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Beyond Numbers: Appraisal Framework of Construction Materials for Reuse

Master's thesis in Design and Construction Project Management

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Abstract

Material reuse is increasingly promoted as a strategy to reduce the environmental impact of the construction sector. However, decisions about whether materials can and should be reused are often made without a structured method for evaluation. Technical requirements, economic constraints, documentation gaps, aesthetic considerations, and market conditions all influence these decisions, yet existing regulations do not provide a comprehensive framework that integrates these factors into a systematic assessment.

This thesis develops a multidimensional appraisal framework for evaluating construction materials for reuse. The study addresses three questions: Which factors are relevant when assessing materials for reuse? How can these factors be evaluated in practice? Which construction materials and building components show the greatest reuse potential when assessed against these factors?

The research combines a literature review, analysis of Scandinavian regulations and industry reports, interviews with practitioners, a survey, and mapping of reused materials across 21 reference projects. The study identifies sixteen evaluation factors grouped into four domains: regulatory boundary conditions, environmental and lifecycle performance, operational and market feasibility, and architectural and cultural value. These factors are translated into guiding questions and assessment metrics, and applied to nine material categories spanning structural, envelope, and space layers.

The results show that reuse potential cannot be predicted from technical or environmental performance alone: materials with comparable climate impact can have significally different reuse outcomes depending on market maturity, regulatory burden, and aesthetic recognition. The framework provides a structured basis for capturing this complexity, supporting transparent and informed decision-making in reuse-oriented construction practice.

Keywords: reuse potential, circular construction, appraisal framework, pre-demolition audit, Nordic construction practice.

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1 Introduction

1.1 Background

The construction and demolition sector is one of the largest generators of waste in Europe, accounting for approximately 36% of total waste volumes in the EU (Eurostat, 2024). Despite growing interest in circular economy principles and material reuse, the actual implementation of reuse remains below 15% in Europe, resulting in continued environmental impact and loss of embedded economic value (Gobbo et al., 2024). Most current policies continue to focus on limiting operational emissions, overlooking the significant resource savings that a more circular construction sector could deliver (Pristerà et al., 2024, as cited by Lambec et al., 2025). The predominant response to demolition waste remains recycling, yet recycling is energy-intensive and still carries substantial environmental burdens. This distinction — between recycling matter and retaining the value of whole components — is central to the circular economy hierarchy, yet it remains poorly supported in practice.

A key reason is structural: conventional demolition does not naturally generate elements suitable for reuse. Enabling reuse requires deconstruction — a deliberate, component-preserving alternative to standard demolition — yet this shift is rarely made, partly because practitioners lack adequate tools to assess reuse potential before a building comes down (Prieto et al., 2025, as cited by Lambec et al., 2025). Without a systematic method for evaluating which materials are worth recovering, valuable resources are lost by default.

Life Cycle Assessment (LCA) has become a central method for addressing environmental performance in construction sector (Kanafani et al. 2021 as cited in Somerset 2025). Standardized under ISO 14040/44, LCA-based climate declarations are now a regulatory requirement in the Nordic countries (Nordic Sustainable Construction, 2023). However, LCA was not designed to support the practical decision-making required at the pre-demolition stage, where reuse potential must be assessed across technical, economic, cultural, and regulatory dimensions simultaneously.

This gap is not unique to reuse. Three decades of green building promotion — through certification systems such as LEED and BREEAM and technical approaches such as passive house design — have achieved only limited uptake relative to the scale of global construction activity, suggesting that technical optimization alone is insufficient to drive lasting change (Chen et al., 2022; Panchalingam et al., 2024; Anand et al., 2023). Studies on circular procurement similarly identify soft barriers — including risk perception, market uncertainty, cost concerns, and organizational resistance — as significant obstacles that purely metric-based frameworks fail to address (Sajid et al., 2024). When reuse is framed exclusively in environmental terms, concerns regarding economic feasibility, aesthetic quality, or performance reliability are left unresolved.

This thesis therefore investigates how environmental assessment can be complemented by economic, regulatory, and aesthetic considerations to support effective material reuse decisions. By integrating these dimensions within a structured appraisal framework and drawing on insights from Nordic practice, the study advances a multidimensional approach to material appraisal in sustainable construction.

1.2 Aim and Research Questions

The aim of this thesis is to identify and structure the factors influencing the evaluation and integration of reclaimed construction materials, and to develop an appraisal framework for their *reuse* in construction projects.

The study is guided by the following research questions:

1. Which factors are most relevant in assessing construction materials for reuse and should be considered in the evaluation process?
2. How can these factors be structured into a systematic framework and applied empirically in practice?
3. Which building components and material categories currently demonstrate the highest potential for reuse when evaluated against the identified factors?

By comparing technical, practical, economic, cultural, and regulatory aspects across case studies, this research aims to generate practical and policy-relevant recommendations that support the systematic evaluation of materials for reuse, thereby contributing to waste reduction and supporting more informed, resource-conscious decision-making in pre-demolition and pre-construction practice.

1.3 Scope and Aspects of the Study

This thesis focuses on the process of auditing the reuse potential of structural and finishing materials in building construction projects in Sweden, Denmark, and Norway. These countries were selected because they host several pilot projects incorporating reused or recycled materials in excess of 30%, providing opportunities to observe and compare practices under similar climatic, regulatory, and economic conditions. By examining practices across multiple countries, this thesis aims to generate insights that can inform strategies to advance material reuse in Sweden, with attention to both practical implementation and policy support.

The case study analysis is limited to construction projects completed within the past eight years, as well as projects currently under construction, to ensure that the findings reflect contemporary industry practices.

1.4 Delimitations

This thesis does not address questions related to the *transformational reuse* of entire buildings or the evaluation of specific building technologies. The investigation is limited to analyzing the evaluation processes of construction materials for further reuse and the methods applied in these assessments.

The historical overview of obsolescence (Section 2.1) is included solely to provide context on the long history of demolition practices and construction waste generation, highlighting the resulting potential for material reuse. However, this thesis does not aim to evaluate obsolescence itself or the decision-making processes associated with building demolitions.

1.5 Terminology

In this thesis, some terms are used in a particular way or with a specific meaning. These are clarified in *Table 1*.

Term	*Definition*
Reuse	The dismantling and recovery of building components or materials from an existing structure and their reintegration into new or renovated construction — on the same site or elsewhere — while preserving their material integrity and embodied value, irrespective of whether the original function is maintained. Excludes building-scale adaptive reuse.
Reclaimed materials	Materials or building components that have been carefully dismantled or recovered from an existing structure and retained in a condition suitable for direct reuse in new construction or renovation projects, either on the same site or elsewhere, with minimal alteration or processing.
Upcycling	The practice of repurposing used or reclaimed building materials for a new function or application that differs from their original purpose, often adding value, aesthetics, or functionality, and typically requiring modification or creative transformation.
Transformational reuse (of buildings)	The process of adapting an existing building for a new function or purpose, often involving structural, spatial, or design modifications, while retaining significant portions of the original construction and materials.
Adaptive reuse	The process of repurposing an existing building for a new function while retaining much of its structure and fabric.
Obsolescence	The condition in which a building material, component, or product is no longer suitable for its intended use due to functional, technical, regulatory, aesthetic, or economic factors, even if the material remains physically intact.
CE marking	CE marking means that a construction product complies with the Construction Products Regulation and can be freely traded across borders within the EEA/EU.
Durability	A material's inherent potential to resist degradation under expected environmental and load conditions.
Service life	A period of time after installation during which a building or its parts meet or exceed the performance requirements.
Residual quality	The *remaining performance capacity* of a material or building component at a given point in time, after it has already been in use.
Remaining service life	A period during which the reused component is expected to continue to meet performance requirements
Building stock	The total collection of existing buildings within a specific geographic area, including their structural, functional, and material characteristics, used as a basis for planning, energy assessment, renovation, or material reuse strategies
Material flow	In circular construction is the movement and timing of building materials through extraction, use, dismantling, and reuse, shaped by when obsolescence makes them available again.

Table 1:Collection of important terminology applied in the thesis.

2 Reuse practice in the construction industry

This chapter reviews relevant literature to contextualize the research on evaluation processes of construction materials intended for reuse. A historical overview of reuse and repair is presented first, tracing shifts in how materials are valued — from obsolescence logic to contemporary sustainability strategies — in order to understand the structural conditions that currently limit material reuse. This is followed by an overview of the Swedish policy landscape and its implications for professional practice, after which existing research gaps and evaluative frameworks are identified.

2.1 From Obsolescence to Resource: Shifts in Material Value Paradigms.

Obsolescence determines when and why buildings are dismantled, shaping the conditions under which materials become available for reuse. As such, the concept of obsolescence is central to understanding material flows, which determines when materials become available again and re-enter circulation. Material flows describe the lifecycle and circulation of building materials through extraction, use, dismantling, and reuse — and obsolescence controls when that circulation happens.

Several scholars have examined obsolescence in relation to contemporary climate change discourse. Notable contributions include the work of Anamarija Batista and Julia Siedle in Rethinking Obsolete Typologies (2025), and Daniel M. Abramson's in Obsolescence: An Architectural History (2016/2025).

Batista and Siedle (2025) argue that obsolescence is not an inherent property of buildings, but a concept shaped by economic, technological, and social value systems. Rooted in 20th-century consumer culture and Schumpeter's notion of "creative destruction," obsolescence sustained economic growth through planned replacement, treating older structures as barriers to innovation rather than resources for adaptation. It has since become a speculative tool in real estate markets, enabling profit through demolition, densification, and reduced communal space (Batista & Siedle, 2025). The authors identify three purposes obsolescence serves:

1) Obsolescence as a tool for maximizing profit by using plots efficiently and catering to changing standards
2) Obsolescence as a tool for Improving Social Infrastructure
3) Obsolescence as a tool for Achieving Ecological Goals

The latter is reflected in current policy frameworks emphasizing the energy performance of buildings. For instance, the EU's Energy Performance of Buildings Directive (EPBD) aims to improve energy efficiency across the building stock and reach combined targets of a 60% emissions reduction by 2030 and climate neutrality by 2050. Financial incentives, such as tax breaks, grants, and low-interest loans encourage energy-efficient renovations, increasing the value of buildings and lower long-term energy costs. However, an emphasis on operational energy over embodied energy can accelerate building obsolescence, as older buildings are often demolished to make way for more energy-efficient structures. In this way, ecological goals can both justify and drive obsolescence (Batista and Siedle, 2025).

This reassessment coincided with the rise of sustainability as a paradigm. Yet as Abramson (2025) notes, sustainability often operates within the same growth-oriented systems that previously justified demolition. At the urban scale, material conservation does not automatically equate to social or ecological justice — *adaptive reuse,* which gained wide application in 60s through the transformation of abundant factories, mills, and warehouses into creative lofts, small business premises, and residential studios, can preserve fabric while displacing communities through gentrification. Abramson calls this *the neutron bomb of urban renewal*: building intact, people gone. Today, sustainability increasingly functions as a marketable identity, reducing ecological value to branding and net-zero metrics while remaining selectively blind to material lifecycles and reuse potential.

This historical reassessment of a building stock coincided with the rise of sustainability as a emerging paradigm. Triggered by ecological crises and institutionalized through preservation policies and incentives, sustainability reframed conservation as a moral and environmental imperative. However, as Abramson (2025) notes, sustainability often operates within the same growth-oriented systems that previously justified demolition. Consequently, while promoting conservation rhetorically, it may fail to fundamentally alter structural dynamics. At the urban scale, adaptive reuse can preserve material fabric while contributing to social displacement, particularly through gentrification. Abramson (2025) compares adaptive reuse to the neutron bomb of urban renewal: "building intact, people gone," referring to the displacement of working-class residents and local communities. In this sense, material conservation does not automatically equate to social or ecological justice.

Today, sustainability increasingly functions as a marketable identity within real estate development, where ecological value is often reduced to branding, metrics, and net-zero targets. Abramson (2025) questions whether sustainability, with its emphasis on balance and continuity, can meaningfully challenge extractive systems or merely replace obsolescence with a new ideological driver. Like obsolescence, sustainability fuels creativity and legitimizes intervention but remains marked by contradiction, selective blindness, and limited attention to material lifecycles and reuse potential (Abramson, 2025).

This historical overview reveals that dominant sustainability strategies — focused on operational performance and symbolic green development — tend to overlook the specific social, economic, and cultural conditions needed to support informed decision-making in the built environment. Valuable materials and entire buildings are consequently downcycled, discarded, or excluded from circulation, generating construction waste, market distortions, and negative community impacts.

2.2 Material Reuse in Construction: Definitions, Scope, and Conditions

Reuse is defined in EU legislation as "any operation by which products or components that are not waste are used again for the same purpose for which they were conceived" (Directive 2008/98/EC, Art. 3(17)). This provides the shared legislative baseline across European construction practice and policy. However, in construction practice, recovered materials and components are frequently reintegrated in functions other than their original one — a pattern confirmed both in the reference projects reviewed and in stakeholder insights gathered in this thesis. This thesis therefore adopts a broader operational definition: reuse refers to the dismantling and recovery of building components and materials without destroying them, with the aim of reintegrating them into new or renovated construction while preserving their material integrity and embodied value, irrespective of whether the original function is maintained.

This definition is distinct from *adaptive reuse*, which operates at the building scale and concerns the reprogramming of entire structures for new uses. The focus here is strictly at the material and component level — construction elements as recoverable resources once buildings are deconstructed.

2.3 Policy Ambitions and Practical Realities of Material Reuse.

Material reuse is increasingly articulated as a key strategy within municipal and national sustainability agendas, yet its implementation in construction practice remains uneven and fragmented. In Gothenburg, reuse forms part of the city's Environmental and Climate Programme 2021–2030 (Göteborgs Stad, 2021), which sets the following targets for 2030:

1. 90% reduction in climate impact from new construction, renovation, and non-food procurement
2. 40% reduction in waste volumes per employee in city operations (30% per resident)

Reuse is a central part of the strategy and is already used in several municipal construction projects - but the scope varies. However, recycling inventories are becoming increasingly common, even in new construction. With a construction volume of approximately SEK 17 billion per year, according to Business Region Gothenburg, the City of Gothenburg has a unique opportunity to drive change (RISE & Runsten, 2025).

"Reuse is already included in some form in most of the City of Gothenburg's construction projects, but the scope varies greatly. Reuse inventories are becoming standard - but it is still often difficult and time-consuming to match supply with demand. There is simply still a lack of market solutions. We see that reuse will be an important component in achieving the city's tough climate goals." (Jacobsson Stålheim, as cited in Runsten, 2025)

Contemporary architectural discourse frames material reuse not only as a technical or environmental strategy but also as a transformation of professional practice. Reuse-oriented design processes require architects to reconsider traditional notions of control, authorship, and aesthetic intention, embracing experimentation, adaptability, and responsiveness to constraints imposed by available materials (Fallon & Ooms, 2025). At the same time, research shows that public authorities can play a pivotal role in supporting reuse initiatives by establishing common frameworks that guide and incentivize such efforts (Gobbo et al., 2024).

Taken together, these conditions reveal a critical gap between available regulatory or procedural frameworks and operational decision-making in the construction sector. Although material reuse is increasingly framed as an environmental imperative, practitioners continue to lack systematic methods and decision-support tools for assessing the potential of reclaimed materials, a shortcoming also highlighted by Kanters (2020) as cited in Dokter et al., 2024. Consequently, decisions regarding reuse are frequently made on an ad hoc basis, driven by individual commitment, project-specific constraints, or symbolic sustainability objectives rather than by structured and transparent evaluations of material value. This disconnect constrains the scalability of reuse practices and contributes to the ongoing loss of potentially valuable construction materials (Dokter et al., 2024).

This thesis thus frames material reuse not as a lack of willingness or awareness, but as a decision-making problem. Addressing this gap requires frameworks that can make the reuse potential of materials visible, comparable, and actionable across different project contexts—an issue that this master thesis seeks to address through the development of a material appraisal framework.

2.4 Existing frameworks for material appraisal for reuse.

Currently, only a limited number of studies review or suggests frameworks for assessing construction materials for reuse potential and no consensus has been established on evaluation criteria, scope, or methodology. Such, a recent study by Lambec et al. (2025) reviewed 21evaluation procedures in identifying reusable elements conducted in Europe and the United States between 2001 and 2021. Through a comparative literature analysis it was found that various stakeholders, such as property owners, contractors, architects, engineers, scientists, local and national authorities were developing diverse and often incompatible methods, with identified subjectivity in data inputs and a lack of consensus on comprehensiveness. The study reveals need for expanded criteria, that include projective values, deconstruction processes, and second-use planning. Furthermore, existing procedures tend to focus on material availability and end-of-life condition, while neglecting costs, timelines, and the positioning of elements along a full lifecycle continuum from reuse to recycling to waste (Lambec et al., 2025). This study however does not suggest a defined list of criteria for the future framework.

A circular construction evaluation framework (CCEF) was developed by Dams et al. (2021) with purpose to evaluate the degree of circularity of design and construction projects, on a element/component level and the building as a whole. It is a scoring method that encompasses material properties, suitability for disassembly and adaptability, material information, and health and safety criteria. Framework was developed to inform construction projects at planning and early design stages (Dams et al., 2021). However, while being based on the international standard BS ISO 20887:2020 that covers principles and requirements for design for disassembly and adaptability, this framework is more feasible in newbuilt projects, rather than in audit process of pre-demolition phases, which this thesis is trying to address as well.

A product-level study, which assess individual materials or components for reuse suitability, was developed by RISE and Business Region Göteborg in 2025 (RISE, Business Region Göteborg, 2025). Nineteen product types (e.g., bricks, radiators) were identified as having high reuse potential, based on the following criteria:

1. *Technically feasible for reuse*
2. *Frequently requested by property owners*
3. *Economically viable, or with the potential to become so*

These products were further categorized according to their suitability for a large-scale reuse market in the Gothenburg region within a 1–3 year time frame. For each product type, an analysis was conducted to determine existing measures in place and the aspects that require further development to make the product marketable. Even though this project provided a concrete list of materials suitable for reuse, it did not address the decision-making process for independent evaluation.

A decision-support frameworks for structural reuse, focused specifically on load-bearing elements was developed by Küpfer et al. (2021). This study proposes a multi-criteria decision framework that balances environmental, technical, logistical, and economic criteria when designing structures with reused components, evaluating factors including total project costs, construction complexity, and the number of deconstruction sites.

These identified gaps in exiting research are particularly evident in the Swedish professional context, where no standardized appraisal procedure exists across project types and material categories. The present thesis responds directly to this problem.

3 Methodology and Methods.

3.1 General research design.

This thesis adopts a qualitative-dominant mixed method research design informed by iterative research logic. The study addresses the emerging and complex phenomenon of material reuse in construction, where evaluation methods and standards are still under development.

A mixed-method approach was considered appropriate, as it addresses both systematic, quantifiable aspects—such as identifying frequently used materials—and qualitative, context-sensitive aspects, including professional judgments and cultural dimensions associated with material reuse. This combination allows the study to capture both technical and contextual knowledge, which is essential to identify relevant assessment factors (RQ1), explore how these factors can be assessed (RQ2), and evaluate material suitability (RQ3).

The research followed an abductive logic, whereby insights from empirical data—emerging from interview transcripts, survey responses, and information from reference projects—were continuously compared with existing literature. This iterative movement between theory and data allowed the analytical process to refine interview and survey questions and narrow the scope of the research, ensuring that the methodology directly supports the development of a practical and theory-informed appraisal framework.

3.2 Methods

Throughout the project, an iterative analysis was carried out, where insights from the different phases were successively processed. It became evident early in the research process that, while certain technical aspects of the research subject could be obtained from reports and peer-reviewed literature, other dimensions, such as *uniqueness,* related to subjective values required qualitative methods, including interviews and the analysis of grey literature. The iterative use of interviews and Mentimeter surveys enabled continuous refinement of the research scope and question focus, thereby facilitating a more precise and targeted collection of relevant information. The overall process is illustrated in *Figure 1* below:

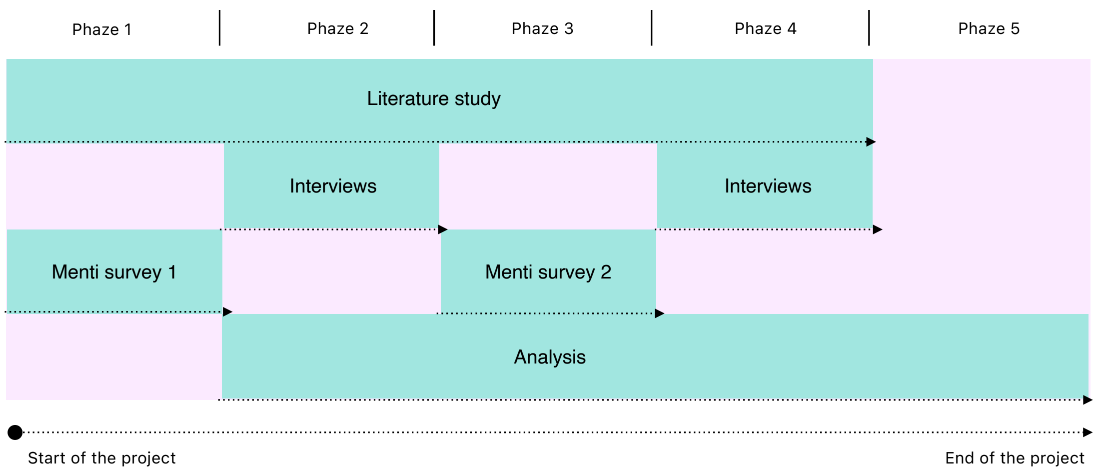

Figure 1: Timeline of the thesis research.

The project employed four methods: literature analysis (Section 3.2.1), interviews (Section 3.2.2), surveys (Section 3.2.3), and data analysis (Section 3.2.4).

3.2.1 Literature analysis

The research started with a review of the current knowledge on reuse of construction materials. Both scientific peer-reviewed literature and grey literature were collected. Scientific literature was gathered using Scopus and Google Scholar. Grey literature included reports and documents available on CCBuild (SE), Byggforskserien (NO) and Skills4reuse (DK), and articles published in periodical journals on architecture and civil engineering (e.g. RUM, Harvard Design Magazine, Bygggindustrin) and books on reuse in a broader discourse (e.g., Återbruks Praktika, 2024; Heterogeneous Constructions, 2024).

Based on the literature review, two projects- Kvarteret Återbruket (Gothenburg) and Kristian Augusts gate 13 (Oslo)—were selected for in-depth analysis to obtain detailed technical data and to conduct interviews with project managers. Following this, available reports, academic articles, and press releases related to these projects were reviewed to support data collection.

The literature study then continued in parallel with other components of the project to ensure a continuously updated and contextually grounded understanding of the reuse issue, as well as to identify relevant aspects for further investigation.

In addition to the case studies, a mapping of reused materials was conducted based on documentation from 21 reference construction projects that incorporated reclaimed or reused building materials. These reference projects were identified through industry reports, related publications, and reuse-focused platforms and were reviewed to identify which types of reclaimed materials were used in each project. The identified materials were recorded in a comparative matrix, Attachment 4.

3.2.2 Interviews

The thesis used both semi-structured and structured approaches in the interviews. While the first approach allowed for a more nuanced understanding of the subject—for example, by allowing participants to propose their own ideas on criteria—the latter enabled the collection of quantitative material to study the relationship between participants' perceptions and the hypothesis, for example, how they rated specific criteria (little–a lot). The interview form with its questions is presented in Attachment 5.

The interview questions were developed based on the purpose of the project, the current state of knowledge according to the literature and the insights that emerged in Menti survey 1. The questions focused on the following areas:

- Decision making process around material appraisal
- Appraisal of specific materials (technical, economic and aesthetic dimensions)
- Aesthetic values associated with material reuse
- Impact of material scarcity on the built environment and its aesthetic qualities
- Hope and optimism in the context of the environmental crisis and the significance of reuse practices
- Professional shifts among architects engaged in reuse-oriented design
- Future trajectories of material reuse in architecture

This research employed a purposive sampling strategy, which was considered as most suitable for addressing the research objectives within the given timeframe. In qualitative research, the selection of sample size is commonly guided by the principles of expertise and data saturation (Mason, 2010, as cited by Ahmed et al., 2016). Although the study adopted a mixed-methods approach, a purposive sampling technique was applied in both the quantitative and qualitative components of the research.

Interview participants were selected based on either their formal position within an organization—preferably in managerial roles—or their level of engagement with reuse-related issues, such as direct participation in reuse projects or research institutes. This approach ensured the inclusion of respondents capable of providing informed insights into decision-making processes related to material evaluation and changes in professional expertise.

According to Guest et al. (2006) as cited in Ahmed et al., (2016), a sample size of twelve interviews is sufficient when the research aim is to explore shared perceptions and experiences within a relatively homogeneous group (as cited in Ahmed et al., 2016). As the present study aligns with this objective, a total of twelve participants was included in the sample. The sample comprised developers, general contractors, sustainability consultants, researchers, and architects. Actors specifically involved in demolition, dismantling, logistics, or waste management were not included, as the research focused on managerial functions and policy-making processes. The final selection of participants is presented in *Table 2* below.

Stakeholder	**Code**	**Participation in the interview**
Real-estate developer (Castellum)	D1	1
Contractor (NCC, Vestia)	C1, C2	2
Architects (Fojab, Fredblad, Gatan, Mad, Acan, Aarhus School of Architecture)	A1, A2, A3, A4, A5, A6	6
Sustainability consultants in architecture companies (White, Wingårdhs)	S1, S2	2
Swedish Standard Institute (SIS)	R1	1
Total		12

Table 2: Participants in the interviews.

42 % of the respondents identified as female and 58 % as male. In terms of educational background, 67 % held a master's degree, 17 % held a doctoral degree, 8 % had completed only high school. Regarding professional experience, 83 % of respondents had more than ten years of experience, while 8 % had between eight and ten years of experience, and 8 % had between four and seven years of experience.

The majority of interviews (n = 7) were conducted online via Microsoft Teams and recorded using the platform, enabling automatic transcript generation. The average duration of these online interviews was approximately 45 minutes. A subset of interviews (n = 3) was conducted in person in Gothenburg, recorded using the Voice Memos application, and subsequently transcribed manually. The average duration of the in-person interviews was approximately 1 hour and 15 minutes. All interview transcripts were consolidated into a single document to facilitate systematic coding and analysis.

Following the seventh interview, the scope and focus of the interview questions were adjusted, allowing for a more in-depth exploration of specific themes identified as critical based on the analysis of the initial round of interviews.

3.2.3 Mentimeter survey

Mentimeter, an online survey tool, was employed to collect data from participants who were not available for in-person or online interviews. Prior to the administration of the first and second survey, the aim of the research and the applied methods were presented to participants using short a slide presentation. Subsequently, a QR code linking to the online survey was displayed. The survey consisted of a combination of open-ended questions, dichotomous (yes/no) questions, and rating-scale questions. Participation was voluntary, and respondents were informed that they could discontinue the survey at any time. Upon completion, participants were able to view aggregated results, allowing them to see how colleagues had responded to the same questions.

The first survey consisted of seven questions. Following the analysis of the results from the first and second group surveys, the scope and focus of the questions were refined to enable a more in-depth exploration of themes identified as critical. The revised second survey comprised thirteen questions.

The first survey was conducted at the office of a real estate company and included three participants, all of whom held managerial positions and possessed practical experience with reuse practices. The second survey was conducted during a seminar associated with *a “climate change group”* for building sector stakeholders and included eleven participants. This group comprised sustainability specialists from real estate companies, municipal organizations, construction firms, and architectural offices.

Response rates varied between 14% and 71%. Of the respondents, 70% identified as female and 30% as male. In terms of educational background, 80% held a master’s degree and 20% held a doctoral degree. Regarding professional experience, 80% of respondents had more than ten years of experience, while 20% had between eight and ten years of experience.

3.2.4 Data Analysis

An iterative qualitative analysis was conducted throughout the research process. Interview transcripts, open-ended survey responses, and relevant literature citations were analyzed and organized thematically. Initial analytical categories were derived deductively from the literature (e.g., technical feasibility, economic considerations, and cultural and aesthetic values), while additional themes emerged inductively during the analysis.

Survey rating-scale responses were analyzed quantitatively to identify variations in the perceived attribution of factors such as barriers, aesthetic values, and other criteria across different materials. These perceptions were then compared with factual data retrieved from the literature review.

Data from real-world projects were analyzed thematically to extract technical and practical insights into material reuse conditions across different building types and contexts.

In addition, a criteria and materials mapping was conducted to examine the frequency with which specific criteria and materials appeared across the reviewed literature and reference projects, respectively. This analysis aimed to identify the criteria and materials most frequently referenced in contemporary construction practice in Sweden, Norway, and Denmark, and therefore most relevant for inclusion in the analytical framework.

3.2.5 Factors and Material Frequency Mapping and Selection process

Factors were included in the framework if they fulfilled at least one of the following conditions:

1. <u>Document-based recurrence.</u>
   A criterion was considered recurrent if it was identified in at least 40% of the reviewed research reports (minimum two reports), or appeared across multiple digital platforms (minimum two platforms). This threshold was applied to ensure that selected criteria reflected recurring considerations rather than isolated references.
2. <u>Regulatory necessity</u>
   The criterion reflects mandatory compliance requirements defined in national or EU regulation.
3. <u>Empirical relevance</u>
   The criterion emerged consistently in interviews and/or received majority support in the survey (e.g., more than 50% agreement that the factor is relevant for material evaluation).

This triangulated inclusion strategy ensured that the framework reflects not only documented practice and regulatory requirements, but also practitioner perspectives and emerging evaluative dimensions.

Materials were included if they:

1. Following the Structure, Skin and Space categorization (see chapter 4.3.2), elements belonging to the Site and Services layers — such as landscape materials and building services installations — were excluded, as these operate under fundamentally different lifecycle and reuse conditions.
2. Materials were included if they appeared in 4 or more of the 22 reference projects (approximately 18% of the sample). As the total number of projects was limited and the highest observed frequency was seven occurrences, this threshold was used to distinguish materials that show repeated use across different projects from those applied only occasionally or in isolated cases. The criterion therefore helps identify materials with broader relevance for reuse, while keeping the analysis focused and manageable.

Materials with lower frequencies were excluded, as they appeared occasionally and did not introduce additional analytical dimensions relevant to the research questions.

3.3 Validity and Reliability

Following Saunders et al. (2019), construct validity was strengthened through triangulation of multiple data sources, including literature, interviews, surveys, and reference projects. Internal validity was enhanced through an iterative research design, in which emerging findings were continuously compared with existing theory and across data sources.

The selected projects and respondents represent a diverse group of professionals from construction companies, research and institutional organizations, real estate firms, and architectural practices. The inclusion of multiple disciplinary perspectives increases the robustness of the findings and supports what Saunders et al. (2019) term analytical generalizability — the ability to inform similar contexts without claiming statistical representativeness.

The educational background and extensive professional experience of the respondents suggest a high level of expertise in the field, supporting the reliability of the professional judgments reflected in the study.

Interview guides and survey instruments are documented in the appendix. Interviews were recorded to support accuracy in analysis; full transcripts are not included in this study to preserve participant confidentiality.

3.4 Use of AI Tools

Artificial intelligence tools (ChatGPT by OpenAI, Claude by Anthropic) were used as a support tool during the thesis process. Specifically, AI was employed for linguistic revision and reformulation of text, as well as for assisting in the review and summarization of regulatory documents and information available on relevant online platforms. All analyses, interpretations, findings, and conclusions were developed, verified, and critically assessed by the author.

4 Development of an assessment tool for material reuse strategy

The development of the framework consisted of four stages: 1) initial conceptualization and identification of assessment factors 2) identification and review of assessment methods and their categorization 3) mapping of materials to be included in the framework
Each stage is discussed below following the sections: 4.1- 4.3.

4.1 Initial conceptualization and assessment criteria

This section addresses Research Question 1 (RQ1): *Which factors are most relevant in assessing construction materials for reuse and should be considered in the evaluation process?*

4.1.1 National regulations

To identify evaluation factors for material reuse, national regulatory and guidance documents from Sweden, Norway, and Denmark were reviewed. These institutions represent the highest level of technical governance in the built environment and therefore shape the regulatory logic within which reuse must operate. The review included: Boverket (Sweden), Direktoratet for byggkvalitet (DiBK) and TEK17 (Norway), Bolig-og Planstyrelsen/Social- og Boligstyrelsen (Denmark), the EU Construction & Demolition Waste Management Protocol (2024 update).

The objective was not to evaluate circular economy ambitions at policy level, but specifically to extract relevant factors for material appraisal in reuse contexts.

Sweden: Performance-Based Assessment with Limited Standardization

In Sweden, Boverket does not provide a standardized checklist for the assessment of reclaimed construction materials. Instead, reuse must comply with existing performance-based building regulations (Boverket, 2025).

General inventory recommendations includes:

- Review of historical building records to understand prior use and potential incidents
- Ocular inspection of components to assess physical condition
- Environmental inventory to identify hazardous substances
- Assessment of damage (e.g., corrosion, deformation, fire exposure)
- Verification that reused components comply with applicable technical requirements

For load-bearing elements, the guidance *Vägledning om återbruk av bärverksdelar* specifies that reused components must meet existing structural and safety requirements as defined in general building regulations (Boverket, 2025). These are:

- Structural safety (e.g., strength, stiffness, shrinkage)
- Environmental and chemical compliance (e.g., hazardous substances)
- Long-term performance under load and weather exposure
- Fire resistance

Importantly, these are not reuse-specific criteria but general performance requirements that apply equally to new and reused materials.

Until 2024, Boverket referred to standards developed by the Swedish Institute for Standards (SIS). At present, there is no dedicated SIS standard specifically regulating technical assessment of reclaimed materials for reuse.

According to interviewee R1 (SIS), the withdrawal of detailed prescriptive references was intended to stimulate market innovation and allow greater flexibility. However, this has resulted in increased variation in assessment practices, as organizations have developed internal routines in the absence of centralized standardization (Interview with R1). At the time of the interview, SIS was participating in an EU-driven standardization initiative aimed at clarifying procedural steps and responsibility allocation in reuse processes.

As stated by SIS: *"A standardized assessment framework is an important tool for reuse. It will be even more important to have an established method to rely on when Boverket withdraws what was previously regulated in general guidelines."* (SIS, 2026)

Overall, the Swedish regulatory logic is performance-based and compliance-oriented. Reuse is permitted provided that materials meet existing technical and safety requirements, but no reuse-specific technical appraisal framework is codified in regulation.

Norway: Structured Domains Including Governance and Liability.

In Norway, reuse is explicitly addressed within the technical regulation TEK17 (*Forskrift om tekniske krav til byggverk*) issued under the Planning and Building Act *(Direktoratet for byggkvalitet)* (DiBK, 2017)

Section § 9-5 ("Byggavfall og ombruk") requires:

- Minimization of construction waste
- Sorting and documentation of waste fractions
- Assessment of reuse potential in demolition and rehabilitation projects

(DiBK, 2017, § 9-5).

While TEK17 establishes general requirements for waste management and reuse mapping, it does not provide a standardized technical appraisal checklist for reclaimed materials. More detailed considerations of what constitutes "responsible reuse" are articulated in a DiBK-commissioned research project, *Forsvarlig ombruk av byggevarer* (ReSirqel, 2019). The report proposes four assessment domains:

1. Technical suitability (structural capacity and load-bearing function, durability and remaining service life, damage and deformation, compatibility with new use)
2. Environmental and health risks (presence of hazardous substances, compliance with chemical regulations, indoor climate implications)
3. Documentation and traceability (existing documentation, knowledge of origin and age, previous exposure; ability to verify compliance with applicable requirements)
4. Liability and responsibility (risk acceptance by client and designers; allocation of responsibility among actors)

(ReSirqel, 2019)

These domains do not constitute binding regulatory requirements but provide interpretative guidance for operationalizing reuse within the framework of existing building regulations.

The report also references environmental product markings such as the Swan Label, EU Ecolabel, and ECOproduct as potential indicators relevant to environmental suitability (ReSirqel, 2019).

Compared to Sweden, the Norwegian context integrates governance, documentation, and responsibility considerations more explicitly in its interpretative framework. However, similar to Sweden, no dedicated reuse-specific technical acceptance criteria are codified in regulation.

Denmark: Strategic Framing and Mandatory Resource Mapping.

In Denmark, reuse is increasingly integrated into national sustainability strategies. From mid-2025, buildings exceeding approximately 250 m² must undergo mandatory resource mapping prior to demolition, identifying materials suitable for reuse, recycling, or appropriate handling (Boligstyrelsen, 2024).

The strategy document *Helhedsorienteret omstilling af byggeriet (HOB): Strategi for udvikling af bygningsreglementet, der understøtter den grønne omstilling* frames reuse within a systemic transformation of the building sector (Boligstyrelsen, 2024). The strategy emphasizes regulatory reform, green transition objectives, and circular economy alignment.

However, similar to Sweden and Norway, Danish regulation does not provide detailed technical performance criteria or standardized inspection procedures for individual reclaimed materials. Reuse must comply with existing building regulations, but no reuse-specific material appraisal framework exist.

Overall, the Danish regulatory logic is characterized by: strong emphasis on resource mapping, integration of reuse into planning and demolition processes, and limited information on material-level technical assessment factors.

European Union: Audit and Market-Oriented Approach.

At EU level, the updated *Construction and Demolition Waste Management Protocol* (European Commission, 2024) promotes pre-demolition audits, selective demolition, waste segregation, and improved traceability of construction materials.

The protocol highlights assessment aspects such as: Demountability and accessibility; Environmental and technical performance; Regulatory compliance; Market readiness (European Commission, 2024)

The inclusion of "market readiness" introduces an economic-operational dimension into reuse evaluation. However, the protocol is guidance-oriented and does not define binding technical performance factors for reclaimed materials.

Comparative Analysis of the regulatory documents.

The comparative analysis demonstrates that reuse across all jurisdictions is regulated indirectly through general building performance requirements rather than through dedicated reuse-specific assessment frameworks. Structural safety, fire compliance, and chemical safety are mandatory baseline requirements. Process-level obligations, such as resource mapping and documentation, are increasingly introduced, particularly in Norway, Denmark, and EU-level guidance. However, none of the reviewed regulatory frameworks define standardized evaluation assessment factors specifically directed to reclaimed materials.

All relevant aspects identified through this review were incorporated into the comparative *Table 3*.

Assessment Dimension	Sweden (Boverket)	Norway (TEK17 / DiBK)	Denmark (BR / Strategy)	EU Protocol (2024)
Compliance with existing technical building regulations	✓	✓	✓	✓
Structural safety must be ensured (if load-bearing)	✓	✓	✓	✓ (must comply with national codes)
Fire safety compliance	✓	✓	✓	✓
Hazardous substances / chemical compliance	✓	✓	✓	✓
Waste minimization requirement	✓	✓	✓	✓
Pre-demolition / resource mapping requirement	Partial (guidance-based)	✓ (§9-5 reuse mapping)	✓ (mandatory >250 m² from 2025)	✓ (audit recommended)
Documentation / traceability emphasis	Partial	Partial	Partial	✓ (audit documentation)
Market readiness dimension	✗	✗	✗	✓
Formal reuse-specific technical appraisal framework	✗	✗	✗	✗

Table 3: Regulatory logic for Material Reuse Assessment.

In addition to technical and environmental requirements, heritage and conservation regulations may influence material reuse decisions. In cases where buildings or components are subject to cultural-historical protection, demolition or alteration may require approval from heritage authorities. Although conservation assessment does not constitute a material appraisal criterion in the technical sense, it represents a regulatory boundary condition that can override reuse or disposal decisions. This dimension was therefore considered in the subsequent synthesis of evaluation factors.

Based on the comparative analysis, the following factors emerge as necessary components of a structured material reuse assessment:

- Structural and Technical Performance (including structural capacity, fire safety compliance, compatibility with intended new use, functional performance under loads and environmental exposure)
- Environmental and Health Safety (including chemical compliance, presence of hazardous substances)
- Condition and physical integrity (including damage, deformation, or degradation)
- Documentation and Traceability (including material origin documentation, traceability of prior use)
- Process and Logistical Feasibility (incl. demontability, accessibility, etc.)

4.1.2 Research institutions, initiatives, and online platforms

In addition to formal regulatory documents, reports from research institutions, industry initiatives, and digital reuse platforms were reviewed to identify operational assessment factors currently applied in practice. Unlike regulation, these sources do not define binding requirements but provide methodological guidance and practical tools for material appraisal.

The review included reports and guidance from RISE and IVL (Sweden), SINTEF/Byggforsk (Norway), and Værdibyg (Denmark), as well as digital platforms such as CCBuild, Loopfront, Genbyg.

Research institutions: Sweden.

A recent report from 2025 by RISE (Research Institutes of Sweden), commissioned by Business Region Gothenburg, identifies evaluation factors grouped in three categories:

1)Technical suitability
2)Attractiveness for a client
3)Economic incentive
(RISE, Business Region Göteborg, 2025)
More detailed information is presented in *Attachment 3*.

IVL (Svenska Miljöinstitutet) published guidance *Återbruksinventering i praktiken* (2025) which provides an example list of practical inventory parameters, including: Dismantlement, Material condition and technical functionality, Environmental and resource savings, Manageability and economic efficiency, Demand and usability, Product flow, Health and safety, Architectural or cultural value, Quantity, Potential climate savings. (IVL; Möberg, Sandra, 2025). More detailed information is presented in *Attachement 2*.

Research institutions: Norway.

Byggforsk, also SINTEF, a research and knowledge institution (not a regulatory authority), provides a guidance on reuse mapping *Ombrukskartlegging av bygninger,* which focuses on:

- Technical condition
- Dismantlability
- Remaining service life
- Compliance with existing technical requirements

See *Attachment 1* for the whole list.

The guidance supports TEK17 obligations but remains technically oriented. Cultural, aesthetic, and contextual factors are not systematically incorporated (Byggforskserien, 2023).

Research institutions: Denmark

The Danish industry initiative *Værdibyg* provides *knowledge bank* reports, which extends beyond technical inventory and introduces broader evaluative considerations. In addition to quantity, condition, dismantling feasibility, and hazardous substances, the guidance explicitly references:

- Reuse or sales potential
- Logistics and storage considerations
- CO_2 savings
- Financial implications
- Need for cleaning/reconditioning

See *Attachment 1* for the whole list.

Notably, Værdibyg introduces qualitative value aspects such as "soul" (*sjæl*), referring to the narrative and experiential qualities of reused materials:

> *"Reuse gives soul : Recycled materials, such as old bricks, beams and interiors, give the building soul and can either tell a story or be something that can be used for storytelling. For many users, this has a high value, which can mean both a willingness to pay more in rent and also that the building is taken better care of."- translated from Danish (Ressourcekortlægning, 2024)*

While not formalized as measurable criteria, this indicates recognition of cultural and aesthetic dimensions within industry discourse.

The report puts more attention on the efficiency of the mapping process, suggesting to align the scope and content of the resource mapping with the real need and the current project, so that an unnecessary amount of time or money is not spent on mapping details that are not relevant (Ressourcekortlægning, 2024).

Online platforms

Digital platforms such as CCBuild (Sweden); Genbyg (Denmark); Loopfront (Norway) function as operational tools for inventory and exchange of reusable materials. See the *Attachment 1* for the comparison matrix.

Across platforms, recurring assessment parameters include:

- Structural integrity/Technical functionality
- Physical condition
- Hazardous substance tagging
- Quantity and dimensions
- Economic value or residual value
- Market demand (partial)
- Documentation/traceability (partial)
- Logistics/storage feasibility(partial)

Unlike research reports, platforms prioritize standardized input parameters that facilitate comparability and market exchange. Their assessment logic is therefore more operational and transaction-oriented. Notably however, Swedish platform CC build suggests to evaluate "aesthetic condition"-*estetisk skick*- of a materials for potential reuse on a scale 1-5, operating with notion of "damage" and visual imperfection of the material or an object. This factor was taken under "Physical condition / damage" to enable comparison with other platforms which describe same qualities.

CCBuild also emphasizes the importance of values such as climate impact reduction, decreased waste volumes, and economic savings as decision-support factors for promoting circularity within projects and organizations.

Preliminary Factors Identified in Institutions Guidance and Digital Platforms

The review of research institutions reports and digital platforms reveals a consistent set of operational evaluation dimensions that extend beyond regulatory compliance. See the *Attachment 1* for the comparison matrix.

While the sources differ in format and purpose, recurring assessment factors include:

- Structural integrity/Technical functionality
- Physical condition and visual damage
- Remaining service life
- Need for reconditioning
- Hazardous substances and chemical compliance
- Climate impact
- Economic feasibility, including reconditioning costs
- Market demand and reuse potential
- Quantity and dimensions
- Documentation and traceability
- Dismantlability and accessibility
- Logistics feasibility and storage

The identified factors demonstrate a clear overlap between research-based guidance and the operational logic embedded in digital reuse platforms. Together, they capture technical, environmental, economic, and logistical considerations that currently shape material reuse practice. This preliminary set of factors provides the foundation for further refinement through the subsequent review of corporate guidance and empirical findings.

4.1.3 Corporate guidelines and practitioner's approach

To complement regulatory and research-based perspectives, corporate strategy documents, internal evaluation frameworks, and interview data from industry actors were reviewed. These sources reflect applied decision-making practices and illustrate how reuse criteria are prioritized within real project contexts.

The analysis included corporate strategy material from Vasakronan (SE), reuse-related evaluation input shared by Castellum and an anonymous Swedish real-estate developer, and the reuse assessment framework developed by Vandkunsten in collaboration with Genbyg A/S (DK). Interviews were conducted with architects and sustainability specialists from Mad Architects (NO), White (SE), Wingårdhs (SE), Vandkunsten (DK), and Fredblad (SE).

Unlike regulatory documents, corporate guidance focuses on feasibility within specific project conditions, including cost, liability, and time constraints.

Climate Impact as Primary Decision Driver.

Across corporate actors, climate impact emerged as a central evaluation parameter. Vasakronan identifies embodied carbon savings as the primary decision driver in material evaluation, followed by ease of reassembly, reuse potential, and the scarcity of raw materials. Economic value—assessed in comparison to equivalent new products—is considered secondary but still relevant.

Similarly, sustainability specialists (S1, S2) emphasized climate savings as one of the dominant criteria in architectural decision-making. These findings reinforce climate impact as a key performance dimension in corporate reuse practice.

Economic and Feasibility Considerations.

Economic feasibility consistently appeared as a decisive factor. Castellum identified climate impact, aesthetics, and economic incentives as primary evaluation criteria. Vandkunsten (2016) operationalizes economic feasibility through production cost performance, labour input, time requirements, process complexity, and sales potential.

An anonymous developer further underscored the importance of systematically accounting for reconditioning costs—such as painting, cutting, and deformation corrections—since these expenditures may exceed allocated budgets. This indicates that economic assessment extends beyond price comparison to encompass implementation risk and operational complexity.

Technical and Lifecycle-Oriented Criteria.

Technical performance remains fundamental. Architect A5 and sustainability specialist S1 emphasized environmental performance, age, remaining service life, material quality, recyclability, hazardous substances, and dismantlability as relevant criteria.

Vandkunsten's framework expands this perspective through multidimensional performance categories, including construction performance (on-site risks and buildability), use performance (maintenance requirements, technical risks, regulatory compliance), and design for disassembly performance. This approach reflects a lifecycle-oriented understanding of material value rather than isolated technical compliance.

Cultural and Aesthetic Value.

Unlike regulatory frameworks and most platform-based material exchange systems, developers and architectural actors explicitly acknowledge the aesthetic and cultural dimensions of reclaimed materials. Several interviewees emphasized that reuse is not solely a technical or environmental matter but also a question of architectural expression and identity.

The project manager at Castellum described aesthetics as a formal evaluation criterion in renovation projects, suggesting that visual and experiential qualities are institutionally recognized within certain development processes. Sustainability specialist S2 similarly highlighted aesthetic value as an integral component of decision-making. Architect A5 and developer D2 further referred to the "narrative potential" of reused materials, underlining their symbolic capacity to communicate historical continuity and site-specific identity. In this sense, reclaimed materials are not treated merely as resources but as carriers of meaning.

This dimension is conceptualized by Vandkunsten (2016) as *cultural performance*, defined through experiential qualities, architectural expression, identity, and materiality. In their internal assessment, materials scoring highly within this category were considered to possess greater cultural value than conventional alternatives. However, in the interview with Prof. Sören Nielsen, it became clear that this evaluation was not conducted through a standardized scoring mechanism. Instead, cultural value was assessed through collective on-site discussions among project stakeholders. The absence of a formalized framework highlights a fundamental tension: while environmental performance is increasingly quantified and standardized, aesthetic and cultural value remains largely dependent on professional judgment and shared interpretation.

Several interviewees (S1, A5) also noted that cultural-historical value is typically assessed by antiquarian specialists when required by regulation prior to demolition or renovation. In such cases, cultural evaluation becomes reactive and compliance-driven rather than proactive and design-integrated. This reinforces the observation that while cultural value is acknowledged, it is rarely embedded in systematic assessment structures comparable to environmental metrics.

Broader interdisciplinary research supports the significance of aesthetic considerations in the built environment. The visual language of architecture plays a crucial role not only in shaping urban skylines but also in influencing how individuals perceive and experience space (Carlson, 1986, as cited in Pei & Cao, 2025). Increasing emphasis on architectural aesthetics reflects recognition that visual and spatial qualities affect psychological well-being, reinforce cultural identity, and contribute to environmental awareness (Cheung & Yiu, 2022, as cited in Pei & Cao, 2025). From this perspective, aesthetic value is not secondary to sustainability—it is deeply entangled with social acceptance and long-term relevance.

This view finds resonance in practice. Architect Sören Pihlmann argues that aesthetic quality in reuse is not imposed but discovered through engagement with a material's inherent properties — and that emotional attachment is a precondition for sustainable choice: if people do not find something desirable, they will not choose it (Rum, 2025). Constraints imposed by material scarcity can, paradoxically, expand rather than limit aesthetic possibility, opening space for experimentation and architectural identity that conventional new-build rarely permits.

Similar insights emerged from the interviews conducted for this thesis. When asked what a lack of resources implies for aesthetic possibilities, practitioners described it as an "interesting challenge," emphasizing "creativity within limitations" and "greater creativity, on a completely new level." These reflections suggest that constraints do not necessarily restrict architectural expression; rather, they can catalyze innovative hybrid construction techniques and careful material use. As one interviewee summarized, such conditions "encouraged careful material use, reuse, and hybrid construction techniques, resulting in architecture of lasting aesthetic and cultural value."

The interviews strongly indicate that aesthetics plays a decisive role in the acceptance and desirability of reuse practices. If circular construction is to become mainstream, its cultural and aesthetic dimensions may be just as critical as its environmental performance.

Aging, Weathering, and Uniqueness.

Two additional factors closely connected to aesthetic and cultural value emerged from the interview and survey analysis: aging/weathering performance and material uniqueness**.**

Several respondents emphasized a preference for materials that age visibly and develop character over time. One survey participant stated: *"I prefer when materials and the built environment are allowed to age naturally and materials that constantly look new do not appeal to me."*

Similarly, architect A4 highlighted the importance of weathering quality:

"Materials that hold well weather and age well. I don't like materials that are either clean or not clean. I like those which can be in the spectrum. For instance stone, it has different stages of aging, even if it's 400 years old. The most important is quality of aging and weathering. Reuse can add a lot of nerve and character to the project."

These reflections suggest that the evaluation of reused materials extends beyond current technical condition to include anticipated aesthetic transformation over time. Aging and weathering are not framed as degradation alone, but as qualities that contribute to architectural depth and narrative continuity.

Uniqueness was identified as a separate evaluation dimension. Architect A1 highlighted the distinctiveness of materials such as marble or teak windows, emphasizing rarity, craftsmanship, and irreplaceable qualities. Unlike technical or environmental metrics, aging and uniqueness are not formalized in existing frameworks. However, their recurrence across interviews indicates their relevance within architectural decision-making.

Synthesis of Corporate-Level Factors

Across corporate guidance and practitioner interviews, the following recurring evaluation dimensions were identified:

- Climate impact and embodied carbon savings
- Technical functionality
- Remaining service life
- Hazardous substances and chemical compliance
- Economic feasibility, including reconditioning costs
- Market and sales potential
- Design for disassembly and future reuse potential
- Aesthetic value
- Uniqueness
- Aging and weathering performance

Compared to research institutions and digital platforms, corporate and architectural actors place stronger emphasis on experiential qualities, cultural value, and project-specific feasibility constraints. These findings expand the preliminary factor pool identified in Sections 4.1.1 and 4.1.2 and further demonstrate the multidimensional character of material evaluation in practice.

4.1.4 Analysis and key findings (RQ1)

The cross-analysis of regulatory documents, research reports, digital platforms, corporate guidance, and interview findings resulted in the systematic identification of recurring evaluation dimensions for material reuse. Applying the inclusion factors defined in Section 3.2.5—document-based recurrence, regulatory necessity, and empirical validation—led to the consolidation of sixteen assessment factors, presented in *Table 4* below.

The first five criteria reflect regulatory compliance and technical baseline requirements. Criteria six through thirteen emerge primarily from research reports, digital platforms, and corporate practice, addressing environmental, economic, and operational feasibility. The final factors—aesthetic value, uniqueness and aging—were primarily derived from practitioner interviews and survey findings, highlighting dimensions insufficiently represented in existing guidelines.

Together, these sixteen factors form the conceptual foundation of the multidimensional appraisal framework developed in this thesis. See the *Table 4*.

Domain 1 – Regulatory Boundary Conditions

Factor	Description (Original Logic)	Guiding Question	Key metrics
1. Structural integrity / technical functionality	Compliance with structural or functional performance requirements	*Can this material category reliably meet required structural or functional performance standards in typical reuse contexts?*	Structural load capacity/Fire classification/Acoustic performance/Regulatory compliance, etc.
2. Hazardous substances / chemical compliance	Verification of absence of harmful substances according to regulations	*Is this material category typically compliant with current chemical regulations without requiring remediation?*	Regulatory eligibility
3. Cultural-historical conservation value	Heritage or conservation status affecting demolition or reuse. This factor does not override safety or compliance.	*Does this material category commonly carry heritage or conservation value that increases chances on avoiding disposal?*	

Domain 2 – Lifecycle & Environmental Performance

Factor	Description	Guiding Question	Key metrics
4. Climate impact reduction potential	Avoided greenhouse gas emissions compared to new production	Does reuse of this material category typically result in significant avoided production emissions?	Avoided CO_2-eq per unit
5.Remaining service life	Residual functional capacity relative to intended reuse	Does this material category typically retain sufficient performance capacity for a second service period?	Years

Domain 3 – Operational & Market Feasibility

Factor	Description	Guiding Question	Key Metrics

6. Dismantlability / accessibility	Ease of removal without damage	Can this material category typically be removed without destructive processes?	Physical feasibility
7. Readiness for direct reuse/no reconditioning	Level of repair or preparation required	How ready is this material category for reuse without significant intervention?	Labour hours saved/Repair complexity avoided
8. Documentation / traceability	Availability of verifiable technical records	How likely is this material category to have sufficient documentation to support regulatory approval?	Availability of EPD/CE markings/Tracebility records/etc.
9. Quantity / dimensional compatibility	Availability in usable volumes and dimensions	Is this material category typically available in volumes and dimensions suitable for reuse projects?	St., sq.m., volumes, etc.
10. Logistics feasibility	Transport and storage requirements	Can this material category typically be transported and stored without excessive complexity?	Transport distance and costs savings
11. Economic feasibility	Cost competitiveness compared to new alternatives	Is reuse of this material category typically cost-competitive?	Comparative cost to equivalent new products
12. Market demand / reuse potential	Demand within secondary material markets. Market demand reflects observed reuse patterns and secondary market activity rather than theoretical suitability.	Is there consistent demand for this material category in current reuse markets?	Presence of established resale/ frequency of listing on reuse platforms/ turnover rate
13. Design for disassembly compatibility	Alignment with reversible construction principles	Is this material category typically installed in a way that supports future disassembly?	Labour hours saved

<u>Domain 4 – Architectural & Cultural Value.</u>

Factor	Description	Guiding Question	Key Metrics
14. Aesthetic value	Visual and architectural contribution	Does this material category typically contribute positively to architectural quality when reused?	Visual condition, perceived architectural value, historic style compatibility, authenticity
15. Material uniqueness	Degree of distinctiveness or craftsmanship	Does this material category possess qualities that differentiate it from standardized new products?	Degree of standardization vs. bespoke character/Presence of craftsmanship/Rarity of material type/ Architectural distinctiveness
16. Aging / weathering performance	Quality of material aging and long-term appearance	Does this material category typically age in a way that maintains or enhances Architectural values?	Naturalness of material/ amount of chemical treatment/ visual transformation capacity

Table 4: Appraisal factors.

4.2 Identification of assessment methods

This section addresses Research Question 2 (RQ2): *How can the identified evaluation factors be assessed in practice?*

Assessment approaches are clarified for factors whose application to reclaimed materials introduces methodological complexity beyond standard procedures. For example, while climate impact reduction and remaining service life can be assessed through established calculations and testing, their application in a reuse context requires specific assumptions and boundary definitions that are addressed here. Similarly, economic feasibility in reuse scenarios involves considerations that differ substantially from conventional procurement.

4.2.1 Climate Impact of reused materials

Climate impact reduction potential refers to the comparative greenhouse gas emissions associated with a reuse scenario relative to the use of equivalent newly manufactured materials. In practice, this comparison is typically conducted using Life Cycle Assessment (LCA), standardized under ISO 14040/44 and operationalized for buildings through EN 15978. However, when applied to reused components, climate assessment requires explicit methodological choices regarding system boundaries and allocation of environmental burdens across multiple life cycles.

In Sweden, climate calculations for construction are regulated through Boverket's climate declaration framework (Boverket, 2023). Although the regulation is not specifically designed for reused materials, it establishes the reference methodology against which reuse scenarios are evaluated. Boverket's climate database provides generic emission factors for construction products, primarily covering modules A1–A3 (raw material extraction and manufacturing) and A4 (transport to site). These values are derived from aggregated Environmental Product Declarations (EPDs) and represent conservative averages for the Swedish market. In reuse assessment, these generic A1–A3 values typically function as the reference burden considered "avoided" when a reclaimed component replaces a newly manufactured equivalent.

Within reuse literature, a distinction is often made between calculating total climate impact and calculating climate savings (Moberg et al., 2022). The latter approach, which focuses on avoided production impacts compared to a linear reference scenario, is considered particularly suitable for decision support in reuse contexts. Moberg et al. (2022) demonstrate that emissions associated with reuse-related processes—such as storage, transport, and reconditioning—are generally significantly lower than the emissions avoided through substitution of new production. This supports the use of comparative climate savings as a practical and communicative metric in reuse appraisal, provided that underlying assumptions are transparently documented.

At the same time, research demonstrates that allocation choices significantly influence results. De Wolf et al. (2020) show that different approaches—such as cut-off, end-of-life, or distributed allocation—can produce substantially different outcomes when assessing reused components, because environmental burdens must be distributed across sequential life cycles. Under the commonly applied cut-off approach, upstream production impacts are assigned to the first life cycle and not reallocated to the reused product, resulting in A1–A3 being set to zero for the second life cycle. Alternative allocation models may distribute impacts differently, leading to variation in reported climate savings. Gobbo et al. (2024) further highlight that the absence of consistent methodological guidance for monitoring environmental performance in reuse projects contributes to uncertainty and limited comparability across studies.

Similarly, comparative LCAs of renovation versus new construction demonstrate that system boundary definition strongly affects calculated results (Hasik et al., 2019). Whole-building assessments must distinguish between retained and newly added materials and consistently include life cycle stages from production (A1–A3) through use and end-of-life (C stages). Because reused materials effectively substitute new production, incorrect inclusion or exclusion of modules may either overestimate or underestimate the actual climate benefit.

In addition to formal LCA procedures, digital platforms have operationalized climate assessment into simplified comparative tools. For example, CCBuild integrates climate calculation functions that estimate avoided CO_2-equivalent emissions when a reused product replaces a new equivalent (CCBuild, 2024). These tools typically rely on generic emission data aligned with national databases or EPD sources and calculate avoided manufacturing emissions while incorporating estimated transport impacts. Although such tools increase accessibility and support early-stage decision-making, they do not constitute full building-level LCAs according to EN 15978. Their results depend on standardized assumptions and may not fully capture project-specific factors such as transport distance, refurbishment intensity, or storage duration.

Several methodological limitations must therefore be acknowledged. First, allocation of upstream impacts remains contested, and results vary depending on the chosen modelling approach. Second, transport distances and logistics can significantly affect the net climate benefit, particularly for heavy components. Third, refurbishment or adaptation processes are not consistently integrated into simplified calculations and may reduce theoretical savings. Finally, generic emission factors, including those provided by Boverket's climate database, represent average conditions and may not reflect the specific environmental profile of a reclaimed material.

Method of Assessment.

For the purposes of this thesis, climate impact reduction is therefore assessed as a comparative, scenario-based calculation grounded in established LCA methodology but requiring explicit documentation of assumptions. The appraisal must clearly state the life cycle modules included, the allocation approach applied, the emission factors used (e.g., Boverket database or product-specific EPDs), and the treatment of transport and preparation activities. Transparent boundary definition is essential for ensuring that climate impact reduction functions as a robust and comparable evaluation factor within the proposed multidimensional reuse appraisal framework.

4.2.2 Remaining Service life

The assessment of the *service life* of materials is a critical factor in evaluating the environmental performance of construction products, particularly when considering reuse. Service life affects the number of replacement cycles, the allocation of embodied impacts, and the definition of the functional unit in Life Cycle Assessment (LCA) studies. Accurate modelling of service life, and of the *remaining service life* (RSL) for reused components, is therefore essential for comparing new and reused materials on an equivalent functional basis.

In construction, several terms related to service life are frequently used, often with overlapping meanings. Clarifying these concepts is crucial for a consistent and transparent assessment of the service life factor.

Service life is formally defined in construction standards as "the period after installation during which a building or its components meet or exceed the performance requirements" (ISO 15686-1, as cited in Silva et al., 2022). Service life is typically linked to regulatory and design standards and serves as a benchmark for planning maintenance and replacements.

Durability refers to a material's inherent ability to resist degradation mechanisms such as chemical attack, moisture ingress, fatigue, or corrosion (ISO 15686; fib, 2006). Durability underpins the potential service life but does not account for functional or aesthetic obsolescence.

Functional life is defined as the period during which a material or building element fulfills its intended function, considering changes in use or functional requirements (Silva et al., 2022). Unlike service life, functional life incorporates the possibility that a component may become obsolete due to functional, aesthetic, or regulatory changes.

Technical lifetime describes the maximum period a product can function before it fails due to material degradation. Importantly, if a product is discarded before reaching its technical lifetime, reuse becomes possible, reducing the demand for new materials to deliver the same functional performance (Silva et al., 2022).

Lifespan is often used as an informal term describing the total existence of a material, from production to end-of-life. It is a broad concept that encompasses both technical and functional aspects of material use, but not a defined technical term. Moreover, according to recent peer-reviewed reports, lifetime definition often differs and in LCA, leading to inconsistency of results (Jerome & Ljunggren, 2025). Lifespan within LCA is treated as a modelling parameter representing the time horizon over which environmental impacts are assessed. In European methodology under EN 15978, this period formally called as Reference Study Period (RSP), often 50-60 years and used to account for replacement, maintenance, operational energy, and end-of-life impacts.

Therefore service life and lifespan are not the same by definition. Lifespan may not reflect actual durability, while service life is based on performance and technical aspects. Since service life strives for precision and varies between components within a building, it is not suitable for comparison of global study period in LCA.
In life cycle assessment (LCA), the modelling of product "lifetime" significantly influences the results. For example, the assumed lifetime determines which processes are included in the assessment (such as the replacement of building components) and influences the magnitude of flows occurring during the use phase (e.g., operational energy consumption). When comparing alternatives with different expected lifetimes—such as durable versus less durable products, or reused versus newly manufactured components—the functional unit must reflect performance over an equivalent time horizon to ensure comparability (Jerome & Ljunggren, 2025).

Despite the importance of this issue, international LCA standards (e.g., ISO 2006a; ISO 2006b) provide limited methodological guidance on how product lifetime should be defined and modelled (Jerome & Ljunggren, 2025). The influence of lifetime assumptions on LCA outcomes has been examined particularly in building-related studies. Different prediction approaches have been shown to substantially affect results (e.g., Grant & Ries, 2013, as cited in Jerome & Ljunggren, 2025; Decorte et al., 2023, as cited in Jerome & Ljunggren, 2025). For example, in comparisons between renovation and new construction, it has been recommended that both options be assessed over an identical total lifetime to ensure a consistent basis for evaluation (Decorte et al., 2023 as cited in Jerome & Ljunggren, 2025). Therefore, when conducting an LCA, the respective service lives of materials must be considered to ensure the accurate allocation of embodied environmental impacts.

While standard does not provide a separate formal definition for service life of reused component, a term *Remaining Service Life* (RSL) seem to be appropriate. This term is an adaptation of ISO 15686, which is a performance-based definition and describes Service Life, as well as Estimated service life and Design service life. Contractors and engineering firms use the RSL term as part of condition assessment and maintenance operations. By RSL is meant "the period in which the structural asset is expected, under the given boundary conditions, to continue to fulfill the required functions (structural stability, serviceability, durability)." ((Darda, 2026).

According to practice-based guidance published by Vandkunsten (2017), RSL assessment should also consider functional, aesthetic, and economic aspects. The assumed "lifetime" of reused products in Life Cycle Assessment (LCA) studies is often based on their residual quality, intended future use and the performance of the substituted new product. Where reused components are restored to a quality comparable to new materials, equivalent technical lifetimes may be assumed; nevertheless, aesthetic qualities such as patina may in some cases extend their economic or cultural lifespan, thereby increasing their value and delaying replacement (Tegnestuen Vandkunsten A/S; Nielsen, K Søren , 2017).

From a circular economy perspective, "lifespan" can also be conceptualized through indicators such as the "longevity indicator," which measures the initial lifetime of a product together with "earned refurbished lifetimes" and "earned recycled lifetime," thereby capturing life extension through reuse and recycling cycles (Franklin-Johnson et al., 2016). This broader understanding of service life highlights that materials can accumulate additional service years through refurbishment and secondary applications and stay longer inside of a product system. Longevity indicator is suggested as a simple metric for evaluating the effectiveness of circular strategies.

Considering RSL of materials is particularly important in design decision-making: materials with significantly different service lives should not be permanently combined in ways that hinder separate replacement or reuse (Strand Nyhlin & Åfreds, 2022). As argued by Nyhlin and Åfreds (2022), components with a 20-year replacement cycle should be designed separately from structural elements expected to last 50 years, in order to avoid premature demolition of long-life materials and to enable future disassembly.

RSL assessment for reuse must also be linked to climate impact. The Swedish Environmental Institute (IVL) identifies three product groups as especially relevant for recycling and reuse due to their climate implications: (1) products with high embodied emissions from extraction and manufacturing, such as plastics, metals and electronics; (2) heavy, high-volume materials such as structural elements, façade materials, stone and concrete; and (3) high-flow products that are frequently replaced or available in large quantities (Boverket, 2024). For these categories, extending service life or enabling multiple life cycles can significantly reduce embodied carbon and improve LCA outcomes. Indeed, service life have been shown to strongly influence LCA results, since longer service life distributes embodied emissions over a longer functional period.

Method of Assessment.

For the framework of this master thesis, RSL factor is suggested to be assessed in following steps:

1) Conduct a technical residual quality assessment, including evaluation of structural integrity, degradation (e.g., corrosion, cracking, fatigue), etc. This step establishes the current technical performance state of the material and forms the basis for further analysis.
2) Estimate the remaining service life with consideration of future exposure conditions (temperature variations, load, etc.)
3) Conduct a functional suitability assessment to determine compatibility with intended new application/ use. If product or material is supposed to be combined with other, check their compatibility, as materials with substantially different RSL should not be permanently combined, in order to avoid premature replacement, aim for Design for Disassembly principle.
4) Adress a circular longevity perspective, evaluating climate savings from refurbishment, adaptation, or secondary applications.
5) Adress the aesthetic qualities such as patina, that may extend material's economic or cultural lifespan, thereby increasing their value and delaying replacement.

4.2.3 Economic Efficiency

Economic efficiency is a critical factor in evaluating the feasibility of reusing construction materials, as it reflects both the costs and benefits associated with material choices.
In the context of the circular economy, economic efficiency extends beyond initial procurement costs and includes whole-life cost considerations, residual value, and end-of-life scenarios, as reflected in ISO 15686-5:2017, Life Cycle Costing (Standardization., 2026). Furthermore, the economic dimension of circular economy strategies encompasses cost premiums, potential cost savings, impacts on total building cost, and market-related factors such as price competitiveness, demand conditions, and alternative solutions (Kirchherr et al., 2017; Nußholz et al., 2020). (Nußholz, 2019)

A comprehensive understanding of the cost composition is essential for assessing the economic efficiency of specific reused materials and for enabling a robust comparison with conventional procurement alternatives. Some of these aspects of this composition are reviewed below.

Cost premiums for reused materials are a primary consideration. These premiums arise from additional labor, deconstruction processes, cleaning, sorting, certification, and transportation, which can exceed the upfront cost of conventional materials. In Sweden, where labor costs are relatively high and quality assurance is required for reused materials, these premiums can be significant. Studies have shown that labor-intensive recovery and quality testing can represent up to 15–25% additional cost compared to new materials (Nußholz & Whalen, 2019).

Conversely, reused materials can generate cost savings by avoiding the purchase of new materials, reducing landfill or waste management fees, and leveraging local sourcing to reduce transportation expenses. These savings must be evaluated alongside cost premiums to provide a complete picture of economic efficiency.

A systematic review of pilot projects in Scandinavia confirmed that cost savings can be achieved through reuse. It was calculated that reusing windows for KA13 achieved cost savings of approx. 60% (Jødal, Hansveen & Hall, 2020, as cited in ENTRA, 2021). The price for the used windows was compared to the prices of new windows in the Norwegian price index. However, in the same project it was reported that reuse of the ceiling panels in mineral wool, used for sound absorption, was found to be 60% more expensive than use of a new alternative (Jødal, Hansveen & Hall, 2020, as cited in ENTRA, 2021). In this case, the extra costs were associated with increased installation time. It was determined that a new alternative would have resulted in a simpler installation process. Similarly, reuse of steel in the KA13 project was found to be 49% more expensive than the purchase of new steel. These cost assessments were conducted by students for an OsloMet bachelor's thesis in 2020. The reused steel included expenses related to identification and sourcing of reused steel, acquisition, dismantling, scanning and testing, processing, temporary storage, transportation, and reassembly. It should be noted that these figures are sensitive to market price fluctuations and have not been subject of independent peer review.

Another example of cost savings is drawn from the project *kv. Återbruket* in Gothenburg, Sweden. According to an interview with a contractor (C1), the reuse of metal sheets for the façade of the residential development resulted in a 72% cost reduction compared to the procurement of new materials.

A case involving the construction of an electric bus depot in Kronenberg Region demonstrated the economic potential of brick reuse. Even in instances where the cleaning process was relatively labor-intensive, resulting in a cost to the client of approximately 12 SEK per brick to the client, the reuse alternative still generated savings compared to newly purchased bricks. For reference, new bricks cost approximately 25 SEK per unit when acquired from a building materials supplier, corresponding to a cost reduction of approximately 52% (Godahus, 2021).

These examples illustrate that both cost premiums and cost savings associated with material reuse are highly context-dependent. Economic outcomes vary across projects, materials, and specific circumstances, as factors such as administrative efforts, material availability, geographical location and transportation requirements, material condition and reconditioning needs, as well as dismantling and installation processes all significantly influence the overall cost structure.

As noted in the report by Godahus, "It is desirable to undertake a more systematic review of the economics of selected reuse projects in order to better illustrate the overall pricing landscape. At the same time, meaningful comparisons between projects remain challenging, as project-specific conditions inevitably differ." (Godahus, 2021)

Ultimately, the economic efficiency of material reuse is strongly influenced by the level of market demand. In the Swedish context, the market for reused construction materials is still evolving, suggesting that current limitations may diminish as the sector matures. For instance, prefabricated concrete elements are considered particularly suitable for large-scale reuse due to their standardized production and structural properties. Efforts are currently underway to develop quality assurance procedures, standards, and methodological frameworks to support their reuse. However, significant barriers remain, including a shortage of specialized actors operating within this segment. Moreover, uncertainties related to economic incentives and the profitability of reuse activities continue to constrain broader market uptake (RISE, Business Region Göteborg, 2025).

Method of Assessment.

The reviewed cases demonstrate that the economic efficiency of material reuse is highly context-dependent and influenced by project-specific conditions, market maturity, and material characteristics. While significant cost savings are achievable in certain applications (e.g., windows, façade materials, bricks), other materials may incur substantial cost premiums due to labor intensity, quality assurance requirements, or complex installation processes. These findings indicate that economic performance cannot be generalized across materials but must be evaluated through a structured, project-specific assessment that accounts for full cost composition, including procurement, processing, logistics, installation, and residual value considerations.

For the purposes of this thesis, economic efficiency is therefore understood as a comparative, life-cycle-oriented assessment rather than a simple upfront cost comparison. A systematic evaluation framework is required to balance cost premiums against potential savings and to consider market-related uncertainties.

4.2.4 Cultural-Historical Conservation value

Cultural–historical conservation value refers to the qualities attributed to buildings or materials based on their historical relevance, authenticity, craftsmanship, social meaning, and contribution to collective memory.

Institutional background.

In Sweden, interventions affecting culturally significant buildings are regulated through a combination of national legislation and professional standards. The primary legal framework is provided by the Historic Environment Act (Kulturmiljölagen) together with the Planning and Building Act (PBL).These laws are complemented by technical standards issued by the Swedish Institute of Standards (SIS) and practical conservation guidance from the Riksantikvarieämbetet.

The Historic Environment Act (Kulturmiljölagen, 1988:950) provides the primary legislative framework for heritage protection. It establishes that both individuals and public authorities must exercise consideration and care when planning or executing works that affect cultural heritage, with the aim of preserving historic values for future generations, § 1, Historic

Environment Act (Culture, 2026). The Act also includes regulates the designation and protection of listed buildings, specifying the conditions under which alterations may occur without diminishing their cultural significance.

However, analysis of institutional guidelines indicates that current frameworks primarily address buildings as wholes rather than individual materials. While practical guidance exists for assessing architectural heritage, detailed methodologies for evaluating the cultural–historical value of specific materials—particularly in the context of reuse—remain underdeveloped at the national level. This reveals a methodological gap when decisions concern dismantling, salvaging, or reusing material components.

To address this gap, established international conservation frameworks provide useful theoretical and procedural foundations.

Internationally, the *Burra Charter* (Australia ICOMOS, 2013) introduced a value-based approach centered on the concept of *cultural significance*, defined through historical, aesthetic, scientific, and social values, and guided by the principles of authenticity, integrity, and cautious change. This values-led methodology has influenced broader conservation theory, including the work of the Getty Conservation Institute, which emphasizes the identification and articulation of multiple heritage values as a prerequisite for decision-making.

At the European level, *EN 16883:2017* provides a structured process for investigating and assessing historic buildings while improving energy performance in ways that respect heritage significance. Although developed for building-scale interventions, its core principles—context analysis, documentation, impact assessment, and respect for character-defining elements—can be applied to the material scale.

Contemporary Tensions in Defining Heritage Value.

The identification of cultural–historical value is not neutral. It is shaped by evolving cultural narratives, aesthetic judgments, and political priorities. The classification of a particular architectural period as "historically valuable" may unintentionally marginalize others, placing them at greater risk of neglet or demolition.

Traditionally, cultural-historical value has often been associated primarily with classical architecture and buildings constructed before the nineteenth century. However, this perception is increasingly being reconsidered. Architectural movements of the twentieth century, including modernism, postmodernism, and particularly brutalism, have in recent decades gained growing scholarly and public attention. As a result, buildings from these periods are progressively being reassessed and, in some cases, granted protected status. This evolving understanding of heritage highlights the need for systematic and inclusive evaluation criteria when determining cultural-historical significance.

Debates in Stockholm illustrate how aesthetic perceptions influence heritage outcomes. Late twentieth-century buildings such as Marievik 15, Snäckan 8, and Passagen have been demolished despite cultural classifications, with arguments of "ugliness" often cited in public discourse. These cases demonstrate how subjective aesthetic judgment may override sustainability considerations and adaptive reuse potential (Hejdelind & Hallemar, 2025).

In response, cultural heritage organisations such as Samfundet S:t Erik, Renoveringsraseriet, and Föreningen Fasad have worked to increase public understanding of postmodern architecture's cultural value. These initiatives believe, that increased knowledge can shift architectural value perception . The issue has also been brought to broader public attention through national radio programs such as Katarina Wikars' *På spaning efter 80-talets hus* (2024), which highlight the vulnerability of this architectural period to redevelopment pressure.

These examples demonstrate that cultural–historical value is dynamic and socially constructed. Therefore, assessment must rely on explicit and transparent criteria rather than fluctuating aesthetic preferences.

Method of Assessment.

Building on value-based conservation theory and European standards, the cultural–historical value of building materials can be evaluated through a structured, systematic approach. The process begins with a *contextual analysis*, which identifies the documented cultural significance of the building, clarifies its legal protection status, and defines the character-defining elements within the structure.

At the material level, each element is evaluated in terms of historical *relevance, authenticity, craftsmanship, aesthetic contribution, and rarity.*

Historical relevance considers whether the material is original to the building and whether it represents a particular architectural period or cultural narrative. *Authenticity* and integrity are assessed through the degree of preservation of the original fabric and the extent to which the material has been altered. *Technological and craftsmanship* significance examines construction techniques, artisanal quality, or representation of innovations. *The aesthetic and architectural contribution* evaluates how the material supports the character-defining qualities of the building, while *rarity* and representativeness consider its uniqueness or its exemplary value within a typology or architectural movement.

Assessment is supported by archival research, on-site inspection, photographic documentation, and reference to heritage inventories or legal frameworks. Based on this systematic evaluation, materials can be categorized according to their level of cultural–historical significance, guiding decisions on whether to conserve them, retain them with cautious adaptive reuse, or reuse them in other contexts with proper documentation.

4.2.5 Hazardous Substances

Institutional background.

Both national building regulations in Scandinavia and European Commission guidance provide a framework for identifying hazardous substances (HS) in buildings, documenting their presence, and ensuring their safe separation and disposal. While the scope and level of detail may vary between countries, these regulations consistently emphasize the importance of systematic identification and safe handling of hazardous materials. For example, the Danish Environmental Protection Agency (Miljø- og Ligestillingsministeriet, Miljøstyrelsen) provides a detailed framework for the sampling and management of environmentally problematic substances that must be addressed during demolition or renovation projects (Miljøstyrelsen, 2024). A strong focus on occupational safety and removal efficiency is also evident in guidance documents issued by other national authorities, such as Boverket. (Boverket, 2025)

Buildings constructed before 1995 require special attention with regard to the potential presence of asbestos. It is a common practice to carry out asbestos inventory before demolition or renovation activities. Asbestos is typically found in pipe insulation, vinyl floor tiles, sprayed coatings, cement boards, and similar products. However, asbestos is not the only substance that falls under the category of hazardous substances.

Examples of hazardous substances and materials of concern in construction include:
- Asbestos
- Polychlorinated biphenyls (PCBs), found in paints, sealants, gaskets, double-glazed windows and electrical equipment
- Polycyclic aromatic hydrocarbons (PAHs) and creosote
- Oil, hydrocarbons, including spill contamination
- Harmful metals such as lead (Pb), cadmium (Cd), chromium (Cr), mercury (Hg), and arsenic (As)
- Brominated flame retardants
- Phthalates

Source: (Wahlström et al., 2019)

The identification and assessment of hazardous substances are generally recommended to be carried out by qualified specialists, preferably independent third parties, to ensure transparency and reliability. Furthermore, decontamination and removal works must be conducted by specialized companies with appropriate certification. While certain hazardous substances in building materials—such as asbestos-containing products or tar-based materials—can often be identified visually or reasonably anticipated based on construction period and material typology, the presence of other contaminants, including PCBs, PFAS, or heavy metals, is frequently difficult to verify without targeted sampling and analysis. These substances may also be particularly challenging to remove or remediate once contamination has occurred, posing significant risks to soil and groundwater (European Commission, 2024).

There are certain limitations in the identification of HS, as some materials may be concealed, encapsulated, or physically inaccessible. Examples include foundations, underground pipelines, and cables, permanent formwork in asbestos cement, etc. (European Commission, 2024). For this reason, audits should be carried out by a qualified expert or team of experts with knowledge not only of HS, but also of historical construction, building technology development, standardization and resource management. In addition, emerging technologies such as AI-supported resource screening tools and handheld X-ray fluorescence (XRF) analyzers can support the detection of heavy metals and hidden material layers, thereby enhancing the accuracy of hazardous substance inventories. Nevertheless, data collection methods such as manual building audits tend to be expensive and slow, while newer methods such as creating digital twins lacks a unified approach (Byers et. al., 20204).

Method of Assessment.

Within the framework of this thesis, the identification of hazardous substances in buildings requires the establishment of a systematic inventory in accordance with relevant building regulations and environmental legislation, to be conducted by qualified and, where appropriate, independent specialists. The audit process shall include both visual inspections and targeted chemical and physical analyses of visible and concealed construction materials. Particular attention must be given to materials associated with specific construction periods or typologies known to contain hazardous substances.

Furthermore, the reliability of this assessment depends on interdisciplinary expertise in hazardous materials management, historical construction practices, and building technology development. The outcome of the hazardous substance inventory serves as a decisive parameter in the material appraisal framework, determining whether materials are suitable for direct reuse, require remediation, or must be excluded from circular reuse pathways.

4.2.6 Uniqueness

Conceptual background.

Uniqueness, as a factor in building material assessment, refers to the degree to which a material lacks equivalent substitutes, exhibits rare or distinctive properties, or occupies a limited position within current supply chains. Unlike other inventory factors, uniqueness is inherently relational and context-dependent: a material may be unique due to its physical properties, production status, historical context, or scarcity within reuse markets. It may also shift over time as manufacturing processes change or materials become discontinue.

Within reuse practice, uniqueness acquires particular relevance. Materials that are no longer produced, that demonstrate specialized performance characteristics, or that appear only sporadically within secondary markets may hold increased strategic value. Integrating uniqueness into pre-demolition assessments therefore supports more informed decisions regarding preservation, salvage, and the reduction of virgin material extraction.

Previous research has addressed uniqueness as a sub-criterion within broader reuse potential frameworks. For example, Coenen et al. (2020) conceptualize reusability of structure materials through disassemblablity, transportability, and uniqueness. In their approach, uniqueness refers to the presence of non-standard or one-of-a-kind elements and is proposed as a quantifiable dimension, calculated as the inverse mass-based share of standardized components within an asset. This perspective highlights that uniqueness may be evaluated not only qualitatively but also through measurable indicators.

Benchmarking.

Assessing uniqueness requires engagement with market dynamics, technological evolution, and cultural valuation. Materials that no longer appear in manufacturer catalogues or current building standards may be classified as rare or discontinued. This benchmarking approach aligns with broader circular construction research, which identifies information gaps regarding material availability as a major barrier to reuse (Byers et al., 2024). When reliable market data are lacking, assessment must rely on professional expertise and contextual interpretation.

Industry stakeholders—including demolition contractors, recycling centers, salvage suppliers, and reuse platforms—can provide insight into secondary market demand and scarcity. At the same time, architects and antiquarian specialists may identify materials with heritage attribution or cultural significance. According to the *Burra Charter*, heritage buildings frequently contain durable materials that are now difficult to source sustainably or have become rare, such as certain marbles, granites, or rainforest timbers. These materials may possess extended lifespans and long-term cultural value when properly maintained (ICOMOS, 2013).

Uniqueness may also stem from exceptional technical performance. For instance, Roman concrete is frequently cited for its extraordinary long-term durability and chemical resilience, combining structural performance with cultural and historical significance (Jackson et al., 2017). Similarly, regionally specific materials such as Gotland limestone may derive uniqueness from geological conditions, aesthetic characteristics, and local heritage associations.

These examples illustrate that uniqueness is not limited to rarity alone; it may result from a combination of scarcity, performance, craftsmanship, and cultural attribution. Consequently, assessment must address both material properties and contextual factors.

Method of assessment.

Within the framework of this thesis, uniqueness is suggested to be evaluated by scoring:

1. Availability in current supply chains (e.g., still manufactured vs discontinued).
2. Degree of standardization or custom design. (e.g., unique dimensions that require custom fabrication).
3. Market presence in reuse supply channels (e.g., salvage yards, material marketplaces).
4. Technical performance (e.g., exceptional structural performance)
5. Cultural or historic significance (e.g., architecturally relevant materials).

Materials that score high across these criteria should be labeled as unique or scarce in the inventory and prioritized for reuse pathways. Uniqueness differs from purely aesthetic or heritage value in that it is strongly influenced by market conditions, technological change, and supply-chain dynamics. It may be measured both qualitatively and quantitatively, and its status can evolve over time. By incorporating uniqueness into pre-demolition inventories through a structured, criteria-based assessment, decision-making becomes more transparent and aligned with circular construction principles. This approach strengthens the likelihood that scarce, high-performance, or culturally significant materials are recognized, preserved, and effectively reused.

4.2.7 Aesthetics

This section explores how aesthetic quality in construction materials can be defined and assessed within the proposed framework.

The attempts to create methodology around aesthetics of materials and architecture has been present since ancient times. Historically, aesthetics was regarded as an objective and transcendent value. Until the eighteenth century, beauty was often considered universal and absolute. From XVIII century onward, the narration shifted towards subjective perception, personal experience, and taste. Aesthetics has commonly been understood as “pleasurable to the senses”. (Hekkert, 2006). Beauty was also defined as moral good. Socrat, Kant or Hegel shifted the discussion on aesthetics towards morality (Kozminska, 2019). Thus, aesthetic judgment involves both perceptual experience and cultural interpretation.

In architectural discourse, John Ruskin developed a moral-aesthetic framework linking beauty to truthfulness. He argued that materials should express their intrinsic nature (“truth to materials”), structural systems should remain legible, and architecture should reflect natural harmony (Ruskin, 2003). This perspective remains relevant in reuse practice, where the visible traces of age and prior use contribute to material legibility and narrative depth.

Contemporary sustainability discourse has increasingly argued that environmental performance and aesthetic quality cannot be separated. Early environmental design movements of the 1960s and 1970s prioritized performance and behavioral change over aesthetic considerations (Lee, 2011). As a result, sustainable architecture often lacked broader aesthetic appeal. More recent discourse suggests that sustainability must operate within what Glen Hill describes as the “aesthetic economy,” where environmental solutions must also be desirable and attractive (Lee, 2011). Sauerbruch and Hutton similarly argue that low-carbon products must be aesthetically compelling in order to be widely adopted (as cited in Lee, 2011). From this perspective, sustainability becomes inseparable from aesthetic quality.

Empirical research further clarifies how aesthetic perception operates at the material scale. Sauerwein et al. (2017) demonstrate that aesthetic appreciation is multisensory and influenced by texture, contrast, familiarity, and tactile engagement. Materials exhibiting balanced variation and surface richness were perceived as more attractive than overly uniform samples. Furthermore, familiarity enhances acceptance, while positive surprise may support engagement with unfamiliar materials. Cross-disciplinary studies further emphasize the role of novelty, typicality, and perceptual coherence in shaping aesthetic evaluation (Pei & Cao, 2025).

These findings align with Hekkert’s (2006) psychological model of aesthetic appreciation, which proposes that aesthetic pleasure arises from principles grounded in shared human tendencies. Relevant principles include:

- *Maximum effect for minimal means:* Strong visual impact achieved with minimal intervention.
- *Unity in variety*: Coherent organization of diverse elements.
- *MAYA principle (Most Advanced Yet Acceptable)*: Balance between novelty and familiarity.
- *Optimal match*: Congruence between material qualities and contextual function.

In this context, reused materials appear to offer particular potential for enhanced tactile engagement. Previous research suggests that the skillful application of reclaimed materials can enrich the sensory perception of architecture, as uneven textures, visible traces of time, and artisanal interventions contribute to a building’s authenticity and local character. Such qualities invite physical interaction and foreground the material's history, thereby expanding the aesthetic experience beyond visual appearance alone (Kozminska, 2019).

Empirical data from interviews conducted in this study further support these theoretical perspectives. Participants emphasized the importance of tactile qualities and material authenticity. One respondent noted that "material value, sensation both tactile and atmosphere… quality of material, like roughness" is central to aesthetic experience (A1). Another stated that reuse "adds nerve and character to the project" and can be chosen purely for aesthetic reasons (A4). These responses confirm the significance of sensory engagement, imperfection, and material legibility in aesthetic evaluation.

Another aspect of aesthetics highlighted in the interviews is formulated as *balance,* referring to how well materials and buildings fit in the existing context and are in harmony with each other (A2,C2, D1, Survey). In the published interview with Sören Pihlmann, the architect explains that beauty often emerges when something is appropriately situated in the world. In his words, *"When something is placed correctly in the world, we often perceive it as beautiful. It becomes a cultural phenomenon—something we have become accustomed to thinking about."* (Dagliden Hunt, 2025, nr. 7).

Empirical findings from practice further demonstrate that aesthetic value in reuse is relational and communicatively constructed. Several interviewees emphasized that the aesthetic acceptance of reused materials depends not only on their intrinsic qualities but on how they are framed within the project narrative (A5, S1,S2). Castellum highlighted that reuse became acceptable—and even desirable—when positioned as a conscious reinterpretation of a 1970s architectural identity rather than as a cost-saving or purely technical decision (Al-Salehi, 2025). This indicates that aesthetic value is actively produced through contextualization and storytelling.

A similar position is articulated by Sébastien Dachy of architecture company Mamout, who argues that the mere existence of a material can serve as aesthetic justification: existing elements are perceived as legitimate precisely because they already exist (Rum, 2025). According to this perspective, reuse shifts aesthetic evaluation from abstract preference toward acceptance grounded in material reality. Dachy further suggests that reused materials are often inherently of higher quality, as elements of insufficient durability do not survive to be reused. This aligns with interview findings in the present study, where participants associated reuse with authenticity, craftsmanship, and material depth (A1, A4).

Method of Assessment.

Based on the theoretical and empirical findings, aesthetic quality of reused construction materials is assessed according to the following criteria:

1. *Sensory richness*: Evaluation of visual and tactile qualities, including texture, surface depth, and material legibility.
2. *Unity and contrast:* Assessment of balance between coherence and variation within the material.
3. *Novelty and familiarity:* Determination of whether the material achieves novelty while remaining acceptable and contextually appropriate.
4. *Truthfulness and authenticity:* Evaluation of whether the material expresses its intrinsic nature and construction honestly.

5. *Contextual belonging:* Assessment of how well material qualities align with architectural function and environment.
6. *Narrative and communication potential:* consideration of the material's capacity to convey historical reference, reuse intention, or project identity.

These criteria provide a structured method for evaluating aesthetic quality beyond purely visual appearance, integrating sensory perception, psychological principles, ethical considerations, and contextual appropriateness.

4.2.8 Aging and Weathering performance

This factor extends the evaluation of aesthetic qualities beyond formal visual attributes by emphasizing the temporal dimension of materials and the experiential value associated with aging and imperfection.

Material aging depends on intrinsic properties and environmental conditions. Some materials deteriorate over time, whereas others mature by maintaining or enhancing certain qualities. The concept of maturation is particularly associated with natural materials such as stone, paper, wood, and leather, which may acquire distinctive scents, colors, and textures that increase their perceived value and impart a sense of antiquity. As van Hinte (1997, as cited in Rognoli & Karana, 2014) observes, many natural materials were once living matter and therefore possess an inherent capacity to engage constructively with the passage of time. Distinguishing between degradation and maturation provides a basis for evaluating how aging influences long-term aesthetic value.

Mostafavi and Leatherbarrow (1993) argue that weathering should not be understood merely as decay but as an ongoing continuation of a material's life. Through exposure to light, moisture, and environmental forces, surfaces evolve and accumulate traces of use. These temporal marks—such as stains, erosion, and patina—contribute to architectural meaning and embed material surfaces within cultural and lived experience. Aging thus adds complexity and depth rather than representing loss.

Patina refers broadly to visible signs of surface aging, including tarnish on metals, sheen on wood, and subtle discoloration or texture changes (Candy et al., 2008; Saito, 2007, as cited in Rognoli & Karana, 2014). Such changes reflect a material's interaction with environmental conditions. While many synthetic materials degrade without maintaining aesthetic coherence (Manzini, 1986, 1990; Fisher, 2004, as cited in Rognoli & Karana, 2014), natural materials often age gracefully. For example, wood exposed to ultraviolet radiation and moisture undergoes photochemical processes that gradually transform its surface to a silver-grey tone while preserving structural integrity (Thurlbourne, 2023). Aging therefore represents not only a physical transformation but also a cultural and sensory enrichment.

The experiential dimension of aging has also been emphasized by Pallasmaa (1996), who notes that materials record time through wear and touch. He critiques modern architecture for privileging formal perfection and novelty, arguing that the ideal of unchanging form neglects the inevitable processes of erosion and entropy that shape material reality. Similarly, Papanek (1995, as cited in Rognoli & Karana, 2014) identifies graceful aging as a fundamental principle of environmentally responsible design, suggesting that materials capable of aging well retain appeal over extended lifespans.

Empirical findings from interviews conducted in this study reinforce these perspectives. Participants expressed preference for materials that "age naturally" and develop character over time. One interviewee stated, "I prefer when materials and the built environment are allowed to age naturally; materials that constantly look new do not appeal to me" (A1). Another emphasized the importance of quality in weathering processes, highlighting that materials should "hold well, weather and age well" (A4).

Method of Assessment

Based on the literature and empirical evidence, graceful aging and weathering are assessed according to three criteria:

1. *Presence and quality of patina:* Evaluation of visible aging characteristics, such as discoloration, surface sheen, texture variation, and environmental marking.
2. *Capacity for maturation:* Assessment of whether the material maintains structural and sensory integrity over time or improves in aesthetic coherence as it ages.
3. *Experiential and cultural value*: Consideration of whether aging contributes to perceived authenticity, historical continuity, or emotional attachment.

These criteria enable evaluation of the temporal aesthetic potential of reused materials, emphasizing their capacity to gain value through time rather than diminish.

4.2.9 Analysis and key findings (RQ2)

This chapter addressed Research Question 2: *How can the identified evaluation factors be systematically and empirically assessed in practice?*

The analysis shows that the sixteen factors identified under RQ1 can be operationalized through a combination of technical inspection, comparative calculation, structured documentation, and qualitative evaluation. The appropriate method depends on the nature of the factor.

Regulatory baseline factors—such as structural integrity, hazardous substances, and cultural-historical conservation value—establish the formal boundary conditions within which reuse decisions occur. Hazardous substance assessment determines whether a material is legally eligible for reuse and constitutes a non-negotiable safety requirement. If a material contains harmful substances, disposal is required regardless of other qualities. Cultural-historical conservation value, in contrast, may restrict disposal and promote retention and careful reuse, but it does not override health or environmental safety legislation. While both factors shape reuse decisions, they do not carry equal normative weight; safety compliance operates as a primary legal condition, whereas conservation value functions as a contextual preservation mandate within those limits.

Technical performance and Lifecycle-related factors—such as climate impact reduction potential (Section 4.2.1) and remaining service life (Section 4.2.2)—require comparative calculations. In the case of climate impact, reuse is evaluated against a reference scenario involving new production using LCA-based emission factors, such as those provided by Boverket's climate database or product-specific EPDs. The assessment depends on clearly defined system boundaries and allocation principles. Similarly, remaining service life is evaluated by comparing the residual technical performance of a reused component with the performance requirements of the intended application. These factors therefore rely on modelling assumptions and must be transparently documented to ensure comparability.

Operational and market-related factors—including quantity and dimensional compatibility, documentation and traceability, and logistical feasibility—are assessed through structured inventory mapping and verification procedures. Digital platforms such as CCBuild, Loopfront and Genbyg, offer consistent documentation and overview on market availability. These methods are empirical in nature but depend on accurate data collection rather than modelling.

Economic feasibility, discussed in Section 4.2.5, is assessed through comparative cost analysis, where the total cost of reuse—including dismantling, transport, reconditioning, and installation—is compared to the cost of equivalent new products. This method requires project-specific data and explicit consideration of risk and uncertainty.

Finally, architectural and experiential factors—such as aesthetic value, material uniqueness, and aging performance—cannot be reduced to purely quantitative metrics. As shown in Sections 4.2.6–4.2.8, their assessment relies on structured professional judgement, collective evaluation processes, and predefined qualitative criteria. While inherently interpretative, such evaluations can be systematized through scoring matrices or documented review procedures to enhance transparency.

Taken together, the findings indicate that systematic reuse assessment does not depend on a single unified calculation method. Rather, it requires an integrated evaluation structure in which each factor is assessed using methods appropriate to its character: compliance testing for regulatory factors, comparative calculation for environmental and lifecycle factors, structured inventory systems for operational feasibility, and documented qualitative appraisal for architectural and aesthetic dimensions.

4.3 Mapping the materials and their application in the framework

This section addresses Research Question 3: *Which building components and material categories currently demonstrate the highest potential for reuse when evaluated against the identified factors?*

4.3.1 Literature-based Identification of Reusable Materials

Existing literature identifies reusable material categories through different institutional and professional lenses.

The Swedish research institute RISE conducted a large-scale market study to identify building products with high reuse potential, considering supply, demand, technical feasibility, and economic viability (RISE & Runsten, 2025). From an initial screening of 130 products, 18 product groups were identified as suitable for large-scale reuse markets, including concrete elements, steel constructions, bricks, windows, ventilation ducts, and interior components.

In Denmark, Værdibyg (Koch-Ørvad & Skouenborg, 2024) developed a guidance through materials suitable for both reuse (*genbrug*) and recycling (*genanvendelse*) and categorized them by level of market establishment.

In contrast, Vandkunsten's *Rebeauty* framework approaches reuse from a design perspective, focusing on architectural value, transformation potential, and market potential of materials for reuse (Genbyg A/S; Nielse, Sören, 2016). Their study introduces qualitative evaluation dimensions that are largely absent from technical guidance documents.

Together, these three sources provide complementary perspectives: market feasibility (RISE), procedural guidance (Værdibyg), and design intervention (Vandkunsten).

4.3.2 Empirical Review of Built Projects with Reuse

In addition to literature-based sources, a review of 21 built Scandinavian projects was conducted (see Attachments 4). Based on this review, the following materials were selected for the framework application, according to the scoring system described in the methodology.

- Concrete HDF/concrete frame, load-bearing steel within the structural layer.
- Bricks, windows, metal sheets within the skin layer.
- Prefabricated staircases, textile floor finishes, acoustic ceiling tiles, and interior doors within the space plan layer.

4.3.3 Layer-Based Categorization

The categorization of materials follows the theory of shearing layers originally developed by (Duffy, 1992) and later expanded by (Brand, 1994). Brand describes buildings as composed of distinct layers—site, structure, skin, services, space plan, and stuff—that change at different temporal scales. Structural systems typically have expected lifespans of several decades to centuries, whereas interior space-plan elements change more frequently. See *Figure 2* below.

Applying this theory to reuse assessment enables differentiation between materials according to their expected lifespan, accessibility, and adaptability. Recognizing these differences is essential for evaluating dismantlability, remaining service life, and market feasibility.

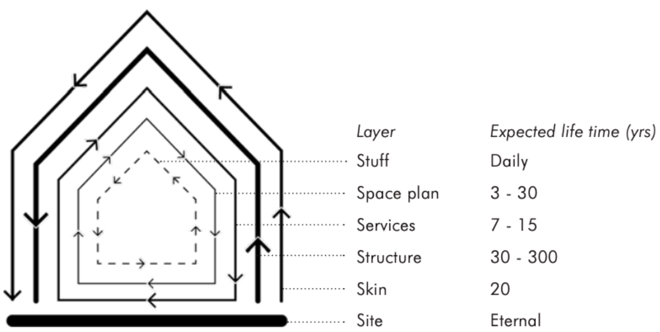

Figure 2. Lifetime layers of a building according to S. Brandt.

In this study, three layers are used as the analytical framework:

The **structural layer** includes load-bearing elements such as structural steel, timber, brick masonry, and concrete frames. Insulation materials are included within this layer when they cannot be removed without damaging the structural system . Structural materials are typically heavy and material-intensive, and empirical research indicates that only a small percentage of structural mass is reused in new construction projects. Renovation projects, however, often retain structural systems and thereby achieve substantial reductions in material demand (Gobbo et al., 2024).

The **skin layer** comprises façade and envelope elements, including windows, brick facing, metal sheets, and associated insulation systems . The façade serves as both a technical interface—providing weather protection and durability—and a communicative architectural element (Thurbourne, 2022). Reuse within this layer requires evaluation of weathering performance, durability, and aesthetic condition.

The **space plan layer** consists of non-load-bearing internal components such as interior doors, floor finishes, plasterboard, and ceiling systems . Due to their shorter life cycles and accessibility, these components are more frequently replaced and are therefore particularly relevant for reuse strategies focused on adaptability and design for disassembly.

4.3.4 Application of the Assessment Framework

The selected materials were evaluated using the sixteen assessment factors identified in Chapter 4.2 and applied in *Table 5.* The matrix demonstrates that reuse potential varies significantly across factors and building layers. Its purpose is not to establish a universal ranking of materials, but to illustrate how reuse potential emerges from different combinations of regulatory, environmental, operational, and architectural factors depending on material characteristics and functional context.

The scoring reflects typical reuse conditions associated with each material category rather than project-specific circumstances. For example, factor "documentation" asks a question "*How likely is this material category to have adequate documentation in typical reuse contexts?"*, and factor "Readiness for reuse" asks "*How ready is this material category for reuse without significant recondition?"*. Readiness, as example, then scored as 0= Extensive repair or adaptation typically required; 1= Moderate cleaning or adjustment required; 2= Minimal preparation typically required. See all guiding questions and metrics in *Table 4* (Section 4.2). Since the guiding questions behind each factor are framed around positive reuse outcomes, a higher score reflects a greater likelihood that the material can be reused.

Note that results in *Table 5* below represent only comparative suitability tendencies based on typical industry conditions. The framework does not predict accurate performance outcomes but provides a structured analytical basis for comparing material categories within a consistent evaluation logic.

Assessment factor	Concrete frame	Load-bearing steel	Brick	Windows	Metal sheets	Prefab staircases	Textile floors	Acoustic ceiling tiles	Interior doors
Technical performance compliance	2	2	2	1	1	2	1	1	1
Hazardous substances / chemical compliance	2	2	2	1	1	2	0	1	1
Cultural-historical conservation value	1	0	2	2	0	1	0	0	1
Climate impact reduction potential	2	2	1	1	1	1	0	0	1
Remaining service life	2	2	2	1	1	2	0	1	1
Dismantlability / accessibility	0	2	1	1	2	1	1	2	2
Readiness for direct reuse *(low reconditioning need)*	1	1	0	0	1	1	0	1	2
Economic feasibility	0	1	1	1	1	1	0	1	2
Market demand / reuse potential	1	1	2	2	1	1	0	1	2
Logistics feasibility	0	1	1	1	2	1	2	2	2
Documentation / traceability	1	1	0	1	1	1	0	1	1
Quantity / dimensional compatibility	1	1	2	1	2	0	1	2	2
Design for disassembly compatibility	0	1	1	1	2	1	0	2	2
Aesthetic value	1	1	2	2	1	2	1	0	2
Material uniqueness	0	0	1	1	0	1	0	0	1
Aging / weathering performance	1	1	2	2	1	1	0	0	1
Total	15	19	21	19	16	16	7	15	23

0 = Low.   1 = Moderate / conditional.   2 = High.

Table 5: Assessment of materials against the factors, example.

4.3.5 Comparative Results Across Material Categories

Interior doors and brick emerge as the strongest candidates, scoring 23 and 21 out of 32 respectively, reflecting their advantageous profiles across practical reuse factors such as dismantlability, market demand, and economic feasibility. Brick's result is further supported by its cultural-historical value and the maturity of the existing secondary market. Load-bearing steel and windows follow closely with equal total scores of 19, though with distinct strength profiles — steel performing better on structural and technical factors, windows on aesthetic value and market recognizability. Metal sheets and prefab staircases occupy a middle range, presenting moderate reuse potential contingent on project-specific conditions. Concrete frame and acoustic ceiling tiles score similarly, with reuse viability limited primarily by dismantlability constraints and chemical compliance uncertainty respectively. Textile floors score the lowest at 7 out of 32, a result consistent with the hygiene, wear, and service-life limitations characteristic of soft floor coverings, making them poor candidates for direct reuse in most contexts.

Overall, structural materials demonstrate high potential for climate impact reduction due to avoided production emissions. However, their reuse is strongly conditioned by structural verification, transport logistics, and regulatory compliance. Detailed documentation, testing, and in some cases re-certification are often required. These findings reflect the framework application under typical industry conditions rather than project-specific assessments.

Skin-layer materials activate both technical and architectural evaluation criteria. Windows and façade elements require assessment of remaining service life, weather resistance, and energy performance, while also contributing to aesthetic and cultural value. Their reuse feasibility depends not only on physical condition but also on compatibility with contemporary performance standards and dimensional constraints.

Space-plan materials generally show lower absolute climate savings but greater flexibility in dismantling and adaptation. Interior doors and flooring often perform strongly in aesthetic value and market demand. However, reconditioning requirements and documentation quality significantly influence their overall suitability.

Across all evaluation factors, no material category satisfies all equally. Instead, reuse potential emerges from the interaction between regulatory boundary conditions, environmental benefit, operational feasibility, and architectural value. These results are derived from the comparative scoring presented in *Table 5* and illustrate typical suitability tendencies rather than definitive performance outcomes.

4.3.6 Analysis and key findings (RQ3)

The framework application confirms that reuse potential is not an intrinsic property of a material category but an outcome of how regulatory, environmental, operational, and architectural factors interact under typical industry conditions. No material category satisfies all sixteen factors equally; instead, each occupies a distinct position shaped by the specific combination of conditions it meets. This internal consistency confirms that the sixteen factors function as practical, distinguishing evaluation criteria rather than overlapping or redundant categories.

5 Discussion

This chapter presents a discussion of the research findings, addressing the study's aim and research questions. It interprets the significance of the developed appraisal framework for material reuse, compares it with existing approaches, and reflects on the study's limitations and the broader implications for architectural practice and policy.

5.1 Evaluation of Research Questions

This thesis aimed to identify and structure the factors influencing the evaluation and integration of reclaimed construction materials, and to develop an appraisal framework for their reuse in construction projects. This was guided by three research questions (RQ1, RQ2, RQ3), which are addressed below

5.1.1 Addressing Research Question 1: Identification of Relevant Factors

The cross-analysis of regulatory documents, research reports, digital platforms, corporate guidance, and interview findings resulted in the systematic identification of sixteen recurring evaluation dimensions for material reuse. These factors, collected in Table 4, form the conceptual foundation of the multidimensional appraisal framework developed in this thesis.

Initially, a dominance of technical and quantitative factors was observed in material appraisal practices. The first five factors identified—Structural integrity/technical functionality, Hazardous substances/chemical compliance, Cultural-historical conservation value, Climate impact reduction potential, and Remaining service life—reflect essential regulatory compliance and technical baseline requirements.

Factors six through thirteen-Dismantlability/accessibility, Need for reconditioning, Documentation/traceability, Quantity/dimensional compatibility, Logistics feasibility, Economic feasibility, Market demand/reuse potential, and Design for disassembly compatibility—addressed environmental, economic, and operational feasibility.

Crucially, the final three factors—Aesthetic value, Material uniqueness, and Aging-highlighted dimensions insufficiently represented in existing guidelines. Their inclusion directly challenges the purely technical appraisal approach and underscores the need for a more comprehensive understanding of value, moving "beyond numbers" to incorporate qualitative aspects that significantly influence decision-making and acceptance in architectural practice.

5.1.2 Addressing Research Question 2: Systematic and Empirical Assessment Methods

Research Question 2 asked: "How can these factors be systematically and empirically assessed in practice?"

The analysis detailed in Section 4.2 demonstrates that the sixteen identified factors can be operationalized through a combination of diverse assessment methods. This integrated approach combines technical inspection, comparative calculation, structured documentation, and qualitative evaluation, each tailored to the specific nature of the factor.

5.1.3 Addressing Research Question 3: High Potential Building Components and Materials

Research Question 3 asked: "Which building components and material categories currently demonstrate the highest potential for reuse when evaluated against the identified factors?"

Beyond identifying high-potential materials, this question served a methodological purpose: testing how the sixteen factors function when applied to real, rather than hypothetical, material categories. The nine categories analyzed were drawn from a review of 21 built Scandinavian projects, grounding the framework's application in observed practice.

The framework application across nine material categories reveals that reuse potential is not uniform across material types. Instead, it emerges from the specific configuration of regulatory, environmental, operational, and architectural factors that characterize each category under typical industry conditions.

Interior doors and brick score highest at 23 and 21 out of 32 respectively, a result that reflects not technical superiority but rather a union of favorable conditions: established secondary markets, high dismantlability, low reconditioning needs, and strong aesthetic and cultural recognition. Their high scores reflect market and logistical maturity rather than inherent material superiority — conditions that could, in principle, be cultivated for other categories through policy or industry intervention.

Load-bearing steel and windows score equally at 19 but for different reasons, illustrating that equal totals can mask fundamentally different reuse profiles. Steel's score is driven by technical and environmental performance, while windows score on aesthetic value and market recognizability — yet windows carry a higher chemical compliance burden, reflecting legacy concerns such as PCB-containing sealants in older glazing units, and face greater performance uncertainty under contemporary energy standards. This divergence suggests that total scores should be read alongside factor-level profiles rather than treated as a standalone ranking.

Taken together, these results indicate that climate impact alone would have prioritized structural materials, yet operational and regulatory barriers limit their practical reuse at scale. Windows succeed instead through a different combination of strengths — aesthetic and market value compensating for moderate environmental and technical performance. This pattern suggests that multidimensional assessment does not simply add complexity to reuse decisions; it reveals which dimensions of value the framework captures beyond climate performance alone, and therefore which considerations risk being overlooked when assessment relies on climate metrics in isolation.

5.1.4 Beyond Technical: The Multidimensional Nature of Material Appraisal

The windows case illustrates a pattern that recurs across the framework's application: qualitative dimensions frequently determine reuse outcomes that technical and regulatory assessment alone would not predict.

Architects, in particular, emphasized their ability to "see potential" in materials that might otherwise be discarded due to a narrow technical assessment (A5). This perspective directly addresses the "implementation gap" where buildings are demolished based on subjective judgments of "ugliness," despite environmental costs (Det sista huset,2023). By integrating the "ethical dimension of aesthetics" (Lee, 2011), the framework advocates for a shift in perspective, recognizing that beauty and longevity can emerge from the inherent properties and histories of existing materials (Kozminska, 2019). This aligns with Sören Thirup Pihlmann's perspective, who argues that resource scarcity can open up a "larger aesthetic playing field," fostering creative solutions that go beyond conventional expectations (Dagliden Hult, 2025).

The study also reveals a tension regarding who should conduct such appraisals, given the multidisciplinary nature of the factors (A5). Architects and environmental specialists are often not invited to the material mapping process — a disconnect the framework aims to bridge by advocating for early, integrated involvement of diverse expertise. This raises a related question about the evolving role of architects, who may need to acquire broader competencies and project management positions to safeguard the quality of material appraisal and maintain authorship in reuse projects.

5.2 Implications and Contribution of the Appraisal Framework

The proposed framework expands material appraisal beyond conventional technical, environmental, and economic assessments by incorporating aesthetics, aging performance, uniqueness, and cultural-historical value. This broadens what counts as "value" in reclaimed materials and addresses the disconnect between sustainability ambitions and practice, offering a structured way to evaluate materials that narrower criteria would otherwise condemn to disposal.

The framework should not, however, be interpreted as a predictive tool. It functions instead as a structured decision-support instrument: the relative importance of its factors may vary substantially depending on project type, stakeholder priorities, regulatory context, and market conditions.

Practically, the framework provides a structured guide for sustainability specialists, architects, and other practitioners involved in pre-demolition or pre-renovation audits. The need for a standardized assessment was strongly voiced by interviewees (S1, S2, D1), suggesting a clear practical demand for such a tool. Additionally, the framework can serve as a decision-making tool for LCA, supporting more informed choices in educational case studies and test-beds. By providing a structured approach to account for various material attributes, especially the qualitative ones, it ensures that LCA studies can be more comprehensive and reflective of true material value (Section 4.2.1).

Finally, the findings offer recommendations for policymakers aiming to advance material reuse. The findings do not establish that national regulation is required, but they do show a clear need for shared, multidisciplinary guidelines — whether voluntary or mandated. Denmark's mandatory resource mapping for buildings exceeding 250 m² (Boligstyrelsen, 2024) illustrates one such policy intervention; similar requirements in other Nordic countries, supported by a comprehensive framework, could significantly increase the amount and quality of reuse. As one Project Manager (D1) noted, there is a "lack of culture" among those assessing buildings before demolition regarding material value — suggesting that policy initiatives should pair regulation with education and awareness-raising across the construction value chain.

The framework's contribution lies in synthesizing previously underrepresented practitioner perspectives — architects, project managers, and sustainability specialists — into a single, structured, and practically applicable appraisal tool.

5.3 Limitations of the Study

Despite its contributions, this study has several limitations that are addressed below.

The significant limitation of this study concerns stakeholder representation. While expert interviews provided valuable insights into material appraisal practices and reuse decision-making, the number of participants directly involved in conducting pre-demolition audits was limited. As a result, the proposed framework is primarily informed by literature, document analysis, and a relatively small sample of industry perspectives. Broader engagement with practitioners responsible for pre-demolition audits and material inventories could have provided additional practical insights and further validated the identified appraisal factors.

Another limitation relates to language nuances in interpretation of existing policies, guidelines, and reports from Sweden, Denmark, and Norway. Although efforts were made to cross-reference sources and clarify terminology, differences in the use and interpretation of concepts such as lifespan, durability, and other technical criteria may have affected the comparability of findings across countries.

Furthermore, the researcher's background and engagement with architectural and sustainability discourse could inherently influence the interpretation of findings, particularly in qualitative data analysis.

Finally, the market for reused construction materials and associated regulatory landscapes are rapidly evolving. The findings reflect the state of practice and policy at the time of data collection (2025-2026). Continuous changes in technology, policy, and market demand mean that some aspects of the framework's applicability might need periodic re-evaluation.

5.4 Reflections on the Research Process and Future Directions

The iterative research design, combining literature analysis, interviews, and Mentimeter surveys, proved effective in refining the research scope and developing a contextually grounded framework. However, initial challenges, such as different interpretations of "reuse" among interviewees, highlighted the critical importance of clarifying terminology early in the research process.

An important observation that emerged during the study was the limited involvement of architects and environmental specialists in material mapping and appraisal processes. Although these professionals expressed strong interest in material reuse and demonstrated relevant expertise, they are often not included in decision-making related to pre-demolition audits. This finding highlights a potential disconnect between material appraisal practices and broader design and sustainability objectives, suggesting an area that warrants further investigation.

Future research could expand stakeholder engagement to include actors directly involved in demolition, logistics, waste management, and material brokerage. A broader stakeholder perspective could provide a more comprehensive understanding of decision-making processes related to material appraisal and help identify potential implementation challenges associated with the framework.

Given the importance of qualitative appraisal factors identified in this study, future research could explore how perceptions of reclaimed materials evolve among different user groups and how design interventions influence their acceptance. In particular, the symbolic and cultural value associated with materials originating from historically significant buildings warrants further investigation. Such research may contribute to the refinement and expansion of the proposed framework. These aspects could potentially shape additional factors to contribute to the framework.

In addition, exploration of how the framework can be integrated with emerging technologies, such as AI-supported resource screening tools, could enhance the efficiency and accuracy of material appraisal.

By addressing these future research directions, the insights from this thesis can be further translated into specific actionable strategies, ultimately contributing to a more circular, sustainable, and aesthetically rich built environment.

6 Conclusion

This thesis developed a multidimensional appraisal framework for evaluating construction materials for reuse. Together, the three research questions show that reuse potential cannot be judged on technical or environmental grounds alone: the sixteen factors identified (RQ1) require multidisciplinary judgment to apply (RQ2), and applying them across nine material categories (RQ3) shows that materials with comparable technical merit can have entirely different reuse outcomes, depending on market maturity, regulatory burden, and aesthetic recognition.

The framework's contribution is to make this complexity legible and actionable: it gives practitioners and policymakers a shared structure for articulating why a material is or isn't worth reusing, rather than reducing that judgment to a single composite score. As discussed in Section 5.3, the framework's conclusions are necessarily bound by the scope of stakeholder input and the current state of a fast-moving market and regulatory landscape; Section 5.4 outlines how broader stakeholder engagement and integration with emerging tools could extend this work.

Ultimately, this thesis argues that material reuse decisions are not just technical or economic calculations, but judgments that require weighing aesthetic, cultural, and historical value alongside performance and cost. Recognizing this is a necessary step toward a built environment that treats existing materials as a resource worth understanding, not just a resource worth measuring.

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7 Attachments

Attachment 1. Comparison across Research Institutions guidelines and Online Platforms.

Assessment Factor	RISE (SE)	IVL (SE)	SINTEF / Byggforsk (NO)	Værdibyg (DK)	CCBuild (SE)	Loopfront (NO)	Genbyg (DK)
Structural integrity / technical functionality	✓	✓	✓	✓	✓	✓	✓
Physical condition / damage	✓	✓	✓	✓	✓	✓	✓
Remaining service life / durability	✓	✓	✓	✓	Partial	Uncertain	Uncertain
Need for reconditioning	✓	—	—	✓	—	—	—
Hazardous substances / chemical compliance	✓	✓	✓	✓	✓	✓	Partial
Climate impact and CO_2 savings	✓	✓	—	✓	✓	Uncertain	Uncertain
Economic feasibility / cost efficiency	✓	✓	—	✓	✓	✓	Partial
Market demand and/ reuse potential	✓	✓	—	✓	✓	Partial	Partial
Potential for return to the supplier	✓	—	—	—	—	—	—
Product flow	—	✓	—	—	—	—	—
Quantity / dimensions	✓	✓	✓	✓	✓	Partial	✓
Documentation / traceability	Partial	✓	✓	✓	Partial	Partial	✓
Dismantlability / accessibility	✓	✓	✓	✓	Partial	Partial	Uncertain
Logistics / storage feasibility	✓	—	✓	✓	Partial	Partial	Partial
Cultural / architectural value	—	✓	—	Partial ("soul")	—	—	—

Platform features were coded based on publicly accessible documentation, demonstration materials, and published reports. Restricted account-only functionalities were not assessed.

Attachment 2. Guidelines from IVL

Criteria	Clarification	Description	Point
Dismantlement	Can the product be removed without causing damage?	Can be dismantled without damage	0-2
Condition and technical functionality	Is the product intact, functional and with a reasonable life remaining?	Is intact, functional, no major damage	0-2
Environmental and resource savings	How much environmental benefit, for example climate benefit and resource/waste savings, is obtained from recycling compared to buying new?)	Reuse provides clear environmental, climate and waste benefits compared to new purchases.	0-2
Manageability and Economic efficiency	Is it practical and economically reasonable to recycle the product, including the storage and transport?	Cost of reuse reasonable compared to new purchase	0-2
Lifespan		Estimated to have a long remaining lifespan	0-1
Demand and usability	Is there a likely use in the project or with another actor?	There is a clear possibility of reuse	0-1
Product flow	Is this type of product that is often recycled and has high turnover in recycling markets or within the organization?	Common product type with established recycling routines	0-1
Health and safety	Is the product free from hazardous substances (asbestos, PCBs, lead, etc.) ?	Free from substances harmful to health and the environment	0-2
Architectural or cultural-historical value	Does the product have architectural, aesthetic and/or cultural-historical conservation value that should be preserved?	Contributes to conservation value or unique expression	0-2
Quantity		The product is available in large quantities/quantities	0-1

Total points can provide a first priority.
Score interpretation – example:
> 8 points = Very high recycling potential
3–8 points = Good potential, supplement if necessary
< 3 points = Limited potential

Source: ”Återbruksinventering i praktiken”, Svenska Miljöinstitute (2025)

Attachment 3. RISE report (2025)

Technical suitability (answering a question, if it is technically possible to circulate the product)	1. Availability of a product: if the product is available within existing buildings and process to find such are established 2. Dismantlability: technical possibility to be dismantled 3. Quality classification potential: are there any preconditions for rational quality assurance 4. Take-back and transport are there any preconditions for transportation of a product and perform reconditioning/reuse locally 5. Reconditioning: are there preconditions to reuse without reconditioning/renovation, methods for reconditioning or compatibility with upgrade initiatives 6. Storage: possibility to store and does the material require special storage conditions
Attractiveness for a client (does the product have circular solution)	1. The need on the market 2. Priority 3. Client's expectations 4. Attractivity 5. Price sensitivity 6. Potential for sending the used product back to the producer
Economic incentive (was the circular business model profitable)	1. Business case built on the minimum volume availability to make it profitable 2. Market: the presence of stakeholders connected to the product 3. Incentive: existence of other reasons to resale from a producer's side 4. Take-back calculation: if reconditioning, logistics and transportation costs are within margin 5. Future interest: if interest into the product is expected to raise 6. Value chain: who is interested in buying this product

Source: (RISE & Runsten, 2025)

Attachment 4. Materials mapping.

Table 1

	Reinforced concrete	Structural steel, patricians	Structural Wood	Insulation	Wooden window frames	Bricks	Wood cladding	Facade: Metal plate, aluminium
Epic Malmö, SE			X		X	X		
Resource Rows, Upcycle house,DK					X		X	
Thoravej 29, Cph, DK	X				X	X		
Trä, Kontor i Aarhus 2024, DK					X			X
Kvarteret Återbruket, SE	X	X	X	X				X
Helsingborgshem, SE						X		
Vintertullstorget, SE	X							
Kvarteret Blästern, Stk, SE	X							
Kvarteret Hugin, Uppsala, SE	X							
Regeringskvarteret i Oslo, NO	X							
Chromet (Vasakronan) Gtbg, SE	X	X			X			X
KA 13, Oslo, NO		X	X		X	X		X
Werket, Jönköping, SE				X		X		
Trikåfabriken, Malmö, SE					X	X		
Lumi, Uppsala, SE	X					X		
Lill-Bilia, Sikh, SE	X							
Hyllieäng, Malmö, SE								X
Onsala space observation station, SE								
Vi på hörnet, Gbg, SE					X			
Bussdepå, Kronoberg., SE				X	X	X		
Friedländers Gata - förskolan, Gbg		X			X			
Total	9	4	2	3	10	8	1	5

	Roof metal sheets	Wings from the wind draft	Climate shell doors	Staircases	Wooden floors	Gypsum boards	Plasterboards	Textil floor
Epic Malmö, SE								X
Resource Rows, Upcycle house,DK					X			
Thoravej 29, Cph, DK								
Trä, Kontor i Aarhus 2024, DK		X						X
Kvarteret Återbruket, SE								
Helsingborgshem, SE								
Vintertullstorget, SE				X				
Kvarteret Blästern, Stk, SE								
Kvarteret Hugin, Uppsala, SE								
Regeringskvarteret i Oslo, NO								
Chromet (Vasakronan) Gtbg, SE	X		X	X				
KA 13, Oslo, NO				X	X			X
Werket, Jönköping, SE				X				X
Trikåfabriken, Malmö, SE								
Lumi, Uppsala, SE						X	X	
Lill-Bilia, Sikh, SE								
Hyllieäng, Malmö, SE								
Onsala space observation station, SE	X							
Vi på hörnet, Gbg, SE								
Bussdepå, Kronoberg., SE								
Friedländers Gata - förskolan, Gbg	X							
Total	3	1	1	4	2	1	2	4

	Doors interior	Ceiling tiles	Window seat	Ventilation pipe	Vent. Ducts	Marble	Armaturer	Cable ladders	Pentry
Epic Malmö, SE									
Resource Rows, Upcycle house,DK				X					
Thoravej 29, Cph, DK									
Trä, Kontor i Aarhus 2024, DK									
Kvarteret Återbruket, SE									
Helsingborgshem, SE									
Vintertullstorget, SE						X	X		
Kvarteret Blästern, Stk, SE									
Kvarteret Hugin, Uppsala, SE									
Regeringskvarteret i Oslo, NO									
Chromet (Vasakronan) Gtbg, SE	X	X		X			X	X	
KA 13, Oslo, NO	X				X		X	X	
Werket, Jönköping, SE	X				X			X	
Trikåfabriken, Malmö, SE									
Lumi, Uppsala, SE	X								
Lill-Bilia, Sikh, SE									
Hyllieäng, Malmö, SE									
Onsala space observation station, SE									
Vi på hörnet, Gbg, SE	X	X	X				X		X
Bussdepå, Kronoberg., SE									
Friedländers Gata - förskolan, Gbg		X							
Total	5	3		2	2	1	3	3	

Attachment 5. Guiding interview questions and survey.

- **Audience (included in the survey)**

1. *What is your gender?*
2. *What is your highest educational level?*
3. *How many years of experience do you have in building sector?*

Motivation: These questions allowed defining the audience.

- **Soft metrics (included in the survey)**

4. Do you think soft metrics are relevant now?
Motivation: This question defines the relevance of upcoming questions on aesthetics and defines social view on the position of such within resume discourse.

5. What principles shape your aesthetic view of the built environment, especially when it comes to materials and how they are experienced?
Motivation: This question helps to define what the interviewee mean by aesthetics in context of built environment.

- **Evaluation (included in the survey)**

6. Evaluate the aesthetic appeal of the reused materials 1-5
Motivation: This question provides with the potential data input for the framework.

7. Evaluate the economic feasibility of reusing these materials from 1 to 5
Motivation: This question reveals the alignment level between with the perceived and actual attribution of data to factor: “economic feasibility” to selected materials.

8. Evaluate the legal feasibility of reusing these materials from 1 to 5
Motivation: This question reveals the alignment level between with the perceived and actual attribution of data to factor: “legal feasibility” to selected materials.

9. Can you think of any other criteria/measures for evaluating materials for reuse?
Motivation: This question complements the identification of assessment factors for the framework.

- **Opportunities (included in the survey)**

10. What opportunities do you think resource shortages provide for the development of urban environments?
This question complements to the discussion section on social perception of value of reuse practice.

11.What does a lack of resources mean for aesthetic possibilities?
This question complements to the discussion section on aesthetic perception of reused materials and its application.

- **Question to another stakeholder (included in the survey)**

13. If you could ask a question to another player in the construction and real estate industry, who would the question be directed to and what would you ask?
Highlights the problems to be studied further within the reuse discourse.

- **Visualization of the reuse aesthetics**

14. Can you imagine a city constructed entirely from reused materials? What do you see? Does it appear attractive, or does it resemble a waste site? How do the building facades look? Are the building volumes similar to those we see today? Please describe what the street environment would look like.
This question complements to the discussion section on social perception of reuse potential from aesthetical perspective.

- **Role of an architect in reuse practice**

15. What does it mean for the role of architect when projects increasingly rely on reused materials?
Complements the discussion section on professional shift for the architects. Architect were chosen in connection with their role in material choice affecting the "soft metrics"

16. What challenges do you think architects will face in terms of creative authorship for the projects built with reused materials?
Highlights the potential obstacles for creative and professional role of architect. Architect were chosen in connection with their role in material choice affecting the "soft metrics"

17. Do you see a risk of architect's profession to become a waste management?
Further highlights the potential obstacles for creative and professional role of architects.

- **Clarification questions to the relevant stakeholders**

1. *Do you use any specific method/ platform for material assessment?*
2. *Which criteria do you include in assessing the materials?*
3. *Do you think the standard should incorporate them?*
4. *How do you evaluate them?*
5. *Who do you think should be involved and responsible for resource screening and audit?*

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