comparable sustainability assessment (Nikolic et al., 2019).

2.3 How Does the Circular Economy Align with Holistic Life Cycle Sustainability Assessments?

Hoppe & Minke (2025) notes that the circular economy complements holistic life cycle sustainability (LCA) by emphasizing efficient resource use, waste reduction and sustainable materials management throughout the product's life cycle. By prioritizing strategies like recycling, reuse and remanufacturing, the circular economy seeks to reduce environmental impact, something life cycle sustainability assessment tracks using metrics like Global Warming Potential (GWP). This assessment framework identifies opportunities to cut resource consumption and boost sustainability.
Ledakowicz & Ziemińska-Stolarska (2023) emphasizes that Life Cycle Sustainability Assessment (LCA) is a valuable tool for measuring a products environmental impact throughout a product's life cycle, making it a key tool for implementing circular economy strategies. They argue for an integration of Life Cycle Sustainability Assessment with circular economy principles to create a more holistic approach to sustainability, helping to pinpoint environmental hotspots and improve resource efficiency. Samani (2023) explores the connection between circular economy and Life Cycle Sustainability Assessment, highlighting their complementary roles.

Ledakowicz & Ziemińska-Stolarska (2023) and Samani (2023) agree that combining circular economy and Life Cycle Sustainability Assessment can lead to better decision making, but they also recognize that neither approach can fully address the complexity of sustainability. This underscores the need for developing integrated frameworks that leverage the strengths of both circular economy and Life Cycle Sustainability Assessment to create a more comprehensive and effective sustainability solution.

3 Literature Review

This chapter presents an overview of prior research and theoretical framework concerning the reuse of building materials, with a particular focus on its function within the circular economy and sustainable construction practices. The chapter also highlights the economic and environmental benefit, the barriers to practical implementation, and existing models for evaluating investments in reuse. This overview forms the foundation for understanding the theoretical context and the necessity for developing a new decision support tool.

3.1 Definition of Reuse

Reuse refers to the practice of prolonging the lifespan of products or their components by repurposing them for their intended function, without classifying them as waste. This approach underscores the importance of establishing and fostering networks that facilitate repair and reuse, aligning with the principles of a circular economy (Reuse and Repair in a Circular and Social Economy, 2022). Yuan and Shen (2011) define reuse as the repeated utilization of construction materials more than once, whether for their original purpose or new function. The concept of reuse can differ based on the context, which makes the definition of reuse vague.

3.2 Reuse of Construction Materials

Kim and Kim (2020) present a framework for reusing steel beams in construction, aiming to significantly reduce CO_2 emissions by as much as 77%. It incorporates a material bank and a design support tool to enhance material efficiency. However, challenges persist, such as possible cost increases and the necessity of assessing economic viability over the entire lifecycle. Knoth et al. (2022) identified obstacles like regulatory challenges and insufficient documentation, while emphasizing success factors such as awareness campaigns and stakeholders' engagements. Fufa et al. (2023) found in a national survey in Norway that there is optimism about the potential for reusing construction products. Effective planning and a supportive regulatory framework can facilitate the establishment of a robust reuse market in the construction field. This analysis resonates with Byers et al. (2024) who argue for the incorporation of digital technologies and regulatory framework to improve material reuse practices in the construction industry.

Zhu and Feng (2024) stress that improving wood waste through design for deconstruction (DFD) can greatly reduce greenhouse gas emissions and generate economic growth. They also emphasize the importance of implementing innovative strategies and fostering cross-disciplinary collaboration to enhance sustainability in the wood sector and address existing challenges. Chiletto et al. (2024) underscores the critical role of innovative strategies and methodologies in fostering sustainability in the wood sector. Effective collaboration among researchers, stakeholders' practitioners will also help address the multifaceted economic and environmental challenges with timber construction. Habib et al. (2025) conducted a study that examined the potential of modular steel buildings to substantially decrease material consumption and energy use compared to traditional construction methods. Their result showed that modular construction allows for precise material usage during prefabrication, which will limit waste. Küpfer et al. (2023) mention the primary challenges in reusing concrete components include the need for higher precision during deconstruction, carefully separating and reassembling salvaged elements with existing structural features.

3.3 The Role of Reuse in a Circular Economy

The idea of reusing materials in the construction industry to reduce cost and embrace reuse initiatives has gained significant traction as the construction sector moves towards circular economy principles (Eberhardt et al., 2019). Reuse is a fundamental principle in the circular economy, helping to reduce waste by extending the lifespan of products and materials. By conserving resources and generating less waste, reuse not only benefits environmental sustainability but also economically by lowering cost and resource optimization (Marek & Zdenek Krejza, 2024). These insights align with Wöhler et al. (2024) who emphasize that reuse is essential in a circular economy, as it prolongs the longevity of components and materials. Effective reuse can significantly reduce waste and conserve resources, helping shift the industry from a linear economy model to a cradle-to cradle approach. However, in emerging economies like India, this potential is often hindered by barriers such as unclear regulations, lack of awareness and insufficient incentives, building on this Kozminska (2020) explores the wider architectural impact of circular economy principles in Nordic countries, advocating for design strategies that focus on material longevity and adaptability.

Papamichael et al. (2023) found that the construction industry's transition to circular economy practices is significantly hindered by economic barriers, inadequate

regulatory frameworks and challenges in waste management. These obstacles impede the effective implementation of reuse and recycling initiatives, ultimately undermining the construction industries' sustainable progress.

Foyn et al. (2023) argue that the construction industry can shift towards material reuse by leveraging digital information systems, establishing standardized certification standards and encouraging stronger partnerships among stakeholders to streamline recycling. Laefer and Manke (2008) offer a broad analysis of building reuse, focusing on both belowground and aboveground structure. They argue that building reuse can lead to cost saving and reduced waste consumption. Laefer and Manke (2008) also explore the complexities of below ground reconstruction in urban environments, where utilities and existing foundations can complicate the reuse. It is crucial to assess both the economic and structural feasibility of reuse, particularly in crowded urban areas where space constraints increase the complexity.

Oliveira et al. (2024) highlights the potential of buildings as repositories for reusable material, emphasizing the importance of urban mining and reduction of resource extraction through efficient Construction and Demolition Waste (CDW) management. A holistic approach is vital, combining digital technologies and design methodologies with tools such as BIM to enhance material traceability. Conversely, Bellini et al. (2024) examines the practical implementation of reuse in the context of integrating reuse into circular economy practices in the construction sector. By introducing a structured three-phase approach to reducing construction materials, which includes collecting information, data collection and strategic reuse planning. Both Bellini et al. (2024) and Oliveira et al. (2024) underscores the necessity of standardized data management and stakeholders' engagement, thereby advancing progress in circular economy practices in the construction industry.

3.4 Bridging Sustainability and Economic Viability

Achieving long-term economic viability in sustainable construction emphasizes that while benefits like lower utility costs and higher occupancy rates are possible, these advantages typically take time to materialise, which can make some investors hesitant, particularly those focused on immediate financial returns. Changing the focus towards long term financial outcomes and raising awareness about the cumulative economic advantage of sustainable construction is vital for overcoming investment barriers and making sustainable practices more widely accepted (Cheng Siew Goh et al., 2023).

Eberhardt et al. (2019) emphasises that bridging sustainability and economic viability in the construction industry requires a move from short-term profits and instead focus on long-term resources efficiency. Embracing circular economy principles, such as designing for easy disassembly and reusing more construction materials can lead to reducing environmental impact and better economic benefits, fostering more sustainable practices. Cervantes Puma et al. (2024) provide a compelling analysis of how reusing structural steel and slag can lead to cutting costs and environmental benefits. Their case studies demonstrate how strategically reusing materials reduces carbon emissions and boosts profitability, reinforcing the importance of circular economy principles. In parallel, Riuttala et al. (2024) explore the broader implications of reusing building components reuse (BCR), with a focus on precast concrete. They highlight how innovative business models can drive cost savings and generate new revenue streams. Additionally, Riuttala et al. (2024) also underscore the need to add value throughout the construction process, showing how reuse initiatives can make traditional construction practices more financially viable.

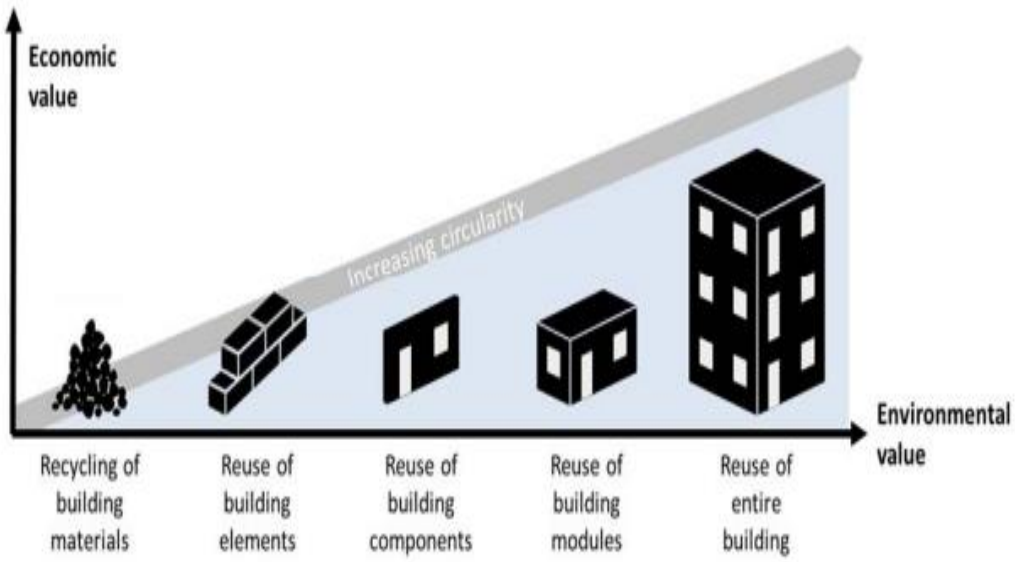

Figure 2: Illustration of the economic and environmental value of recycling and reuse potential in the construction industry (Eberhardt et al., 2019).

3.5 Environmental and Economic Benefits of Reuse in Construction

Rydberg et al. (2022) mentions that the benefits of reusing construction materials can make a huge difference for the environment. It could cut down building waste by roughly 900.000 tons each year and lower greenhouse gas emissions by 1.3 million tons of CO_2 equivalents, representing approximately 7% of the total emissions from the Swedish building industry. In their study Rydberg et al. (2022) estimate socio-economic savings of around 2.3 million euros, primarily due to reduced spending on waste management and a decreased demand for new building materials. This amount illustrates the economic benefits of implementing reuse practices within the Swedish building sector. Hu & Jakub Świerzawskib (2024) argue that adaptive reuse not only preserves valuable resources but also helps maintain the cultural, historical and social value of older buildings while improving their functionality and sustainability. Upgrading existing structures to comply with modern standards can often be less costly and more environmentally friendly than constructing new buildings.

Charlotte et al. (2022) indicate that reusing materials in the construction industry can make a huge difference in significantly reducing greenhouse gas emissions. Even with a 50% reuse, the environmental benefit would still be significant, underscoring how important circular economy practices are in the construction sector. Kim & Kim (2020) note that reusing construction materials, particularly steel beams can lead to a significant reduction in CO_2 emissions. However, higher processing costs create financial challenges, highlighting the delicate balance between sustainability and economic feasibility in the construction sector.

Al-Najjar & Malmqvist (2025) argue that reusing concrete elements in construction can dramatically cut carbon emissions by up to 82% compared to traditional methods. This approach helps mitigate greenhouse gas emissions but also promotes a circular economy by lowering the demand for new materials, thus addressing climate change effectively. Iacovidou & Purnell (2016) mention that promoting reuse in the construction sector can conserve resources and reduce costs for material and waste disposal. Additionally, offering incentives for reuse and recycling, paired with specialized education and training, can drive major changes in the construction

industry, paving the way for more sustainable operations and stronger long-term performances.

3.6 Barriers and Strategic Enablers for Reuse in Construction Projects

A circular construction sector where construction products with a remaining technical lifetime are reused reduces waste, improves resource utilisation and reduces the climate impact of the construction sector. However, some barriers affect reusability's effectiveness, such as lack of knowledge, quality uncertainty, and an immature market (Gerhardsson et al., 2020). Stakeholders lack knowledge and experience in implementing reuse efficiently in construction and remodelling processes. The uncertainty regarding which building materials to reuse, how to manage reused components, and what quality standards these materials meet is a key reason why raw materials remain the preferred choice (Gerhardsson et al., 2020; Kim & Kim, 2020). McNamee et al. (2023) point out that reusing materials with fire classifications presents difficulties under Swedish building regulations. Fire regulations and certifications may occasionally cause doors, cables, and load-bearing systems to be "disqualified" for reuse.

The lack of structured systems to manage and store information on reusable materials hinders reuse in the construction industry. According to Kim & Kim (2020), the absence of a centralised database containing information on the availability, specifications and quality of reused building materials makes it difficult for planners and designers to plan with reused materials. Information is often spread across multiple platforms or stored in static formats, such as PDF files, making it difficult to access in real time and aggravating the challenge. Foyn et al. (2023) highlight additional barriers, such as lack of profitability, lack of standardised quality assessments, and difficulties with material storage. The lack of clear documentation on material qualities and certification processes creates uncertainty, which leads to clients opting out of reused materials in construction projects. According to Foyn et al., (2023) without an effective system to manage recycled materials throughout their lifecycle, the construction sector will continue to maintain a linear rather than circular use of materials.

3.6.1 Lack of Adapted Business Models and Economic Incentives

Compared to traditional construction processes, reuse work can demand more time and resources in dismantling, transporting and storing the materials. Clients have relatively little financial incentive to select reuse over new construction due to the construction procurement methods frequently prioritising the lowest cost in the short term (Gerhardsson et al., 2020). Raw materials will continue to dominate the construction industry unless there are efficient tools to assist with material selection and procurement and compliance with existing building rules for recycled materials (Kim & Kim, 2020). Furthermore, the lack of financial incentives and high costs, especially in remote areas, discourage the adoption of reuse (Crawford et al., 2017).

According to Crawford et al. (2017), the main obstacles to reuse are the lack of financial incentives and additional expenses associated with logistics, material separations, and quality assurance. Price and material availability uncertainties stem from the absence of a professional reuse market and framework, which furthers stakeholder investment in circular solutions. Until there are financial incentives or regulatory support for the cost difference between raw and reused materials, reuse will continue to be a less appealing alternative economically in construction projects (Crawford et al., 2017).

3.6.2 Key Approaches to Increasing Material Reuse

Rose and Stegemann (2018) argue that building materials should be seen as resources rather than waste and reuse should be part of an active "component management system". To enable such an approach, their study shows a need for early identification of reusable components, access to databases showing available materials, and increased co-operation between actors and third parties who can certify and upcycle components to be reused.

According to Ericsson et al. (2024), increasing the use of reusable materials requires early incorporation of reuse, better design approaches, and enhanced abilities for circular working practices. To overcome financial obstacles, a professionalized reuse market, adaptable procurement procedures, and clear price structures are essential. In a similar vein, Gerhardsson et al. (2020) emphasize important procedures including circular building design, reuse targets, and procurement incentives. Long-term document strategies and digital tools like material passports and inversion platforms are required to build a more scalable reuse system.

Gobbo et al. (2024) emphasise the importance of systematically reporting reuse measures throughout the construction process using digital tools such as BIM (Building Information Modelling) to visualise the economic benefits and enable real-time monitoring. These insights are complemented by Iavovidou and Purnell (2016) by emphasising design interventions and technical solutions, such as Design for Deconstruction (DfD) and Design for Reuse (DfR) to enable a more efficient reuse of materials. Durmisevic et al. (2021) argue that there is still a lack of concrete guidance in practice and that standardisation is needed for the use of DfD and Design for Adaptability (DfA). The authors highlight the need for cross-industry collaboration among actors such as architects, contractors and authorities to jointly develop standards that support reuse as early as the design stage of a project. A standardisation can act as a catalyst to reduce resource consumption in line with the EU climate goals (Durmisevic et al., 2021).

Adaptive reuse, smart technologies, and selective demolition instead of full demolition are crucial to make the reuse process more efficient. Foyn et al. (2023) propose a digital framework based on ISO 19650 to create a centralised and accessible source of information using digital twins and BIM. The purpose of such a framework is to provide stakeholders easy access and up-to-date information on the availability of materials for reuse, as well as their quality and standards. Digital platforms can also be linked to reuse marketplaces, increasing economic viability and contributing to a circular building sector. In line with this, Bertin et al. (2020) propose a framework based on an extended BIM information levels of LOD/LOI (600 & 700) that supports reuse by including critical indicators such as disassembly potential, residual lifespan, remaining strength, and environmental impact. To improve traceability and assessments of structural components, these values are stored in a material database to match reusable elements with construction needs. This approach allows for real-time decision-making where lifecycle performance and environmental impact of reused materials can be evaluated in early design stages.

Tools such as Interface Management Systems (IMS) are proposed as a solution to address the increased complexity of reuse projects by clarifying communication, responsibilities and deliverables between involved actors. Eray et al. (2019) mention that most of the barriers to reuse are often linked to interfaces between project partners.

By defining physical, organizational and contractual interfaces already in the early phases, the implementation of IMS can help to reduce delays and improve the quality of the project end product.

3.7 Decision-making Models for Reuse Investments

Various elements influence investment decisions regarding the reuse of construction materials. Yet, in traditional economic models, financial rewards are typically prioritized over environmental benefits. Fregonara (2023) describes Discounted Cash Flow Analysis (DCFA) as a traditional investment model for determining the profitability of real estate investments. In contrast, this approach rarely addresses environmental components such as Embodied Energy (EE) and Embodied Carbon (EC), limiting the ability to incorporate climate consequences and environmental costs into decision-making processes. The concept of global cost has been introduced to account for environmental aspects, where environmental indicators are combined with traditional economic factors to visualise a more comprehensive picture of the long-term sustainability of an investment (Fregonara, 2023).

Fregonara (2023) suggests that EE and EC should be monetised by integrating both environmental impacts and economic costs over the entire building life cycle, from construction to reuse or demolition. Through this approach, decision-makers can better evaluate the long-term economic and environmental trade-offs between reuse and new construction, creating a more holistic and sustainable investment assessment. To support informed decision-making regarding reuse, Kim and Kim (2020) propose a decision support system that generates material suggestions and optimized procurement plans. By incorporating Life Cycle Assessment (LCA) and Life Cycle Costing (LCC), the tool also provides calculations of environmental impacts and economic consequences. This enables early-stage analysis of both climate impact and costs, thereby improving the quality of decision-making related to reuse.

Similarly, Bulle and Love (2011) propose a decision model for adaptive reuse, in which capital investment, regulations, and building conditions are considered three key factors influencing decisions. The study shows that the primary determinants are often construction and operating costs in decisions to reuse or demolish. Regulatory requirements and the technical condition of buildings also influence the feasibility of reuse and thus affect decision-making processes (Bullen & Love, 2011).

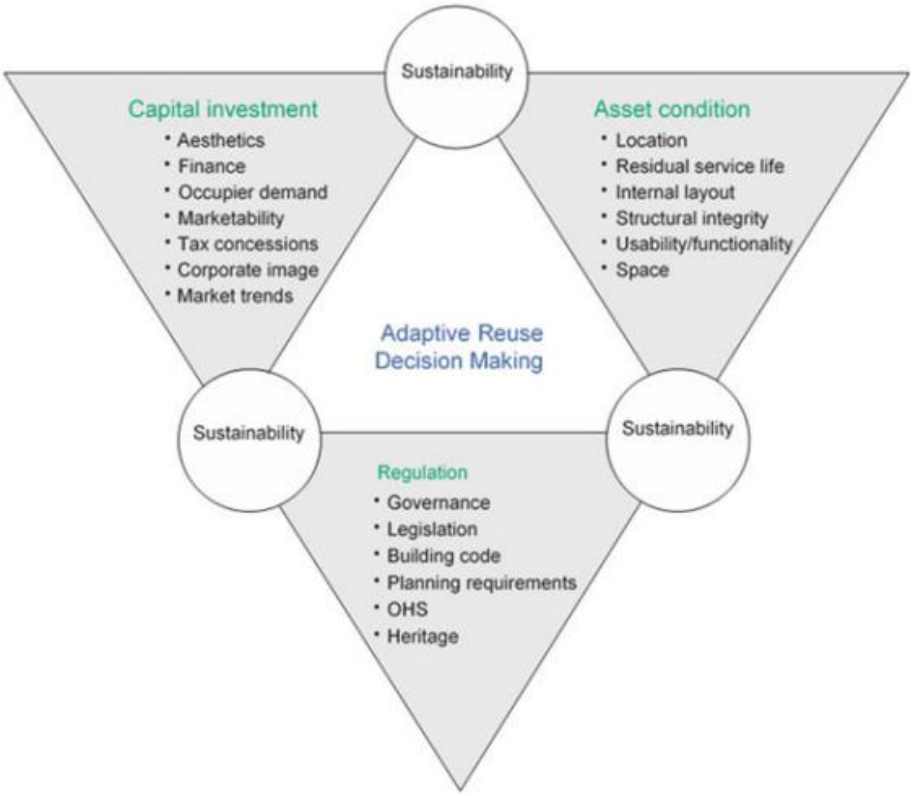

Figure 3: Adaptive reuse decision-making framework (Bullen & Love, 2011)

According to Bullen and Love (2011), an effective decision-making model should include a balance between economic investment, the building lifespan, and regulatory requirements. The need for a structured approach that responds to market trends, regulatory constraints, and potential sustainability gains is stated as crucial to ensure an evidential and sustainable approach.

To enable a more circular construction sector, a systematic model is needed so that decision-makers can evaluate the long-term benefits of reuse from both an economic and environmental perspective. By analysing 32 construction and renovation projects, Gobbo et al. (2024) show that reuse levels vary depending on the size of the project, with some indoor spaces and facades having higher reuse potential than structural components. The proposed methodology is to categorise reusable materials according to functional building codes such as facades, indoor structures and outdoor surfaces.

Key criteria and indicators allow investments in reuse to be managed and visualised more effectively and make their impacts more understandable. Gobbo et al. (2024) identify 3 key indicators in a framework to quantify reuse monitoring in construction

and renovation projects. The central indicator is the reuse rate (RR), which describes the reused proportion of embedded materials in a project. RR is measured in mass (kg) to connect climate calculations and visualize prevented carbon dioxide emissions, as shown in equation 1.

$$RR\sim(\text{Reuse rate}\sim[\%]) = \frac{Q_{\text{Reuse}}\sim(\text{Quantity of materials effectively reused in the functional layer [kg]})}{Q_{\text{Layer}}\sim(\text{Total quantity of materials used for the works in the functional layer [kg]})}$$

Eq. 1

Pati et al. (2021) indicate that reuse decisions are complex and involve a wide range of stakeholders. To address this complexity, some decision-making models have been proposed. Among these are Mohamed and Alauddin's (2016) adaptive reuse decision model that includes five criteria considered particularly relevant when assessing climate benefits and economic viability. The decision model includes economic attributes, meaning access to finance and risk assessment. Environmental attributes focus on resource efficiency and sustainability aspects, architectural factors deal with the technical condition of buildings, social factors include how cultural values can contribute to societal benefits, and legislative factors relate to environmental regulations and permit processes.

3.8 Multi-Criteria Decision-Making for Material Reuse

To balance environmental, economic, technical and logistical factors, Küpfer et al. (2021) propose a decision-making framework based on a multi-criteria analysis (MCDA) to support decision-makers in designing reused components. The MCDA model includes four main criteria:

1. Environmental impact - LCA is used to visualise the impact of reuse compared to new production.
2. Economic factors - Cost calculations in comparison with new production.
3. Logistical challenges - Need for a functioning supply chain, including disassembly and transport.
4. Construction constraints - Reuse components may require certain design solutions.

Then PROMETHEE, a methodology within MCDA, is used to identify the most optimal design options based on decision-makers' preferences. The study demonstrates that reuse rates of around 65% provide the best balance between environmental benefits and economic viability. Furthermore, Costa et al. (2019) state that MCDA is one of the most effective methods in LSCA for dealing with complicated decisions integrating environmental, economic, and social factors. MCDA is considered critical for integrating many sustainability criteria and comprehending their implications. Sustainability indicators are integrated utilizing MCDA methodologies such as AHP (Analytic Hierarchy Process) and TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) to produce a balanced assessment of the sustainability of various design approaches.

AHP is a prominent method used in complex decision-making situations to weigh different indicators against each other. Vardopoulos et al. (2021) show how AHP in combination with SWOT and PESTLE analysis can be used to identify and prioritize sustainability factors in adaptive reuse projects. The study identifies 24 indicators distributed across political, economic, technological, social, legal and environmental dimensions (PESTLE), which are classified according to strengths, weaknesses, opportunities or threats (SWOT) and finally pairwise comparisons are made by the researchers using the AHP method.

The analysis revealed that political and economic factors have the greatest impact on the sustainability of reuse. Environmental, technical and legal aspects were more limited, with a supporting role. The SWOT analysis showed that indicators linked to strengths and opportunities outweighed threats and weaknesses, with 70.4% of the total weight assigned to positive factors. The integrated AHP-SWOT-PESTLE decision model captures strategic and operational perspectives and is useful when deciding on climate benefits, societal benefits, and profitability of a reuse project (Vardopoulos et al., 2021)

3.9 Key Indicators

According to Guinée et al. (2018), decision support for sustainable choices must be based on quantifiable and comparable indicators that are relevant across all sustainability dimensions. The authors propose a combination of environmental indicators, such as global warming potential (GWP) expressed in kg CO_2 equivalents,

with economic aspects such as life cycle costs (LCC). The need to develop social LCA (SLCA) is also emphasised in the paper, although the methodology is still under development.

Van den Berg et al. (2020) found that reuse occurs only when three specific criteria are met. The first criterion is that there is an economic demand for the component; the second criterion is that the component can be disassembled in a practical and safe manner; and the third criterion is that there is access to check the component's functionality and that it does not deteriorate during storage until it is reintegrated into a new project. According to the study, if these parameters are not met, materials with high reuse potential will nonetheless end up as waste, for example, due to uncertain demand or logistical issues.

The model proposed by Fregonara (2023) includes the market values created by the building's transformation, the amount of EE retained, and EC emissions avoided by using reused components. By including the concept of Global benefit, which visualises the potential for material recycling and avoiding emissions, the traditional NPV model can be adapted to visualise the true long-term value of recycling investments (Fregonara, 2023).

Table 3.9.1 summarises key indicators identified in the literature that are crucial for visualising the impact of reuse investments. The indicators allow for a holistic approach to decision-making covering environmental, economic and social dimensions. Indicators such as Global Warming Potential (GWP), Life Cycle Costing (LCC) and Reuse Rate provide decision-makers a better understanding of the trade-offs and long-term benefits of material reuse. For instance, Global Warming Potential (GWP) and Embodied Carbon (EC) are often used together to assess climate impact. These indicators support more sustainable and evidence-based investment strategies in the construction sector.

Table 3.9.1. Key indicators for evaluating reuse investments.

Category	Key Indicator	Description	Source
Environmental	Global Warming Potential (GWP)	Measured in kg CO_2 equivalents to quantify climate impact	Guinée et al. (2018)
Environmental	Embodied Energy (EE)	Amount of energy retained through reuse	Fregonara (2023)
Environmental	Embodied Carbon (EC)	Avoided CO_2 emissions by reusing materials	Fregonara (2023)
Environmental + Technical	Reuse Rate (RR)	Share of reused materials (by mass) in a project, linked to CO_2 savings	Gobbo et al. (2024)
Economic	Life Cycle Costing (LCC)	Calculates economic costs throughout the life cycle	Guinée et al. (2018)
Economic	Cost Savings from Reuse	Cost calculations in comparison with new production.	Kupfer et al. (2021)
Environmental + Economic	Global Benefit	Visualizes the potential for recycling and avoided emissions	Fregonara (2023)
Social	Social Life Cycle Assessment (SLCA)	Assesses social impact of reuse (still under development)	Guinée et al. (2018)

4. Method

This chapter outlines the methodological approach undertaken for data collection and analysis, aimed at addressing the study's research questions. The study integrates a systematic literature review with qualitative interviews conducted with key figures in the real estate industry, capturing both the theoretical and practical perspectives on material reuse. Furthermore, an analytical framework is introduced to structure and compare alternatives, using the multicriteria method TOPSIS to visualize the economic and environmental impact of reuse investments. Combining both the qualitative and quantitative methods enables a holistic approach, enhancing both the reliability and practical relevance of the study.

4.1 Systematic Literature Review

To set a sound theoretical foundation for the study, a systematic literature review was conducted, following the protocol outlined by Snyder (2019) and Paul and Criado (2020). The review aimed to uncover and investigate scientific literature on reuse in the construction sector particularly focusing on indicators, decision-support tools, and the relationship between environmental and economic performance. The second research question, that seeks to select relevant criteria and indicators for depicting an effect of reuse investments, formed the starting point for the literature review. Scopus, Web of Science, Google Scholar, and the discovery tool provided by Chalmers Library were used to ensure access to credible and peer-reviewed sources.

A preliminary broad search was conducted based on general terms applied to "reuse", "circular economy", "construction materials", and "sustainability". However, these terms yielded a high volume of results, many of which were too general or only marginally pertinent. To refine specificity and pertinence, a narrowing strategy was employed. This involved coupling keywords with Boolean operators and introducing more specific terms considering what was discovered through preliminary readings. Search terms such as "reuse" AND "building elements" AND "decision-making", "life cycle assessment" AND "CO_2 savings", and "TOPSIS" AND "renovation" AND "multi-criteria" were used to limit the scope. Keywords such as "adaptive reuse," "building life span," and "economic viability" were added iteratively, based on often recurring topics of first search results.

To have a consistent and clear selection process, exclusion and inclusion criteria were employed. A study was included if it was published between 2010 and 2024, peer-reviewed, and clearly addressed material reuse in construction, life cycle assessments, or decision-support methods. Grey literature, articles not addressing construction, and articles with unclear methodology were excluded.
This iterative, systematic process ensured that the literature selected was not just comprehensive but also context-specific, constituting the foundation of the TOPSIS application and of the indicator framework for the empirical part of the study.

4.2 Interview Study

It was decided that a qualitative interview would be used in this study. Qualitative interviews with industry professionals and reuse experts will be conducted to address Research Question two and Research Question three. The interviewees were selected based on their expertise and relevance to the thesis, ensuring various perspectives. The interviews were semi-structured, providing flexibility to explore emerging themes while maintaining focus on the research questions. Open-ended questions was used to foster detailed responses so that new insight can be uncovered. The interviews with the respondents were recorded and lasted between 30 to 60 minutes. The respondents represented Familjebostäder, Bostads AB Poseidon and Bostadsbolaget. The study's interview questions are included in the Appendix A.

Additionally, there is a responsibility to ensure that the respondents feel respected and aren't taken advantage of during the study (DiCicco-Bloom & Crabtree, 2006). Eight out of the ten interviews were conducted via Teams making it harder to build trust. Guo et al. (2024) argue that without physical presence, picking up on nonverbal cues becomes much harder. While online interviews enhance accessibility and make participation easier for the respondents, it needs careful planning to foster thoughtful interviewees to increase engagement and spontaneity.

Table 4.3.1. List of respondents and their role in the company

Title	Type of company	Interview Method
Senior project manager 1	Real Estate company	On-site interview
Senior project manager 3	Real Estate company	Microsoft Teams
Senior project manager 3	Real Estate company	Microsoft Teams
Senior project manager 4	Real Estate company	Microsoft Teams
Site manager 1	Real Estate company	On-site interview
Site manager 2	Real Estate company	Microsoft Teams
Site manager 3	Real Estate company	Microsoft Teams
Environmental coordinator 1	Real Estate company	Microsoft Teams
Environmental coordinator 2	Real Estate company	Microsoft Teams
Quality, Environment, Health and Safety Manager	Real Estate company	Microsoft Teams

4.3 TOPSIS – Technique for Order of Preference by Similarity to Ideal Solution

TOPSIS, or Technique for Order Preference by Similarity to Ideal Solution, is a multi-criteria decision-making method (M-CDM). The goal of TOPSIS is to identify the alternative that is closest to the positive ideal solution (PIS) and the farthest from the negative ideal solution (NIS). It ranks alternatives by measuring their distance from these ideal points to rank them effectively. This method is particularly useful for evaluating and selecting alternatives when multiple conflicting criteria are at play (Huang & Jiang, 2017). One of the main advantages of TOPSIS is that it is a simple calculation process, which makes it easy to apply. Additionally, the flexibility of TOPSIS allows it to be applied across various areas, such as renewable energy,

agriculture and water management. Its versatility makes it a powerful tool for solving complex decision-making challenges in diverse fields, making it a preferred method among practitioners in decision analysis (Krishnan et al., 2023).

TOPSIS has been used in this study to combine indicators related to reuse, including cost (SEK), CO_2 savings (kg), technical feasibility, logistics and other project specific factors. These indicators, differing in units and orientation, were first normalized and weighted based on their importance to sustainable reuse. Each reuse alternative was then assessed and ranked based on its closeness to the ideal solution. This method facilitates the transparent and consistent identification of the most sustainable and economically viable options, thereby aiding strategic decision-making in complex reuse projects.

The following is a step for step for step breakdown of how TOPSIS was applied in this study:

Step 1. Normalisation of the decision matrix

In order to compare different units (e.g. kg CO_2, crowns, points), each criterion must be rescaled to a value between 0 and 1. This is done by dividing the value by the square root of the sum of the squares for each column, to obtain a normalised and comparable value.

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^2}}$$

Eq. 2

Where r_{ij} is the normalised value, x_{ij} is the value for option i and criterion j.

Step 2. Weighting of criteria

The normalised values are then multiplied by a weight $w_j$that reflects the relative importance of the criterion. These weights can be determined via expert judgement or other prioritisations.

$$v_{ij} = w_j \cdot r_{ij}$$

Eq. 3

Where v_{ij} is the weighted value of options i and criteria j.

Step 3. Determination of ideal and negative ideal solution

The ideal solution (A+) represents the best value for the criterion such as highest benefit or lowest cost, the negative ideal (A-) solution represents the worst possible.

$$A^{+} = \{\max(v_{ij})\ for\ benefit\ criteria,\ \min(v_{ij})\ for\ \cos t\ criteria\}$$
$$A^{-} = \{\min(v_{ij})\ for\ benefit\ criteria,\ \max(v_{ij})\ for\ \cos t\ criteria\}$$

Eq 4.

Step 4. Calculation of distances to ideal points

Euclidean distance is calculated to both the ideal and the negative ideal solution for each option. The better the option, the closer the value is to the ideal point and the farther from the negative one.

$$S_i^{+} = \sqrt{\sum_{j=1}^{n}\left(v_{ij} - A_j^{+}\right)^2}$$
$$S_i^{-} = \sqrt{\sum_{j=1}^{n}\left(v_{ij} - A_j^{-}\right)^2}$$

Eq 5.

Step 5. Calculation of the proximity coefficient

The value of the proximity coefficient ranges from 0 to 1 and indicates how close an option is to the ideal solution; a higher value indicates a better option.

$$C_i = \frac{S_i^{-}}{S_i^{+} + S_i^{-}}$$

Eq 6.

The options are ranked according to the highest C_i value, the option with the highest value is ranked as the best.

4.4 Synthesis of Literature and Empirical Data for TOPSIS Framework

To ensure that the TOPSIS model developed considers both theoretical foundations and practical circumstances, a combination of the findings from the literature review and the interview study was conducted. By combining these two sources of data, the most relevant criteria and indicators for evaluating reuse options in restoration projects could be determined and prioritized. This mix is in accordance with the philosophy of

methodological triangulation where different data sources are mixed as a way of ensuring maximum validity (Flick, 2004).

The most relevant Global Warming Potential (GWP), Life Cycle Costing (LCC), and technical lifespan metrics were selected based on their frequency in the literature (Fregonara, 2023; Gobbo et al., 2024; Guinée et al., 2018). The technical lifetime of reused materials was found to be a primary indicator for determining how long a reused component can be expected to function before it needs to be replaced, in order to determine the economic efficiency and carbon footprint of long-life components.

The indicators were both normalized and weighted in the TOPSIS model based on both their theoretical significance as well as the stakeholder priorities identified in the interviews. This provided for context-sensitive and evidence-based application of the model, which takes into consideration practical constraints as well as long-term reuse objectives in the projects of the organization.

4.5 Ethics

Helmchen (2011) highlights how vital informed consent is in research with individuals before taking part in the study. Respondents must be fully informed of the research purpose, risks and procedures. These steps will ensure respondents make rational decisions and ensure their rights. Okorie et al. (2024) emphasises how crucial it is to keep respondents' personal information safe by following ethical data collection practices. It demonstrates the importance of transparency and respecting privacy to ensure data is handled responsibly. By adhering to established ethical norms, researchers can protect the respondents' rights and the integrity of the research process.

The thesis will adhere to ethical research principles to ensure integrity and transparency. The interviewees anonymity will be protected. The data will be collected and analysed responsibly to avoid misinterpretation and ensure accuracy. All respondents will be informed about the consent process prior to their participation, clearly understanding the research purpose, their rights, and how their data will be used. Verbal consent will be obtained before any data collection begins. Another essential ethical consideration is ensuring diversity among respondents. This research will gather data from individuals of various ethnicities, genders and professional backgrounds. The research will strictly adhere to GDPR to safeguard personal information. The research findings

will be transparently disclosed, and findings will be presented honestly. By upholding these principles, the research aims to contribute to valuable knowledge while maintaining respect for the respondents and preserving the integrity of academic research.

To help with translating and transcribing the interviews, software algorithms such as those developed by OpenAI (ChatGPT) were used to support the process.
Importantly, no sensitive or confidential information was included in the data processes shared with these tools. Details such as company and project names, or any related identifiers were removed by hand before any use. Additionally, in line with GDPR guidelines, all interview recordings were permanently deleted after the research report was completed.

5. Empirical Results

The chapter presents the empirical results from the qualitative interviews with several key figures in the real estate sector. The aim is to shed light on practical experience, challenges and opportunities related to material reuse in renovation projects. The results are presented thematically, based on recurring patterns identified in the respondents' responses. Emphasis is placed on how climate impact, technical performance and economic feasibility influence decision-making. Additionally, the chapter emphasizes the critical need for the development and implementation of standardized indicators, visualization tools and organizational framework to facilitate a more systematic and long-term approach to material reuse.

5.1 Technical Performance, Climate Impact, and Economic Feasibility

Technical durability, CO_2 savings and economic feasibility were the three main factors identified as crucial when considering reuse in renovation projects. Among these, the most crucial aspect highlighted was the technical assessment of the remaining life cycle of the material. Several respondents emphasize the importance of only reusing materials that are in good condition to avoid early replacement of the reused material, which can lead to increased costs and climate emissions. *"The technical aspect is absolutely the most important factor. We don't want to reuse something that needs to be replaced again in five years."* (Respondent 1, Senior project manager). In addition, some respondents mentioned that certain materials such as roof tiles or sanitary components only are reused if their lifetime is considered adequate and aligns with the durability of the surrounding or related building components. Ensuring that the materials perform equally over time is considered essential to maintain environmental and economic sustainability.

Porcelain, interior doors and roof tiles are examples of components that are commonly considered suitable for reuse because of their ease of inspection and long technical life. On the other hand, windows, ventilation systems and kitchen fittings require costly renovation and can be difficult to fulfil energy efficiency and sound insulation requirements; therefore, reuse of these types of components is usually discouraged.

The potential to reduce CO_2 emissions was highlighted as the second key factor in all interviews. Reuse was described as an integral part of every project, in line with achieving the company's climate targets to reduce emissions by 50% by 2025 and 90% by 2030. Several respondents mentioned that reuse is always considered regardless of the size and scope of the project.

"Reuse is part of how we reach our emissions targets. It's something we try to do in every project, in some form." (Respondent 2, Senior Project Manager*)*

Economic factors were often mentioned in the interviews, however, most respondents emphasised that the economy is not the main driver of reuse decisions. Environmental objectives and technical feasibility were instead highlighted as more central to achieving the organisation's long-term goals. Several respondents mentioned that reuse is always integrated into projects even when it does not lead to direct cost savings, if it contributes to sustainability objectives.

"We don't do reuse to save money—we do it because we believe in it, and because it's part of our mission." (Respondent 3, Project Manager)

However, economic reasonableness is still a realistic requirement for project approval. Savings were noted to be easier to obtain with components such as porcelain and doors, rather than bigger architectural parts or technical systems, where reuse usually results in increased complexity and costs.

5.2 Challenges and Enablers for Reuse in Renovation Projects

The interviewees mentioned several barriers to increased reuse in renovation projects, with varying frequency. Diagram 1 shows how often a barrier was mentioned in the interviews:

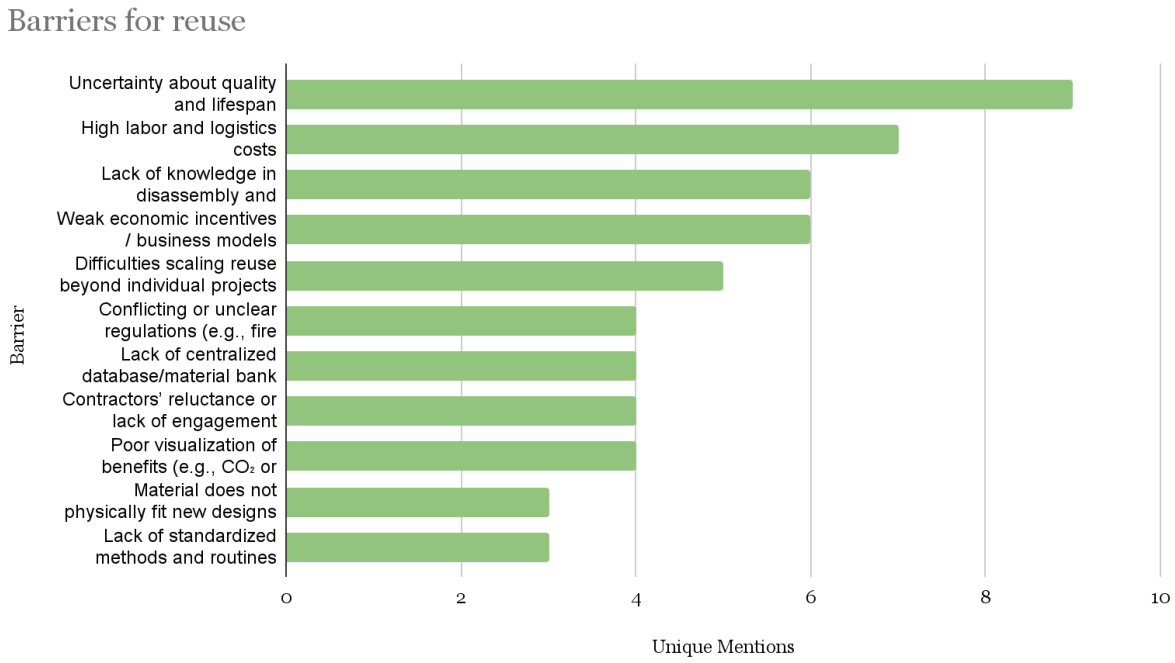

Diagram 1: Most frequently mentioned barriers to increased reuse.

The interviews show that implementing reuse in renovation projects is affected by practical barriers and organisational enablers. Several respondents mention uncertainty about material quality, high labour costs, and a lack of standardised methods as central challenges. However, factors such as strong management support, internal knowledge building and clear procedures are highlighted as keys to enabling reuse in refurbishment projects.

Uncertainty about quality and longevity was the most common barrier mentioned by the respondents. Project managers and clients often lack sufficient information on the quality of the material, creating uncertainty of how well the reused products will perform, especially in the case of technical systems or components subjected to high loads.

"We can't reuse something we don't trust—it's too risky if it fails later." (Respondent 1, Senior project manager)

Another recurring challenge highlighted in relation to reuse was the financial constraints. Although reused products are usually free or require a minor refurbishment, there are often high labour costs. The material is usually dismantled, cleaned, stored and transported before it can be reassembled. As a result, labour costs are disproportionately high compared to the value of the material.

"Economics are difficult. It adds up to a lot of hours for a product that you could otherwise have bought cheaply mass-produced new." (Respondent 9, Environmental Coordinator)

Respondents expressed that they were at the forefront of reuse compared to contractors, which led to a lack of standardised methods. For example, some referred to having to develop internal procedures for reuse themselves. *"We had to create our own methods for how to package reused windows to prevent damage. Now the contractors know what to do next time."* (Respondent 1, Site Manager)

The interviews mention several challenges, but they also reveal some enabling factors. Strong management commitment is a recurring factor, because of climate targets and political directives, organisations have started to work with reuse, which creates legitimacy and gives space to test new ways of working. Internal capacity building is another supportive factor, which is created by pilot projects where experience exchanges between reuse consultants and other actors have built internal capacity, leading to organisations being more able to manage without external help.

5.3 Indicators and Data Requirements for Conducting and Integrated Analysis of the Economic and Environmental Impact of Reuse

According to the respondents, there is a growing need for more structured data management and consolidated indicators to balance climate impact against economic factors when making decisions about reuse. At present, factors like energy use, CO_2

savings and cost estimates are typically evaluated separately, without a unified framework for comparison. This underscores the need to develop cohesive indicators and data requirements for conducting an integrated analysis of the environmental and economic effect of reuse. Several respondents also point out that current calculations often rely on standardized assumptions or tools created by external consultants, which makes it hard to integrate them into the specific context of each project. The absence of system support and clear indicators often leads to decisions being based more on experience than data-driven comparisons.

*"While we report CO_2 savings for each project, there is no structured approach to correlating these with cost data. This is something we are genuinely interested in developing further" (*Respondent 2, Senior Project Manager)

One of the main challenges highlighted in the interviews is that the labour costs associated with reuse risks overshadow its climate benefits. Since reuse typically involves more manual processes, such as deconstruction, reconditioning and storage, it can be difficult to demonstrate its cost-effectiveness compared to producing new material. The need for a new type of indicator or decision-support tool that can demonstrate climate savings relative to each unit of investments. It would improve transparency in situations involving conflicting goals and help focus on long-term priorities. Another recurring obstacle is the lack of technical information and traceability when it comes to reused materials. This issue is particularly evident when materials are sourced from external suppliers or demolition sites, where information regarding a component's lifespan, quality, or environmental impact is often unavailable.

"We don't purchase much reused material from external sources, it is difficult to know what one is getting." (Respondent 9, Environmental Coordinator)

However, there is a clear and pressing need to develop more transparent indicators, to enable informed decision-making that balances climate benefits with economic feasibility. This is crucial for ensuring that reuse can be prioritized in a more systematic and commercially viable manner in future projects.

5.4 Visualization Tools for Decision-Making

A recurring theme among the interviews was the need for improved visualization of the impacts of reuse to facilitate the decision-making process in reuse projects. Some respondents mentioned that climate calculations are often carried out but that the results of these are often difficult to interpret and are not integrated with any economic facts to a large extent

"We calculate CO_2 savings, but we don't link them to cost in a clear way. That's something we really want to develop."
(Respondent 2, Senior Project Manager)

A need for a tool that can help to visualize clear trade-offs between climate benefits and economic investment was requested by many respondents. One concrete idea mentioned in some interviews is to show "CO_2 equivalents saved per invested krona" to have a comparison value between different reuse options

"We need a reference value – how much are we willing to pay to save a kilo of CO_2? That would make decisions much easier."
(Respondent 9, Environmental Coordinator)

"If we had a tool showing exactly how many kilos of CO_2 are saved per invested krona, it would be easier to make the right decisions, even if they're not the cheapest."
(Respondent 3, Project Manager)

Several respondents mentioned that the current performance formats used are insufficient to visualize reuse impacts in a clear and comparable way. For example, bar charts are preferred to pie charts, as there is a perception that pie charts often hide proportions, creating confusion about what has the greatest climate impact. As one site manager expressed: "Pie charts are confusing - they make it hard to compare. *I prefer bar charts where you can actually see the drop in emissions."*
(Respondent 1, Site Manager).

Visualization is not only used as a decision support tool but is also seen as a communication tool. Several respondents mentioned how good visualization, such as

before-and-after pictures and simple diagrams showing climate savings, was crucial and used to convince internal and external stakeholders. *"We once reused all the interior materials in an apartment and showed the before-and-after. It looked brand new. That helped convince others it's possible.*" (Respondent 6, Senior Project Manager). In addition, some stakeholders use visualization at early stages of projects to identify materials with high climate impact to prioritize initiatives that provide the greatest effect in reuse investments. This is considered particularly useful for guiding material selection in the design phase and for communicating the value of reuse to contractors and consultants.

5.5 Internal Competence, Organization and Learning: Enablers for Systematic Reuse

A recurring insight from the interviews is the crucial role of internal expertise and a well-structured organization in enabling consistent reuse practices. Early-stage projects had to lean on external climate advisors and reuse consultants, which made projects more expensive. However, overtime in-house competency has grown, allowing teams to independently manage tasks that once required outside support. Across numerous organizations, knowledge about reuse has grown naturally over time, through experience. In the absence of prior knowledge, project teams stepped up early on by developing their own internal routines, especially in the early phase when contractors lacked prior experience for things like safeguarding and storing reclaimed material. The importance of contractor engagement and skills is also emphasised.

Respondents also note that having contractors with prior experience in reuse significantly improves the chances of successful implementation, especially in terms of handling material, keeping them in good condition and reinstalling them correctly. Even with progress in reuse practices, the high labour cost continues to be a major challenge. Since reuse involves more manual handling than using new materials, the added cost of labour can quickly surpass any cost savings from avoiding new purchases.

"It is quite expensive with labour costs today, and that is often what tips the scale against reuse." (Respondents 9, Environmental Coordinator)

Several respondents highlighted that reuse cannot depend on individual enthusiasm or personal commitment. Long-term strategies and organizational support are necessary

to make reuse a standard practice rather than an exception. In summary, building internal competence, reducing dependence on external consultants and putting clear internal processes in place are key enablers for scaling up reuse. These elements create the groundwork that allows reuse to become a sustainable and economically viable over in the long run.

"The biggest barrier is getting reuse into the actual decision-making structure; it is still too reliant on a few committed individuals pushing for it." (Respondent 4, Environmental Strategist)

5.6 Conflicts between Environmental and Financial goals: Reuse in Real-World Trade-Offs

A few respondents describe clear goal conflicts between sustainability goals and financial limitations in renovation projects. Although reuse is widely viewed as an environmental and desirable approach, justifying it economically can be challenging, especially when projects are operating with a strict budget.

"We are expected to meet both climate and budget goals, but they don't always align- so when there is a conflict, decision-makers aren't always sure which one to prioritize." (Respondent 9, Environmental Coordinator)

Respondents emphasize that economic feasibility is still required for project approval, even in organizations with strong sustainability agendas. In some situations, reused materials are significantly more expensive than due to added work, logistics, quality control and logistics, especially when there is no established reuse infrastructure in place.

Reuse often turns out to be more expensive because the process isn't efficient yet. We have hired reuse consultants, which added to the cost, even though the intent behind it was good. (Respondent 4, Environmental Strategist)

Several respondents argue that not all reuse measures need to be profitable immediately. For components with significant environmental impact, some are open to higher costs if the CO_2 savings are clear and substantial. The key, they say, is being able to measure and show those benefits. This issue is made worse by current procurement systems, which tend to prioritize the lowest price over long-term sustainability. Respondents

emphasized the need for new procurement models that factor in environmental impact, not just the initial cost.

"We still procure based on price. I'd really like to see climate impact included in the criteria, otherwise it's hard to justify reuse." (Respondents 4, Environmental strategist)

The findings suggest that decision-makers face real dilemmas: Should they focus on long-term sustainability or immediate cost savings? Without clear indicators and consistent ways to measure value against financial cost, these decisions often rely on personal judgment. A key step forward is the development of tools and metrics that make it easier to fairly compare economic and environmental value, making it easier to make informed decisions.

5.7 Roles, Responsibilities, and Collaboration in the Reuse Process

Numerous respondents stressed the importance of clearly defined roles and responsibilities to support a structured and consistent reuse process. Today, reuse tends to rely on driven individuals rather than embedded into how organizations operate. Without a clear mandate, these initiatives can easily be deprioritized when time or budget is tight.

"We need a clear structure where everyone knows their responsibility, otherwise things just slip through the cracks". (Respondent 6, Senior Project Manager)

There is also uncertainty surrounding how responsibilities are divided between consultants, clients, and contractors. Several respondents raised questions about who should guarantee the quality of reused materials, who handles storage and transport, and who tracks the environmental impact. Contractors are vital in realizing reuse ambitions, but respondents report large variation in engagements and competence. Projects usually go well when contractors are motivated and familiar with reuse. If they are not interested or don't have the right knowledge, progress can quickly come to halt.

"We have had contractors clean and reinstall toilets, and it turned out really well. But that only happens when they are truly on board". (Respondents 6, Senior Project Manager)

In projects where reuse has worked well, success was often tied to clearly assigning responsibility from the start and a shared sense of purpose across the whole team. It is also crucial to involve key stakeholders early in the project such as design teams, environmental coordinator. Some organizations have started to investigate having dedicated reuse coordinators or support teams to assist project managers and ease the workload on individual roles. Others call for internal databases and shared routines that can be applied across multiple projects to streamline the reduce process. To sum up, the findings suggest that clearly defined roles, aligned goals and organized collaboration are essential to making reuse work. Without this foundation, reuse is dependent on individual initiatives instead of becoming a standard practice of how construction projects are done.

6. Analysis

This chapter discusses the findings of the study considering the theoretical foundation outlined in the earlier chapters. The analysis builds on core concepts like circular economy, Life Cycle Sustainability Assessment (LCSA) and multi-criteria decision-making (MCDM), particularly through the TOPSIS method. The analysis looks at how the empirical results align with or challenge theoretical expectations and sheds light on practical issues like choosing the right indicators, organizational competence and balancing environmental goals with financial limits.

6.1 Technology, Climate and Economy Converging in Decision-Making

Making decisions about reuse in renovation projects is a complex process that requires trade-offs between technical requirements, environmental ambitions, and economic conditions. The empirical study shows that technical lifetime is often considered the most important criterion when choosing reusable materials, to mitigate the risk of replacing the reused component, which loses both the economic and environmental benefits. These insights are confirmed by Kim and Kim (2020) who emphasise in their study that technical lifetime should be the first criterion in reuse decisions and by Gerhardsson et al. (2020), who highlight the lack of clear quality assessments and documentation as an obstacle to the widespread implementation of reuse in the construction industry.

The interviews show that often, climate objectives outweigh financial considerations in the company. Several project managers use reuse to achieve the company's long-term sustainability goals, even when it does not lead to direct cost savings. This provides a value shift in decision-making where non-financial goals are given greater weight, which is also highlighted by Fregonara (2023), who advocates that environmental impact as embodied carbon should be integrated into traditional financial investment decisions.

Decisions tend to be based on traditional and short-term economic calculations rather than a holistic view because there is a lack of business models and economic incentives that support reuse. As Crawford et al (2017) point out, it is mainly high labour costs

and logistical challenges that make reuse unprofitable in the short term. This is a problem that could have been mitigated by political funds or new business models with integrated environmental perspectives.

The study has applied the TOPSIS model to address the conflicting objectives that arise in reuse decisions. The model makes it possible to weigh several criteria with different units such as (CO_2, SEK, technical lifetime etc.) to transparently compare different options. With high cost and significant climate benefits, TOPSIS provides clear decision support for reuse choices by showing which option is 'closest to the ideal'. For project managers lacking a structured decision-making basis, such model is crucial, as also emphasised in the study by Küpfer et al. (2021).

6.2 Visualisation and Decision support: From insight to Action

A recurring observation from the empirical data is the lack of a tool that enables integrated and transparent decisions on material reuse. The interviews show that there is a need for a tool that not only collects data on CO_2 emissions and costs but also visualises these in a clear and comparable format. Visualisation appears to be crucial to strengthening the argumentation around reuse for internal and external actors such as consultants, contractors, and clients. This is in line with Gobbo et al. (2024) who emphasise the importance of using indicator-based visualisation of reuse to create understanding throughout the chain of a project, while Costa et al. (2019) propose MCDA-based tools for complex decisions that combine environmental and cost considerations.

6.2.1 Criteria and Weighting: Structuring Priorities in Reuse Decisions

The most crucial criteria for deciding on reuse in renovation projects were identified through a combination of systematic literature review and semi-structured interviews with key people in the real estate and construction industry. The literature review was the basis for the formulation of the first set of criteria, where CO_2 savings, economic life and cost were recurrent factors in previous research on reuse. CO_2 savings were given particular weight based on its central role as a key climate metric in early MCDA studies.

Through the interviews, respondents identified the criteria that weigh most heavily in decision-making on reuse. The most frequently mentioned criteria with the highest importance were given more weight in the model. For example, CO_2 savings and technology lifetime were emphasised as the most important criterion by all respondents. Economic aspects were most often described as important but not as decisive if there is a clear environmental benefit. After coding and qualitatively analysing the interviews, the criteria were weighted according to how often they were mentioned by the respondents. The final weighting for each criterion is shown in the table below and represents how the criteria are handled in the TOPSIS model.

Criterion	Type	Weight (%)
Cost	Non-beneficial	15
CO_2 emissions	Non-beneficial	35
Logistics complexity	Non-beneficial	10
Lifespan	Beneficial	25
Energy savings	Beneficial	15

Table 3: Weighting of Decision Criteria in the TOPSIS Model

6.2.2 Applying the TOPSIS Model in a Reuse Context

The aim of the TOPSIS-model in this study is to provide technical comparability between options and to be used as a communication tool by providing stakeholders with clearly scored results. This is in line with the Vardopoulos et al. (2021) study, which shows how AHP and TOPSIS can be used to make assessments of reuse options by including environmental, economic and technical criteria in a construction project.

The model was applied to evaluate two windows alternatives by inserting the material data in the table below, see figure 4. The table in the figure outlines the key input data employed in the TOPSIS-based decision support tool for window analysis. Two alternatives are compared: a new window and a reused one. The estimation process depends on 5 aspects as follows: cost (SEK), carbon dioxide emissions (kg CO_2), logistical complexity (rated on a scale of 1-10), lifetime (years) and annual energy savings (kWh/year). Each criteria has its own weight assigned above, with CO_2 emissions having the most significant weight (0.35) making it the main concern in the study.

The purpose of the table is to compare the environmental and economic aspects of each option quantitatively. The example in the table shows that the recycled window has significant climate benefits and lower costs, while the new window has a longer lifetime and slightly better energy performance. The logistics aspect suggests that the reuse of a window introduces higher process complexity, as it requires careful dismantling to avoid damage, additional coordination for transport, and customized reinstallation procedures.

Windows					
Weightage	Non Benf	Non Benf.2	Non Benf.3	Benf.	Benf.2
	0.15	0.35	0.1	0.25	0.15
Alternative	Cost (SEK)	CO2 emissions (kg)	Logistics (1-10)	Lifespan (years)	Energy savings (kWh/year)
New Window	6000	120	5	30	250
Reused Window	4000	20	8	20	160
Material 3					
Material 4					
Material 5					

Figure 4: Material input from excel sheet.

The values in the table serve as input to the TOPSIS model, where they are first normalized and weighted according to the relative importance of each criterion (see Eq. 2 and Eq. 3). This procedure ensures a fair comparison between the alternatives regardless of units or magnitude. Next, the distance of each alternative to both the ideal (positive) and the least desirable (negative) solution is calculated (see Eq. 4 and Eq. 5). Finally, a closeness coefficient (Ci) is determined for each alternative (see Eq 6), indicating how close it is to the ideal solution. The alternatives are then ranked based on their Ci values, with higher values indicating more sustainable and well-balanced options.

In the example shown in Figure 5, the recycled window achieved the highest Ci value (0.68), making it the most desirable alternative from both economic and environmental perspectives. This is also illustrated by the green highlight in the figure.

Windows								
Alternatives	Cost	CO2 emissions	Logistics	Lifespan	Energy savings		Si+	Si-
New Window	0.83205	0.986393924	0.52999894	0.832050294	0.842271401		0.371	0.245
Reused Window	0.5547	0.164398987	0.8479983	0.554700196	0.539053696		0.156	0.332
Material 3	0	0	0	0	0		0.243	0.377
Material 4	0	0	0	0	0		0.243	0.377
Material 5	0	0	0	0	0		0.243	0.377
V+	0	0	0	0.208012574	0.12634071			
V-	0.12481	0.345237873	0.08479983	0	0			
Alternatives	Cost	CO2 emissions	Logistics	Lifespan	Energy savings	Pi		
New Window	0.12	0.35	0.05	0.21	0.13	0.40		
Reused Window	0.08	0.06	0.08	0.14	0.08	0.68		
Material 3	0.00	0.00	0.00	0.00	0.00	0.61		
Material 4	0.00	0.00	0.00	0.00	0.00	0.61		
Material 5	0.00	0.00	0.00	0.00	0.00	0.61		

Figure 5: TOPSIS calculations and results.

Figure 5 illustrates an example of the form of the results of the TOPSIS analysis within the Excel file. For ease of comparisons among different reuse alternatives, the same type of table has been created for six different material groups, with each table including appropriate indicators such as cost, climate impact and technical evaluation. Each group has been analysed separately to ensure that specific conditions and requirements inherent to the nature of the material are part of the decision-making foundation.

In some cases, the criteria "energy savings" is not included, either to unavailability of data or being not applicable to the provided material. Therefore, weighting for the remaining criteria in some of the tables has accordingly been adjusted proportionally in order to maintain consistency and that the evaluation is reflective of realistic priorities.

6.2.3 Consolidating Results: Visualisation as a Decision-Making Tool

The best-performing reuse alternative per material group is shown in the results flick, as illustrated in figure 6. The total cost (SEK) and CO_2 emissions (kg) is provided. The purpose of this visualisation is to display the outcomes of different tables in a single snapshot so that materials with favourable climate performance and economic reasonableness can be separated.

Group	Best alternative	Score	Cost (SEK)	CO2 emissions (kg)
Windows	Reused Window	0,81	3000	20
Doors	New door	1	1000	40
Group 3	Reused steel	0,70256816	500	100
Group 4	Material 3	0,557358488	20000	400
Group 5	Reused Brick	0,853200692	500	100
Group 6	Reused WC	0,782512319	100	230
			25100	**890**

Group	Second Best Alternative	Score	Cost (SEK)	CO2 emissions (kg)
Windows	New Window	0,705235057	6000	120
Doors	Reused door	0,547069793	3800	50
Group 3	Structural Steel	0,424629662	1000	1000
Group 4	Reused Gypsum	0,513437746	15000	900
Group 5	New Brick	0,61700281	1000	100
Group 6	Material 4	0,622196857	0	0
			26800	**2170**

Figure 6: Visualisation of best material choices from six different material groups according to TOPSIS analysis.

The key figure CO_2 savings per invested krona is used as a way of materialising the link between investment and climate gain, as asked by many respondents during the interviews. This is calculated as shown in Equation 7, by dividing the emission difference between the second-best and best alternatives by the cost of the best option.

$$CO_2\ savings\ per\ SEK\ = \frac{CO_2^{second_best} - CO_2^{best}}{Cost_{best}}$$

Eq. 7

6.3 The need for Indicators and Systematised data collection

There are currently no established standards for measuring reuse in construction projects. Several project managers emphasized in the interviews that they would like to work more data driven, but that there is a lack of standardized or reliable tools that pull all the key metrics together. Leading to decisions being driven by gut instinct or past experience instead of solid analysis.

The data reveal that the issue isn't just picking the right metrics, it is also about how they are collected. Several respondents mentioned that information on reuse is often scattered, hard to track down, or locked away in outdated documents. Byers et al. (2024) reached a similar conclusion, without modern digital databases or a central hub for

material quality, environmental metrics and reuse potential, circular construction simply can't advance.

A suggestion that kept coming up by the respondents in the interviews is to introduce the indicator "cost per invested krona of CO_2 saved" as a key performance metric. This allows for a direct comparison of, for example, the climate payoff of reusing doors against reusing roof tiles on per krona invested. Gobbo et al. (2024) advocate for this kind of approach, arguing that linking environmental benefits to clear economic figures helps anchor decision-making. If you can clearly demonstrate that one reuse action saves five times more CO_2 than another for the same price, it's much more likely to be chosen. In other words, it is not just a technical tool but a political one as well.

Both the literature and the interviews consistently highlighted the need for clear and reliable indicators to evaluate reuse options. Empirical findings identified three indicators as essential to assessing reuse alternatives: Life Cycle Cost, Global Warming Potential (GWP) and technical lifespan. These indicators capture the environmental and financial considerations while supporting long-term decision-making. Respondents stressed that reused materials should last as long as their surrounding components, an aspect directly tied to technical lifespan. Similarly, Life Cycle Cost enables a comprehensive view of cost implications over time and Global Warming Potential is vital for understanding CO_2 savings. These indicators came up often in the literature (Fregonara, 2023; Guinée et al., 2018) and were also confirmed during the interviews. Together, they provide a more balanced and measurable way to assess reuse strategies, which is why they were built into the TOPSIS model used in this study.

6.4 Internal Competence and Organisational Maturity

The organization's internal capacity to work with reuse proved to be one of the most critical factors in this study. In practice, it is not just knowing the materials or doing climate calculations that is decisive; it is also the ability to turn that knowledge into clear routines, structured decision-making, and project management. However, this also makes reuse vulnerable. If key individuals leave, when deadlines tighten, or other priorities emerge, reuse initiatives frequently get sidelined.

Empirical evidence shows that having the right skills in-house and a culture of learning within an organization are vital factors for reuse to be implemented in a structured way.

This is confirmed in the literature by Ericsson et al. (2024), who demonstrate that developers who already know how to work with reuse are better equipped to spot reuse opportunities early and handle the process without needing outside help. The findings don't just show how theory is manifested in practice but also exposes the challenges that emerge when simplified models are applied to complex realities. This underscores the importance of creating tools and processes that can effectively deal with these challenges, rather than assuming they do not exist.

Rose and Stegemann (2018) emphasize the importance of establishing a proactive system for managing components, where reuse is a normal part of the process, instead of being treated as a rare exception. Their study reveals that the key to successful reuse is based on early identification, proper storage and facilitating effective information sharing, something that several respondents also confirmed. Durmisevic et al. (2021) points out that the industry lacks standards for Design for Disassembly (DfD) and Design for Reuse (DfR), which forces individuals to create their own solution. This need is echoed in the empirical findings, where some respondents reported having to create their own procedures for packing and storage due to the lack of clear direction. Ericsson et al. (2024) add that developers with their own reuse expertise not only identify more opportunities but also implement them more efficiently.

Another important theme is the competence of external partners, especially contractors. According to several respondents, the contractor's attitude towards reuse often determines whether it works in practice. Projects tend to struggle when contractors are not motivated or interested in reuse. In contrast, when contractors are experienced and engaged, reuse usually runs more smoothly. Iacovidou and Purnell (2016) also point this out, noting that reuse often fails at the interfaces between different actors, which is why it's important to clearly define responsibilities in contracts and procurement processes.

In the end, it all comes down to organizational maturity, which is essential to succeeding with reuse. Competence must exist at several levels: from top management to project management, and all the way to those carrying out the work. Clear processes, defined responsibilities and ways to track progress and share what's been learned is essential. Without that structure, reuse remains the exception rather than the norm.

6.5 Conflicting Objectives in Practice: Economy vs Climate

Tensions between financial and environmental goals are a central theme in both the empirical data and the literature. Respondents recount cases where reuse, despite offering clear climate benefits, was overlooked in favour of less expensive new construction, particularly in procurement processes where cost is the deciding factor. Fregonara (2023) supports this view, pointing out that traditional tools like Net Present Value (NPV) fail to account for environmental impact because CO_2 emissions aren't assigned a financial value.
Crawford et al. (2017) highlight logistic challenges and a lack of financial incentives as a major obstacle to reuse, concerns that are also raised by numerous respondents who cite higher labour costs for disassembly and storage. Kim and Kim (2020) make a similar point that although reuse may be technically feasible, the additional steps involved often lead to higher costs, making it too expensive to be a realistic option.

One way to balance these conflicting goals is to develop indicators, such as " CO_2 saved per invested krona" which facilitate clearer and more transparent comparisons of different options. This approach is supported by both the empirical findings and by Gobbo et al. (2024) and Vardopoulos et al. (2021), who illustrate how multi-criteria models can help weigh both climate impact and economic objectives. In summary, solving this conflict of goals means rethinking how value is defined, shifting from focusing on short-term cost savings to prioritize long-term sustainability. Procurement models that include climate indicators in their selection process can play an instrumental role in supporting this shift towards more sustainable decision-making, as proposed by Berlin et al. (2020).

When the handoffs between everyone involved, like the client, architects, contractors and environmental coordinator, aren't clear, vital decisions about dismantling, reuse and storage gets delayed or overlooked. Iacovidou and Purnell (2016) notes that many obstacles to reuse come from interface gaps, where no one takes full responsibilities. To address this, Eray et al. (2019) propose the use of Interface Management System, which clarifies responsibilities, timelines and expected deliverables. In summary, practical reuse demands more than enthusiasm and expertise, it needs a solid framework.

6.6 Roles, Responsibilities and Co-Operation in the Reuse Process

Both the literature and empirical findings emphasize that clearly defined roles and responsibilities are vital for successful reuse. Respondents described how a lack of structure causes initiatives to get lost along the way, a phenomenon Eray et al. (2019) call a lack of interface management. Their research shows that when coordination between different parties is missing, it frequently results in project delays and reduced levels of reuse. This not only illustrates how theory plays out in real situations but also reveals the limitations of idealized models when they encounter the complexities of actual practice. Numerous respondents recommended creating the role of a dedicated reuse coordinator, someone who according to Foyn et al. (2023), can serve as the link between technical expertise and project management. This also aligns with Bertin et al. (2020), who advocate for a systematic role for reuse throughout the entire project lifecycle.

Durmisevic et al. (2021) emphasize that making reuse work requires close collaboration between architects, clients and contractors right from the start of the design process. This was also a common theme in the interviews, where early coordination and a unified vision are essential for success. The contractor's role is particularly crucial in reuse projects. Contractors who already know how to dismantle, store and reinstall become key figures in making reuse plans into reality. As a result, there is an increasing demand for pre-qualification or training for contractors during the procurement stage. Researchers like Bertin et al. (2020) and Gobbo et al. (2024) show how a tool like BIM can clarify responsibilities and improve real-time monitoring.

7. Discussion

This chapter discusses the empirical findings in relation to the theoretical framework and literature review, with the aim of critically exploring how reuse practices can be enhanced through more effective decision-making, clearer visualization and more effective organizational practices. The discussion is structured around key themes that emerged during the analysis, such as the alignment of environmental and economic objectives, the importance of in-house expertise and the demand for standardized tools and indicators.

The theory-based analysis identifies reuse as a core principle of the circular economy, highlighting its potential to reduce environmental footprints and enhance economic efficiency. Empirical evidence supports this by showing that real estate companies now see reuse more as a commitment out of necessity as opposed to a voluntary step towards sustainability because of the realization of its alignment with long-term climate aspirations. The study also reveals that there exists a gap between environmental vision and day-to-day practice, especially regarding challenges in finance as well as logistics. Respondents never missed to emphasize that while reuse is environmentally friendly, technical practicability and lifecycle performance remain the overarching decision-making drivers. This reflects the focus of the literature on material quality and durability as the prerequisites of reuse (Kim & Kim, 2020; Gerhardsson et al., 2020). Balancing reuse activities with building control, energy efficiency requirements, and functional lifespan is thus essential to grow reuse practice in a sustainable way.

The conflict between economic constraints and environmental objectives emerges as a central theme in both the interviews and the reviewed literature. Interviewers acknowledged these costs but highlighted the long-run advantage of achieving climate targets even if there are no short-run economic rewards to be obtained. This corroborates Fregonara's (2023) argument that traditional economic measures such as NPV fail to account for embodied carbon and energy impacts. There is also a need for better visualization tools to convey the benefits of reuse. Several respondents noted that while CO_2 savings are often calculated, they are seldom presented in a way that allows for easy comparison with costs or other project factors. This observation is consistent with Gobbo et al. (2024), who suggest that real-time visual indicators, such as reuse rate (RR) and avoided emissions are essential for making informed decisions. An

example suggested in the interviews was a metric such as CO_2 saved per invested SEK. This kind of measure would help project teams not only compare options based on total impact but also evaluate how efficient resources are being used and return on investment. The approach is also supported in the literature: Fregonara and Guinée et al. (2018) emphasise the importance of integrated indicators that combine climate performance with life cycle cost metrics.

Visualization was a powerful impetus for reuse adoption. Empirical research (Gobbo et al., 2024; Costa et al., 2019) and literature point to the lack of tool sets that holistically compare climate and cost advantages as the key deficiency. Use of the TOPSIS model in this work filled this gap by enabling stakeholders to evaluate reuse alternatives against a range of criteria in a structured way. The model supports decision-making and facilitates communication between distant stakeholders. From the above findings, graphical outputs such as bar charts or before-and-after appearances boost stakeholder confidence and facilitate buy-in. This shows the capacity of data-driven tools to not just optimize decisions but also influence cultural mindsets and organizational behaviour toward reuse.

Although TOPSIS provides a systematic method for handling multi-criteria decisions, its utilization in reuse decision-making warrants thoughtful application. Its weighting of the criteria, for example, is subjectively determined. Stakeholder interviews showed diverging priorities, whereas environmental coordinators prioritized climate performance, project managers and site managers were inclined to focus on practicality and cost-effectiveness. This would imply that the weightings and selection of criteria in the TOPSIS methodology may be open to general contention among project teams, thereby jeopardizing bias in the results.

TOPSIS assumes linearity of trade-offs among criteria, which may not be the case in real life. For example, climate targets such as those cited by respondents aiming for a 90% reduction in emissions by 2030 are typically non-negotiable. A linear trade-off between emissions and cost will oversimplify decisions that are made with some environmental limits to be met regardless of economic sacrifices.

Further, the effectiveness of TOPSIS is highly dependent on data availability and quality. As proposed by the interviews, integrated systems for contrasting CO_2 savings with costs are usually not available in organizations. This not only limits the model's

accuracy but also poses a challenge to its continued application to projects. As Fregonara (2023) stressed, there exists a development gap of incorporating environmental and economic aspects in most life cycle investment models. Future studies can investigate different approaches, e.g., PROMETHEE (Küpfer et al., 2021), AHP (Vardopoulos et al., 2021), or fuzzy logic-based models, which are potentially better equipped to address uncertainty and qualitative assessments in intricate reuse situations.

The success of reuse initiatives largely depends on the organizational maturity. The literature emphasises the need to develop internal competencies, establishing consistent processes and involving contractors early on (Ericsson et al., 2024; Durmisevic et al., 2021). Respondents reinforced this view, noting that their reuse practices improved through pilot practices and shared knowledge internally. Despite this progress, many respondents still depended heavily on individual effort rather than structured systems in place. The discussion indicates that without clear routines and defined roles, reuse efforts remain unstable, vulnerable to changes in the project or team. Assigning dedicated roles, like reuse coordinators and adopting digital tools to monitor material performance and availability, are simple and effective ways to make reuse a regular part of an organization's everyday operations.

Another important takeaway was the structural limitation of existing procurement systems. Several interviewees criticized how cost-focused procurement models often undermine reuse efforts, even when environmental benefits are clear. This concern is echoed in the literature, which notes that unless environmental metrics are embedded into the procurement criteria, reuse tends to get overlooked (Berlin et al 2020; Iacovidou & Purnell, 2016). This underscores the need for broader systematic changes, such as policy incentives, updating tender process and procurement criteria that account for the full environmental cost of carbon emissions.

8. Conclusion

This study has investigated how reuse decisions within the building sector can be optimized through an equilibrium between economic and environmental factors through the support of visualization tools and optimally organized decision-making models. The study combines theoretical results in circular economy and life cycle sustainability assessment with practical experiences collected through qualitative interviews among real estate professionals. The outcome decision-support framework offers a data-based approach to evaluate reuse possibilities based on CO_2 savings, financial viability, and technical feasibility.

The findings indicate that, although environmental goals are likely to promote reuse initiatives, there are significant barriers. They include high labour costs, uncertain material quality, a lack of standard indicators, and a shortage of integrated tools for assessing climate and cost trade-offs. Nevertheless, most companies are willing to accord reuse priority whenever it is associated with long-term climate goals, even in the absence of short-term economic incentives. This is a change of values, from short-term financial prosperity to long-term environmental care.

One of the key contributions of the thesis is the use of the TOPSIS model, which makes it easier to compare reuse options against a set of criteria. The model gives decision-makers a capability to identify which option is closest to the "ideal solution" and offers an explicit and systematic way to justify reuse investments. Furthermore, the use of metrics such as "CO_2 saved per SEK invested" has been particularly helpful to demonstrate trade-offs and to support the argument for reuse in those cases where environmental objectives and economic interests are likely to conflict.

Another key takeaway is how vital internal skills and organizational maturity are for making reuse work in a consistent way. Organizations that prioritize staff training, set up clear routines and foster strong internal coordination are better positioned to turn reuse into a regular practice. The study also points out the need for procurement models that go beyond just looking at cost, emphasizing the importance of making sustainability a central part of the decision- making process.

Ultimately, this study highlights that successful reuse in construction is not solely a technical issue, but also a matter of organizational capability. Visualization is vital for

making reuse more concrete and easier to communicate. The study found that existing tools are often inadequate when it comes to combining CO_2 and cost data. Respondents emphasised the usefulness of clear, intuitive indicators and expressed a clear need for interactive dashboards that can display trade-offs in real time. These kinds of tools can help build understanding and acceptance of reuse strategies, especially among stakeholders without technical background. With clear decision-making tools, well-designed visual tools and better internal capacitors, reuse has the potential to shift from a niche practice to becoming a key part of sustainable building practices

8.2 Suggestions on Future Studies

Although this study has provided valuable insight into how visualization and structured decision-making can support reuse, there are still several areas that still need further developments. There is also a strong need for standardized indicators, "such as CO_2 savings per krona" to allow for more transparent comparisons and strengthen the incentives for reuse in the procurement process.

In addition, more research is needed on policy development, economic instruments and how these affect stakeholders' willingness to invest in circular solutions to drive the industry's transition. Long-term life cycle analyses can help to highlight the economic value of reuse over time in relation to property value and operating costs. Finally, competence development through training and internal procedures should be prioritised, making reuse a natural part of the construction process rather than an exception.

References

A systematic review of life cycle sustainability assessment: Current state, methodological challenges, and implementation issues. (2019). *Science of the Total Environment*, *686*, 774–787. https://doi.org/10.1016/j.scitotenv.2019.05.435

A Wöhler, Hollberg, A., Rosado, L., & Wallbaum, H. (2024). Circular Building Strategies: A Categorization Framework. *IOP Conference Series Earth and Environmental Science*, *1363*(1), 012038–012038. https://doi.org/10.1088/1755-1315/1363/1/012038

Al-Najjar, A., & Malmqvist, T. (2025). Embodied carbon saving of reusing concrete elements in new buildings: A Swedish pilot study. *Resources, Conservation and Recycling*, *212*, 107930. https://doi.org/10.1016/j.resconrec.2024.107930

Anastasiades, K., Goffin, J., Rinke, M., Buyle, M., Audenaert, A., & Blom, J. (2021). Standardisation: An essential enabler for the circular reuse of construction components? A trajectory for a cleaner European construction industry. *Journal of Cleaner Production*, *298*, 126864. https://doi.org/10.1016/j.jclepro.2021.126864

Bellini, A., Andersen, B., Nora Johanne Klungseth, & Tadayon, A. (2024). Achieving a circular economy through the effective reuse of construction products: A case study of a residential building. *Journal of Cleaner Production*, *450*, 141753–141753. https://doi.org/10.1016/j.jclepro.2024.141753

Bertin, I., Mesnil, R., Jaeger, J.-M., Feraille, A., & Le Roy, R. (2020). A BIM-Based Framework and Databank for Reusing Load-Bearing Structural Elements. *Sustainability*, *12*(8), 3147. https://doi.org/10.3390/su12083147

Bertin, I., Saadé, M., Le Roy, R., Jaeger, J.-M., & Feraille, A. (2022). Environmental impacts of Design for Reuse practices in the building sector. Journal of Cleaner Production, 349, 131228. https://doi.org/10.1016/j.jclepro.2022.131228

Bullen, P., & Love, P. (2011). A new future for the past: a model for adaptive reuse decision-making. *Built Environment Project and Asset Management*, *1*(1), 32–44. https://doi.org/10.1108/20441241111143768

Byers, B. S., Raghu, D., Olumo, A., De Wolf, C., & Haas, C. (2024). From research to practice: A review on technologies for addressing the information gap for building material reuse in circular construction. *Sustainable Production and Consumption*, *45*, 177–191. https://doi.org/10.1016/j.spc.2023.12.017

Casey, G., & Galor, O. (2017). *Avoiding Trade-Offs: Can population policies promote environmental protection and alleviate poverty?* https://mahb.stanford.edu/wp-

content/uploads/2017/01/MAHBBlog_AvoidingTradeOffs_GCaseyOGalor_Jan2017.pdf

Cervantes Puma, G. C., Salles, A., Turk, J., Ungureanu, V., & Bragança, L. (2024). Utilisation of Reused Steel and Slag: Analysing the Circular Economy Benefits through Three Case Studies. *Buildings*, *14*(4), 979. https://doi.org/10.3390/buildings14040979

Charlotte, L., Eberhardt, M., & Birgisdottir, H. (2022). Building the future using the existing building stock: the environmental potential of reuse. *IOP Conference Series: Earth and Environmental Science*, *1078*(1), 012020. https://doi.org/10.1088/1755-1315/1078/1/012020

Cheng Siew Goh, Su, F., & Rowlinson, S. (2023). Exploring Economic Impacts of Sustainable Construction Projects on Stakeholders: the Role of Integrated Project Delivery. *Journal of Legal Affairs and Dispute Resolution in Engineering and Construction*, *15*(3). https://doi.org/10.1061/jladah.ladr-963

Chiletto, T. O., E Knapen, & Passarelli, R. N. (2024). Design for Disassembly and Reuse: A Synthesis for Timber Construction. *IOP Conference Series Earth and Environmental Science*, *1363*(1), 012040–012040. https://doi.org/10.1088/1755-1315/1363/1/012040

Crawford, R. H., Mathur, D., & Gerritsen, R. (2017). Barriers to Improving the Environmental Performance of Construction Waste Management in Remote Communities. *Procedia Engineering*, *196*, 830–837. https://doi.org/10.1016/j.proeng.2017.08.014

DiCicco-Bloom, B., & Crabtree, B. F. (2006). The Qualitative Research Interview. *Medical Education*, *40*(4), 314–321. https://doi.org/10.1111/j.1365-2929.2006.02418.x

Eberhardt, L. C. M., Birgisdottir, H., & Birkved, M. (2019). Potential of Circular Economy in Sustainable Buildings. *IOP Conference Series: Materials Science and Engineering*, *471*(9), 092051. https://doi.org/10.1088/1757-899x/471/9/092051

Ellen MacArthur Foundation. (n.d.). *Circular economy introduction*. Ellen MacArthur Foundation. Retrieved February 28, 2025, from https://www.ellenmacarthurfoundation.org/topics/circular-economy-introduction/overview

Environment, U. N. (2017, September 16). *Towards a life cycle sustainability assessment: making informed choices on products*. UNEP - UN Environment Programme. https://www.unep.org/resources/report/towards-life-cycle-sustainability-assessment-making-informed-choices-products

Eray, E., Sanchez, B., & Haas, C. (2019). Usage of Interface Management System in Adaptive Reuse of Buildings. *Buildings*, *9*(5), 105. https://doi.org/10.3390/buildings9050105

Ericsson, F., Mjörnell, K., & Janson, U. (2024). Reuse of building materials—the perspective of Swedish clients. *Cleaner Engineering and Technology*, *23*, 100848. https://doi.org/10.1016/j.clet.2024.100848

Flick, U. (2004, January 1). *Triangulation in qualitative research*. https://www.researchgate.net/publication/284388447_Triangulation_in_qualitative_research

Foyn, T., Fahlstedt , O., & Bohne, R. (2023). Digital information management to increase the reuse of building materials. *Journal of Physics*, *2600*(19), 192013–192013. https://doi.org/10.1088/1742-6596/2600/19/192013

Fregonara, E. (2023). Building upcycling or building reconstruction? The "Global Benefit" perspective to support investment decisions for sustainable cities. *Frontiers in Sustainable Cities*, *5*. https://doi.org/10.3389/frsc.2023.1282748

Fufa, S. M., Brown, M. K., Hauge, Å. L., Johnsen, S. Å., & Fjellheim, K. (2023). User perspectives on reuse of construction products in Norway: Results of a national survey. *Journal of Cleaner Production*, *408*, 137067. https://doi.org/10.1016/j.jclepro.2023.137067

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

Gobbo, É., Nia, E. M., Straub, A., & Stephan, A. (2024). Exploring the effective reuse rate of materials and elements in the construction sector. *Journal of Building Engineering*, *98*, 111344. https://doi.org/10.1016/j.jobe.2024.111344

Guinée, J. B. (2015). Life cycle sustainability assessment: What is it and what are its challenges? In R. Clift & A. Druckman (Eds.), *Taking stock of industrial ecology* (pp. 45–68). Springer. https://doi.org/10.1007/978-3-319-20571-7_3

Guo, D., Ramos, R. L. M., & Wang, F. (2024). Qualitative online interviews: Voices of applied linguistics researchers. *Research Methods in Applied Linguistics*, *3*(3), 100130. https://doi.org/10.1016/j.rmal.2024.100130

Habib, A., Ausamah Al Houri, Bashar Alibrahim, & Habib, M. (2025). Behavior and sustainability benefits of modular steel buildings. *International Journal of Sustainable Engineering*, *18*(1). https://doi.org/10.1080/19397038.2025.2459715

Hansen, J. (2013). Assessing “Dangerous Climate Change”: Required Reduction of Carbon Emissions to Protect Young People, Future Generations and Nature. *PloS One*, *8*(12). https://doi.org/10.1371/journal.pone.0081648

Helmchen, H. (2011). Ethical issues in naturalistic versus controlled trials. *What Can We Learn from Naturalistic vs Controlled Trials?*, *13*(2), 173–182. https://doi.org/10.31887/dcns.2011.13.2/hhelmchen

Hoppe, A. C., & Minke, C. (2025). Reducing Environmental Impacts of Water Electrolysis Systems by Reuse and Recycling: Life Cycle Assessment of a 5 MW Alkaline Water Electrolysis Plant. *Energies*, *18*(4), 796. https://doi.org/10.3390/en18040796

Hu, M., & Jakub Świerzawskib. (2024). Assessing the environmental benefits of adaptive reuse in historical buildings. A case study of a life cycle assessment approach. *Sustainable Environment*, *10*(1). https://doi.org/10.1080/27658511.2024.2375439

Huang, Y., & Jiang, W. (2017). Extension of TOPSIS Method and its Application in Investment. *Arabian Journal for Science and Engineering*, *43*(2), 693–705. https://doi.org/10.1007/s13369-017-2736-3

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

Ioana, A., Cristina, D., Constantin, N., Augustin Semenescu, Marina, R., Dumitru Viorel Deonise, & Istrate, A. (2024). *Strategies for Carbon Neutrality: Innovations in Construction Material Production and Usage*. https://doi.org/10.20944/preprints202406.1352.v1

Isuri Amarasinghe, Liu, T., Stewart, R. A., & Mostafa, S. (2024). Paving the way for lowering embodied carbon emissions in the building and construction sector. *Clean Technologies and Environmental Policy*. https://doi.org/10.1007/s10098-024-03023-6

Jiahua, P. (2021). Lowering the Carbon Emissions Peak and Accelerating the Transition Towards Net Zero Carbon. *Chinese Journal of Urban and Environmental Studies*, 2150013. https://doi.org/10.1142/s2345748121500135

Kim, S., & Kim, S.-A. (2020). Framework for Designing Sustainable Structures through Steel Beam Reuse. *Sustainability*, *12*(22), 9494. https://doi.org/10.3390/su12229494

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

Kozminska, U. (2020). Circular Economy in Nordic Architecture. Thoughts on the process, practices, and case studies. *IOP Conference Series: Earth and Environmental Science*, *588*, 042042. https://doi.org/10.1088/1755-1315/588/4/042042

Krishnan, A. R., Hamid, M. R., Tanakinjal, G. H., Asli, M. F., Boniface, B., & Ghazali, M. F. (2023). An investigation to offer conclusive recommendations on suitable benefit/cost criteria-based normalization methods for TOPSIS. *MethodsX*, *10*, 102227. https://doi.org/10.1016/j.mex.2023.102227

Küpfer, C., Bastien-Masse, M., & Fivet, C. (2023). Reuse of concrete components in new construction projects: Critical review of 77 circular precedents. *Journal of Cleaner Production*, *383*, 135235. https://doi.org/10.1016/j.jclepro.2022.135235

Küpfer, C., Bertola, N., Brütting, J., & Fivet, C. (2021). Decision Framework to Balance Environmental, Technical, Logistical, and Economic Criteria When Designing Structures With Reused Components. *Frontiers in Sustainability*, *2*. https://doi.org/10.3389/frsus.2021.689877

Laefer, D. F., & Manke, J. P. (2008). Building Reuse Assessment for Sustainable Urban Reconstruction. *Journal of Construction Engineering and Management*, *134*(3), 217–227. https://doi.org/10.1061/(asce)0733-9364(2008)134:3(217)

Ledakowicz, S., & Ziemińska-Stolarska, A. (2023). The role of life cycle assessment in the implementation of 1 circular economy in sustainable future. *Chemical and Process Engineering: New Frontiers*, 37–37. https://doi.org/10.24425/cpe.2023.147396

Marek, M., & Zdenek Krejza. (2024). Sustainable building: Circular economy as a key factor for cost reduction. *E3S Web of Conferences*, *550*, 01009–01009. https://doi.org/10.1051/e3sconf/202455001009

McNamee, M., Göras, T., Mossberg, A., Wetterqvist, C., Lundh, K., Blomqvist, P., & Blomqvist, S. (2023). Challenges and opportunities for reuse of products and materials with fire safety requirements – A Swedish perspective. *Fire Safety Journal*, *140*, 103857. https://doi.org/10.1016/j.firesaf.2023.103857

Nikolić, D., Jovanović, S., Skerlić, J., Šušteršič, J., & Radulović, J. (2019). METHODOLOGY OF LIFE CYCLE SUSTAINABILITY ASSESSMENT. *Proceedings on Engineering Sciences*, *1*(2), 793–800. https://doi.org/10.24874/pes01.02.084

Niu, J. (2021). The impact of technological innovation on carbon emissions. *E3S Web of Conferences*, *275*, 02039. https://doi.org/10.1051/e3sconf/202127502039

Okorie, G. N., Udeh, C. A., Adaga, E. M., & Oriekhoe, O. I. (2024, January 2). *ETHICAL CONSIDERATIONS IN DATA COLLECTION AND ANALYSIS: A REVIEW: INVESTIGATING ETHICAL PRACTICES AND...* ResearchGate; Fair East Publishers. https://www.researchgate.net/publication/378789304_ETHICAL_CONSIDERATIONS_IN_DATA_COLLECTION_AND_ANALYSIS_A_REVIEW_INVESTIGATING_ETHICAL_PRACTICES_AND_CHALLENGES_IN_MODERN_DATA_COLLECTION_AND_ANALYSIS

Oliveira, J. de, Schreiber, D., & Jahno, V. D. (2024). Circular Economy and Buildings as Material Banks in Mitigation of Environmental Impacts from Construction and Demolition Waste. *Sustainability*, *16*(12), 5022. https://doi.org/10.3390/su16125022

Papamichael, I., Voukkali, I., Pantelitsa Loizia, & Zorpas, A. A. (2023). Construction and demolition waste framework of circular economy: A mini review. *Waste Management & Research*. https://doi.org/10.1177/0734242x231190804

Patil, D. T., Patil, A., & Patil, J. (2021). The Decision-Making Criteria for Adaptive Reuse for Sustainable Development. *Lecture Notes in Civil Engineering*, 599–607. https://doi.org/10.1007/978-981-33-6969-6_52

Paul, J., & Criado, A. R. (2020). The art of writing literature review: What do we know and what do we need to know? *International Business Review*, *29*(4). https://doi.org/10.1016/j.ibusrev.2020.101717

Reuse and Repair in a Circular and Social Economy. (2022). https://www.interregeurope.eu/sites/default/files/2022-12/Policy%20brief%20on%20reuse%20and%20repair%20in%20a%20circular%20and%20social%20economy.pdf?utm_source=chatgpt.com

Riuttala, M., Harala, L., Aarikka-Stenroos, L., & Satu Huuhka. (2024). How building component reuse creates economic value – Identifying value capture determinants from a case study. *Journal of Cleaner Production*, 141112–141112. https://doi.org/10.1016/j.jclepro.2024.141112

Rose, C., & Stegemann, J. (2018). From Waste Management to Component Management in the Construction Industry. *Sustainability*, *10*(1), 229. https://doi.org/10.3390/su10010229

Rydberg, T., Andersson, J., Gerhardsson, H., Kultje, E., Lewrén, A., Carina Loh Lindholm, Löfving, J., & Moberg, S. (2022). Environmental and socio-economic benefits of circularity in real estate management. *E3S Web of Conferences*, *349*, 01010–01010. https://doi.org/10.1051/e3sconf/202234901010

Samani, P. (2023). Synergies and gaps between circularity assessment and Life Cycle Assessment (LCA). *Science of the Total Environment*, *903*, 166611. https://doi.org/10.1016/j.scitotenv.2023.166611

Santos, F. D., Ferreira, P. L., & Pedersen, J. S. T. (2022). The Climate Change Challenge: A Review of the Barriers and Solutions to Deliver a Paris Solution. *Climate*, *10*(5), 75.

Schramm, A., Richter, F., & Götze, U. (2020). Life Cycle Sustainability Assessment for manufacturing – analysis of existing approaches. *Procedia Manufacturing*, *43*, 712–719. https://doi.org/10.1016/j.promfg.2020.02.115

Snyder, H. (2019). Literature review as a research methodology: An overview and guidelines. *Journal of Business Research*, *104*(1), 333–339. ScienceDirect. https://doi.org/10.1016/j.jbusres.2019.07.039

van den Berg, M., Voordijk, H., & Adriaanse, A. (2020). Recovering building elements for reuse (or not) – Ethnographic insights into selective demolition practices. *Journal of Cleaner Production*, *256*, 120332. https://doi.org/10.1016/j.jclepro.2020.120332

Vardopoulos, I., Tsilika, E., Sarantakou, E., Zorpas, A., Salvati, L., & Tsartas, P. (2021). An Integrated SWOT-PESTLE-AHP Model Assessing Sustainability in Adaptive Reuse Projects. *Applied Sciences*, *11*(15), 7134. MDPI.

Y. Takva, Çağatay Takva, & Zeynep Yeşim İlerisoy. (2023). Sustainable Adaptive Reuse Strategy Evaluation for Cultural Heritage Buildings. *International Journal of Built Environment and Sustainability*, *10*(2), 25–37. https://doi.org/10.11113/ijbes.v10.n2.1060

Yuan, H., & Shen, L. (2011). Trend of the research on construction and demolition waste management. *Waste Management*, *31*(4), 670–679. https://doi.org/10.1016/j.wasman.2010.10.030

Zhu, S., & Feng, H. (2024). Enhancing circularity of wood waste through deconstruction in building sector. *Journal of Cleaner Production*, 144382–144382. https://doi.org/10.1016/j.jclepro.2024.144382

Appendix A – Interview Questions

1. Can you tell us a bit about your role at your company and how you work with reuse in renovation projects?
2. What types of renovation projects are you most often involved in where reuse is a relevant strategy?
3. How have you evaluated and justified decisions on reuse in your projects so far?
4. What factors are most important when deciding on the reuse of materials in a renovation project?
5. How do you balance economic factors (cost, profitability) with sustainability objectives (CO_2 reduction, circular economy)?
6. Are there any internal or external models/methods you use to balance these factors?
7. What challenges do you see in integrating both economic and environmental impacts in the decision-making process?
8. What key performance indicators do you currently use to measure the economic profitability and environmental impact of reuse?
9. Are there any specific indicators you are missing or would like to use to better understand the impact of reuse?
10. How clearly do you feel these indicators communicate the long-term benefits of reuse to decision-makers?
11. How do you collect and analyse data to quantify these impacts?
12. How do you currently present data on the economic and environmental impacts of reuse in your projects?
13. What kind of visualisations (graphs, dashboards, simulations, etc.) could help decision-makers understand the data?
14. Do you have examples of when good (or poor) visualisation influenced reuse decisions?
15. How do you think improved data visualisation could help to make more investment decisions in favour of reuse?
16. If you could develop an ideal model for making reuse decisions, what factors would it include?
17. Is there anything else you would like to add or any insights you would like to share on the topic?

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