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Low Impact Materials Market Acceptance: Accelerating Net Zero in Dutch Construction

CME Master Thesis

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Alin-Paul Zullas

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Executive Summary

In addressing the transition towards Net Zero by 2050, it is imperative to acknowledge the construction industry's pivotal shift in perspective: sustainability must transition from being a 'maybe' to a 'must' (Hu, 2019). This research delves into the Dutch construction sector's journey in making this critical transition. The Netherlands, committed to becoming fully circular and achieving Net Zero emissions by 2050, faces a significant challenge in the widespread adoption of Low Impact Materials (LIMs). Despite various government initiatives and pilot projects aimed at fostering sustainable construction, the industry remains hesitant to fully embrace LIMs due to concerns over durability, commercial viability, and established practices.

Context and Background

The study begins by contextualizing the global and Dutch scenarios, focusing on the construction industry's substantial contribution to carbon emissions. In the Netherlands, construction is a key sector in achieving national sustainability targets. Despite substantial efforts, including stringent regulations, financial incentives, and public awareness campaigns, there is a notable reluctance within the industry to adopt LIMs. This reluctance stems from perceived risks associated with new materials, higher upfront costs, and uncertainty regarding long-term benefits.

Research Methodology

To investigate these challenges, this research employs a robust methodology combining an extensive literature review with semi-structured interviews involving industry practitioners. The literature review lays the groundwork by identifying existing barriers and drivers for LIM adoption. These insights are further enriched by interviews with key stakeholders, offering a nuanced understanding of the practical challenges and opportunities within the Dutch construction context.

The research categorizes the barriers and drivers into two primary directions: “Understanding Low Impact Materials” and “Accelerating the Adoption.” This dual approach allows for a comprehensive examination of both the technical aspects of LIMs and the social dynamics that influence their adoption.

Understanding Low Impact Materials

The first analytical path focuses on the critical information necessary for the effective use of LIMs during the design phase. The study identifies a pressing need for clear definitions and standardized evaluation criteria, including Lifecycle Assessments (LCAs) and Environmental Product Declarations (EPDs), which are essential for evaluating the sustainability of materials. The Dutch MPG (Environmental Performance of Buildings) framework, while a useful tool, is criticized for its complexity, limited scope, and the need for more stringent, mandatory regulations to enhance transparency and reliability.

Furthermore, the research underscores the importance of transparency in material data, vital for informed decision-making. Understanding the long-term impacts of materials—through residual value calculations and the development of material passports—is critical for integrating

sustainability early in the design process. The study also highlights the importance of involving a broad range of stakeholders, including Small and Medium-sized Enterprises (SMEs), in pilot projects to validate new materials and democratize the innovation process.

Accelerating the Adoption

The second analytical path delves into the social and collaborative aspects of LIM adoption. The research explores the perceptions and interactions of key stakeholders—governmental officials, clients/project developers, consultants (architectural/engineering), sustainability consultants, contractors, suppliers and SMEs. It reveals that the adoption of LIMs is not merely a technical challenge but is deeply intertwined with human interactions, perceptions, and the collective efforts of all involved parties.

Governmental officials are identified as central figures in setting the regulatory framework and providing necessary incentives. However, their efforts must be met with proactive engagement from other stakeholders. Clients and project developers are seen as the primary drivers of demand for LIMs, setting the tone for sustainability in construction projects. Consultants and contractors play a crucial role in translating this demand into practical, on-the-ground solutions, ensuring that sustainable practices are effectively implemented. Suppliers, as innovators and providers, are responsible for ensuring the availability and quality of LIMs. Meanwhile, SMEs contribute significantly through their agility and capacity for innovation, often serving as early adopters and testers of new materials.

Conclusions

The research concludes that the effective adoption of LIMs in the Dutch construction industry necessitates a holistic approach that addresses both technical and human factors. The key elements for success are collaboration, transparency, and communication among all stakeholders. The study draws a parallel with the Dutch "Polder Model," a well-known Dutch approach to cooperation that emphasizes pragmatic recognition of diversity and collaboration despite differences. This model serves as an apt metaphor for the construction industry, where no single driver or barrier can solve the challenge alone. Instead, progress will come through collective efforts, leveraging the strengths and insights of all parties involved.

The overarching message for the industry is encapsulated in the phrase, "Just do it." This call to action urges all stakeholders to adopt a proactive, network-oriented approach where initiative and collaboration are paramount. By fostering a culture of shared responsibility and embracing the principles of the Polder Model, the Dutch construction industry can accelerate the adoption of LIMs and achieve its ambitious sustainability targets. This collective effort will contribute to a more sustainable built environment, not just as an option, but as the new standard for future generations.

Keywords: Low Impact Materials, Net Zero Carbon Buildings, Accelerating the Adoption, Sustainability, Design Phase, Dutch Construction Industry, Market Acceptance

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1. Introduction

1.1. Global Context

The crucial objective of keeping the increase in the average global temperature to well below 2°C above pre-industrial levels, with an aspirational target of not exceeding 1.5°C, is emphasized by the international agreement on tackling climate change, as expressed through the Paris Agreement. With enhanced global reaction through different measures, such as reduced emissions, improved attempts at adaptation, and financial and technological help to developing nations, this framework seeks to considerably minimize the risks and consequences of climate change. A historic step toward uniting all nations behind a single cause to launch bold initiatives to fight climate change and prepare for its repercussions is the adoption of the Paris Agreement during the COP21 in Paris in December 2015 (NRDC, 2021).

As a result, legally binding agreements were made at the COP21 in Paris to guarantee a collective decrease of all carbon emissions worldwide to zero by 2050. The precise percentage that the building and construction sector contributes to global carbon emissions varies greatly depending on the source, although most estimates range from 35 to 40 percent (World Green Building Council, 2022; Deloitte, n.d.). These numbers are mostly the result of energy consumption in building operations as well as the materials and procedures used in new construction and renovation projects. This has prompted calls for urgent action within the industry to mitigate carbon emissions.

1.2. Dutch Context

In an era marked by heightened environmental awareness, the Netherlands is hosting a plethora of pilot projects, aligning its efforts with the global stride towards sustainability. The nation has set forth ambitious targets, aspiring to achieve Net Zero emissions and establish a fully circular economy by 2050 (Ministerie van Infrastructuur en Waterstaat, 2023; Ministerie van Algemene Zaken, 2023). This commitment is gradually unfolding through an array of initiatives, projects, and advanced practices that collectively contribute to the nation's sustainable development trajectory.

Reports like the Holland Circular Hotspot (2022)'s "Circular Buildings: constructing a sustainable future" shed light on the sector's transformative journey, delineating a holistic shift towards sustainability that goes beyond conventional practices. This shift is not confined to the adoption of eco-friendly materials but also involves the integration of innovative business models, circular design principles, and cutting-edge technologies such as robotics, VR, AR, and 3D printing. Initiatives like the Dutch WindWheel exemplify the integration of these technologies, which are instrumental in ushering in an era of sustainable and efficient construction (Strasdat, 2023).

While the government's intent to support sustainability and circularity is manifested through various policy frameworks (Van Langen & Passaro, 2021), the concrete impact and direct support of these policies in driving substantial change remain topics of discussion. The ambitious goal of constructing one million nearly energy-neutral homes by 2035 (Bartolo, 2021; Bosma & Beimer, 2020), coupled with explorations into alternative materials like hempcrete by companies such as the Dun Agro Hemp Group (Desai, 2022), are indicative of the incremental steps being taken towards embedding sustainability at the heart of the building industry.

1.3. Sustainability as a “must”

However, despite the projected progress and stated commitment to achieving Net Zero by 2050 (Ministerie van Algemene Zaken, 2021; Ministerie van Economische Zaken en Klimaat, 2019), a prominent challenge surfaces: the industry's reluctance to broadly embrace environmentally sustainable construction materials. Despite the pilot developments and the apparent governmental support and recommendations, questions about the durability, commercial acceptability, and dependability of Low Impact Materials generate a complex dynamic. (Karji et al., 2021; Bartolo, 2021). This hesitance manifests a significant disconnect between policy objectives and their actualization, transcending technical or regulatory impediments.

In addressing the transition towards Net Zero by 2050, it is imperative to acknowledge the construction industry's pivotal shift in perspective: sustainability must transition from being a 'maybe' to a 'must' (Hu, 2019). This shift necessitates a deeper exploration focusing on market and social acceptance, and the readiness of the industry to implement sustainable practices. Such an analysis should commence with consultants, contractors, clients and governmental representatives, also, if possible, others that are at the forefront of this transformation.

Most of the barriers and drivers are mentioned or discussed in the literature regarding sustainable construction practices and the adoption of Low Impact Materials (LIMs), but these materials are still underutilized, and the drivers are not used, often confined to a few pilot projects or experimental cases. It is therefore crucial to understand the specific drivers and barriers that influence their broader application within the industry. So, there is still a gap in the research focused specifically on identifying the barriers and drivers related to the adoption of LIMs within the building sector, particularly in the context of the Dutch construction industry. This study aims to fill that gap by exploring the unique challenges and opportunities that exist in this specific sector.

1.4. The Crucial Role of the Design Phase

In the building process, which spans phases from inception to completion, the design phase is a crucial point that significantly impacts a project's sustainability results (Haponava & Al-Jibouri, 2010). It acts as the starting point for important choices on the selection of materials, technologies, and resource allocation. Realizing that every stage of construction is interrelated, the design stage determines the course of following actions and shapes the project's overall sustainability profile.

From differing angles, the works of Yu et al. (2018) and Mavi et al. (2021) agree on the essential idea of integrating sustainability into building projects from start to finish. Mavi et al. (2021) emphasize how crucial it is to incorporate sustainability factors from the very beginning of the design process, stressing the significance of a comprehensive strategy that influences the project's lifespan. According to their findings, sustainability must be carefully considered throughout the development and implementation of projects rather than being an afterthought.

Yu et al. (2018) also explores the topic of sustainable project planning in construction engineering projects, explaining important aspects including work consensus, risk response, and management control. The results of their study underscore the need of taking preemptive action and collaborating with others to effectively tackle environmental issues. When the findings from the two studies are combined, sustainable construction requires a multifaceted strategy that includes strategic planning, stakeholder engagement, and ongoing monitoring all the way through the project, beginning with the design phase that establishes the framework for the subsequent stages.

1.5. Acceptance of Low Impact Materials

Understanding the acceptance of low impact materials is critical for their successful adoption in the construction industry. Acceptance, both social and market-based, determines whether these materials will be integrated into mainstream building practices. Without acceptance from key stakeholders such as policymakers, industry professionals, and the general public, even the most sustainable and innovative materials may fail to gain traction (Weniger et al., 2023). In the Netherlands, there is a growing awareness and supportive regulatory environment for sustainable construction practices. However, the level of acceptance varies among different stakeholders, and there is still a significant need for broader market and community buy-in to achieve widespread adoption of LIMs (Giesekam et al., 2015).

2. Research Overview

2.1. Research Problem

The Dutch construction industry is facing a crossroads in the pursuit of Net Zero by 2050, with possibilities and difficulties to be encountered along the way. Although there is no doubt about the commitment to this objective, getting there will need coordinating many different players and complicated pathways and reaching the objective is not guaranteed. This complex process necessitates a deeper awareness of the drivers and barriers that will shape the project's trajectory, as well as an appreciation of the favorable circumstances that support this goal and the identification of key people who will lead these initiatives.

The favorable circumstances in the Netherlands are encouraging to begin with. A strong foundation is created by the high levels of public awareness of the value of sustainability. Furthermore, the prevalence of technical developments and novel materials within the industry gives the means essential for transformation. Beneath the surface of advancement and dedication to achieving Net Zero by 2050, however, a mixed issue arises that extends beyond the domains of technology and regulations into the complex dynamics of market forces, public acceptability, and policy.

That being said, no one organization has exclusive responsibility for achieving the Net Zero goals. It takes a communal effort, an ensemble created by government authorities, industry leaders, contractors, clients, and the community at large (Zhang et al., 2021). Given this, it is imperative to ask: “who can steer the sector in the correct direction, and who is impeding progress?”. These inquiries aim to not only identify obstacles but also the leaders and influencers who can successfully negotiate this complexity and steer the construction sector in the direction of sustainability.

Understanding the barriers and enablers is equally crucial, as emphasized by the literature in adjacent domains closely related to construction industry (Caldera et al., 2020; Lou et al., 2023). Given this, a thorough mapping of these circumstances, stakeholders, barriers, and enablers must be the first step towards accomplishing the Net Zero buildings by 2050. This entails carrying out in-depth research to pinpoint and comprehend the subtleties of each component, and understanding the cycle that would push the industry towards precise, doable actions while considering the interaction of these complex variables.

2.2. Problem Statement

Although the goal is clear for the Dutch construction industry to reach net zero emissions, navigating the implementation of low impact materials from early design phase poses a challenge. Both real-world experiences and literature reveal significant gaps in implementation and market acceptance of LIMs, leaving key barriers and drivers shrouded in uncertainty. Additionally, the understanding of these materials within the Dutch market remains unclear. Furthermore, the intricate dynamics among stakeholders concerning material choices are largely unknown, further complicating the path toward sustainable construction practices.

2.3. Research Overview

The next chapter goes over the primary questions that will direct this study, outlining the main research question, the objectives that hope to be accomplished, and the sub-questions that will direct the investigation.

2.3.1. Main Research Question

- ***How can the Dutch construction industry accelerate the market acceptance of low impact materials to achieve net zero building ambitions?***

2.3.2. Sub-Questions

1. **SQ1 Barriers and Enablers**
    - What factors hinder or facilitate the market acceptance of low impact materials in achieving net zero building ambitions?
2. **SQ2 Material Information**
    - What critical information about low-impact materials is needed to make informed decisions?
3. **SQ3 Stakeholder Dynamics**
    - What are the perspectives of key stakeholders regarding the acceleration of use of low impact materials?

2.3.3. Interrelation of Sub-Questions

To address the main research question effectively, it is essential to break it down into more manageable sub-questions, each focusing on a specific aspect of the problem. These sub-questions are interrelated and together provide a comprehensive understanding necessary to formulate actionable strategies for accelerating the market acceptance of low-impact materials in the Dutch construction industry.

1. **Relation between SQ1 and SQ2**

SQ1 focuses on identifying the barriers and drivers that affect the market acceptance of low-impact materials. These factors are crucial because they directly influence the decision-making process during the design phase and the later phases. By understanding what hinders or facilitates acceptance, we can pinpoint areas that require critical information about materials (addressed in

SQ2). Thus, SQ1 sets the stage for understanding the broader landscape, while SQ2 delves into the detailed information needs that arise from these broader issues.

2. **Relation between SQ1 and SQ3**

SQ1 also lays the groundwork for understanding the barriers and enablers from a systemic perspective, which directly ties into the stakeholder dynamics explored in SQ3. SQ3 investigates the perspectives of key stakeholders, providing insights into how these barriers and enablers manifest in real-world scenarios. By understanding stakeholder dynamics, we can develop more targeted strategies to engage with different actors, address their specific concerns, and leverage their influence to overcome barriers identified in SQ1.

3. **Relation between SQ2 and SQ3**

SQ2's focus on the critical information needed about low-impact materials is intrinsically linked to stakeholder perspectives explored in SQ3. Different actors have varying informational needs and priorities. By analyzing stakeholder perspectives (SQ3), we can tailor the dissemination of critical information (SQ2) to meet the specific needs of each group, thereby facilitating better acceptance and adoption.

4. **Synthesis towards the Main Research Question**

Together, these sub-questions provide a holistic approach to answering the main research question. SQ1 identifies the overarching factors that influence market acceptance, SQ2 ensures what necessary information should be available to make informed design decisions about materials, and SQ3 aligns actor interests and actions towards a common goal. By addressing these sub-questions, the research can formulate comprehensive strategies that tackle both systemic and specific challenges, ensuring that the Dutch construction industry can effectively accelerate the market acceptance of low-impact materials during the design phase.

2.4. Research Purpose

2.4.1. Goal and Objectives

The primary goal of this research is to catalyze the Dutch construction industry's adoption of LIMs during the design phase, thereby contributing significantly towards the achievement of net zero building ambitions. To achieve this overarching goal, the research is structured around several key objectives:

- Identify and Analyze Barriers and Enablers
- Understanding Materials
- Examine Stakeholder Dynamics
- Develop Strategic Recommendations

2.4.2. Deliverable

The primary deliverables of this thesis are comprehensive insights and actionable strategies to accelerate the adoption of LIMs in the Dutch construction industry during the design phase, aiming towards net-zero carbon building ambitions by 2050. Additionally, this thesis aims to provide an objective view of how practitioners in the field perceive the ongoing transition to low-impact

materials and the road to 2050. It seeks to understand, from both the literature and the practitioners' perspectives, what changes should be implemented to accelerate this transition.

2.4.3. Audience

This research targets a broad range of stakeholders within the Dutch construction industry, focusing particularly on those involved in the design and development of buildings.

1. **Clients/Project Developers**:
    - Clients and project developers are pivotal in advancing sustainable construction within the Dutch construction industry. This research targets these stakeholders, aiming to enhance their understanding and implementation of net-zero carbon building practices. By providing insights into Low Impact Materials, the research will support developers in improving their early design processes.
2. **Contractors**:
    - Individuals and firms responsible for executing building projects. This research will provide them with recommendations and considerations to incorporate LIMs during construction, ensuring that projects align with net-zero carbon goals from the outset.
3. **Consultants**:
    - **Engineers, Architects, and Sustainability Consultants**: Professionals involved in the design phase of construction projects. This research offers valuable insights for incorporating Low Impact Materials, thereby improving the overall sustainability of their designs and how to approach the other actors.
4. **Governmental Officials**:
    - Government officials and regulatory bodies responsible for setting and enforcing policies related to sustainable construction practices. The findings of this research can inform policymaking and support the development of regulations that promote the use of LIMs.
5. **Any Interested Party**:
    - This includes any stakeholder with an interest in sustainable construction practices, such as environmental organizations, industry associations, and educational institutions. The research aims to provide these parties with a comprehensive understanding of the current state and future potential of LIMs in the Dutch construction industry.

2.5. Research Relevance

As explained in the previous sections, it is unclear for practitioners in the Dutch construction industry how to effectively incorporate LIMs during the early design phase. Simultaneously, this ambiguity presents an opportunity to enhance traditional design practices. To achieve the ambitious net-zero carbon objectives by 2050, business-as-usual practices must evolve. Rethinking the early design process could challenge and transform established norms in the construction industry, accelerating progress towards a net-zero carbon built environment.

2.5.1 Societal Relevance

The societal relevance of this research is primarily tied to the urgent need to decarbonize the construction sector to prevent catastrophic climate change. Achieving net-zero emissions at both sectoral and global levels by 2050 requires a fundamental shift in building development practices. Significant improvements can be made to the traditional design process by integrating sustainable practices from the outset.

Operational carbon mitigation approaches have already made substantial progress in reducing overall carbon emissions in construction projects. However, given the increasing importance of embodied carbon, it is crucial for the construction industry to address these emissions as well. Currently, the standard practice in the Netherlands involves assessing embodied carbon only after the design or building is completed, often through assessments like the 'Milieu Prestatie Gebouw' (MPG). This research is particularly relevant in the Dutch context as it aims to embed sustainable material considerations much earlier in the design process, promoting proactive rather than reactive measures.

2.5.2 Scientific Relevance

The scientific relevance of this research lies in providing a new perspective on the adoption of LIMs within the Dutch construction industry. To date, the perspectives of contractors, consultants, and other key stakeholders have been underrepresented in discussions about reducing the embodied carbon footprint of buildings. This research addresses this gap by incorporating the views of these stakeholders, thereby enriching the existing body of knowledge.

Furthermore, this research expands the understanding of the critical early design phase, highlighting the roles and responsibilities of design team members in integrating sustainable practices. By focusing on the nascent but growing phenomenon of net-zero carbon buildings, this research contributes to the limited literature available on this topic.

2.6. Research Structure

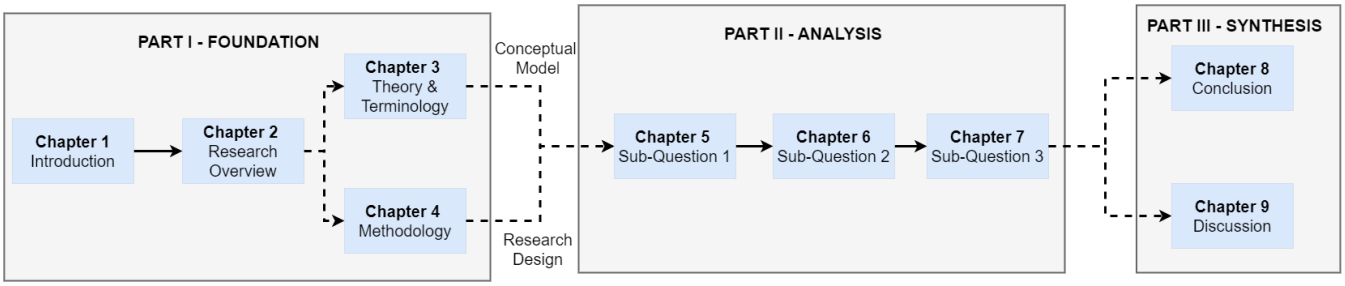

Figure 1 - Research Structure

2.7. Scope

To identify the complex factors preventing the Dutch construction industry from building Net Zero buildings, a thorough investigation is conducted in this paper. The goal is to tell a story that, while highlighting the existing situation, also pushes the industry in the direction of creative solutions by utilizing the Netherlands' solid heritage of technological innovation and environmental concern.

Also, important to note that there is a visible lack of study on the demand side of sustainable building, despite the supply side—which includes the creation and technical assessment of LIMs—

having received considerable attention in the literature. This covers the responsibilities that people and organizations play in putting these technologies into practice, as well as the market and societal acceptability of such advancements. By examining how social views and market dynamics in the construction industry affect the uptake and efficacy of sustainable building methods, the research seeks to understand this disparity.

In this case, the goal goes beyond simply identifying the drivers and barriers; it aims to identify the trigger mechanism for a paradigm change in the construction sector, enabling a move toward practices that are no longer only seen as optional but rather as essential.

2.7.1. Sample Population

The journey to building Net Zero is a collective endeavor that necessitates the collaboration and alignment of various actors. While the industry comprises a wide array of stakeholders, this research will primarily focus on consultants, contractors, clients, governmental officials and suppliers. This targeted technique is utilized to provide a controllable scope and to make it easier to collect comprehensive, useful information. Because of their direct engagement in building projects and relative accessibility for interviews, these actors are given special attention.

2.7.2. Geographical and Temporal Boundaries

Geographically limited to the Dutch construction sector, the study concentrates on the special traits, difficulties, and prospects found there. It is anticipated that the conclusions and suggestions will offer valuable perspectives specifically pertinent to the Netherlands, with limited immediate relevance to other nations because of dissimilar cultural, and business contexts. The study's temporal focus is on the industry's present methods and prospects for accelerating achieving the 2050 Net Zero goal. It notes that the findings' long-term application may be limited by the dynamic character of the building sector, which is impacted by changes in policy and technology. Therefore, the research attempts to take a moment picture of the industry's existing course, keeping in mind that future advancements can call for more study and strategy modification.

2.7.3. Thematic Exclusions

To keep the study focused and manageable, several themes and issues are left out even though the goal is to present a comprehensive picture of the Dutch construction industry's shift to Net Zero. This research does not cover in-depth technical assessments of particular building materials, comprehensive financial analysis of building projects, or micro-level investigations of certain construction techniques. These omissions are a result of the study's wide emphasis, which avoids delving into extremely specific technical or financial specifics in favor of understanding general trends, enablers, barriers, and stakeholder interactions with regards to market and social acceptance of Net Zero.

2.7.4. Limitations and Challenges

The study admits several potential restrictions and difficulties that might affect its results. The range of viewpoints obtained, and the representativeness of the sample may be constrained by the availability and willingness of stakeholders to engage in interviews. The construction sector is constantly changing due to changes in regulation and technology, which might impact the findings' long-term applicability. Furthermore, biases may be introduced by the subjective interpretation of qualitative data from interviews.

3. Theory and Terminology

3.1. Net Zero Carbon Buildings

The highest standard of sustainable building is represented by Net Zero Carbon buildings, which combine cutting-edge design with the strict objective of reducing greenhouse gas emissions over the course of their lifetime. To have a net zero effect on the climate of the earth, these structures aim to achieve an ideal balance between the carbon emissions they generate and the carbon that is offset or stored (Tirelli & Besana, 2023). A strategic emphasis on energy efficiency and the integration of renewable energy sources, supported by wise material and technological selections, is essential to achieving this goal (Hu, 2019).

Defining "net-zero carbon buildings" precisely is challenging due to the existence of several related terms like nearly zero-energy building (NZEB), zero-energy building (ZEB), and net-zero energy building (NZEB). These terms primarily address minimizing a building's operational energy consumption (Hu, 2019). Recently, the concepts of zero carbon building (ZCB) and net-zero carbon building (NZCB) have emerged, but consensus on a standard definition is lacking. Some interpretations focus solely on operational carbon emissions, while others consider both operational and embodied carbon emissions (Tirelli & Besana, 2023). Understanding the complete Building Life Cycle involves grasping how both Operational and Embodied aspects contribute to the entirety, as depicted in Figure 2.

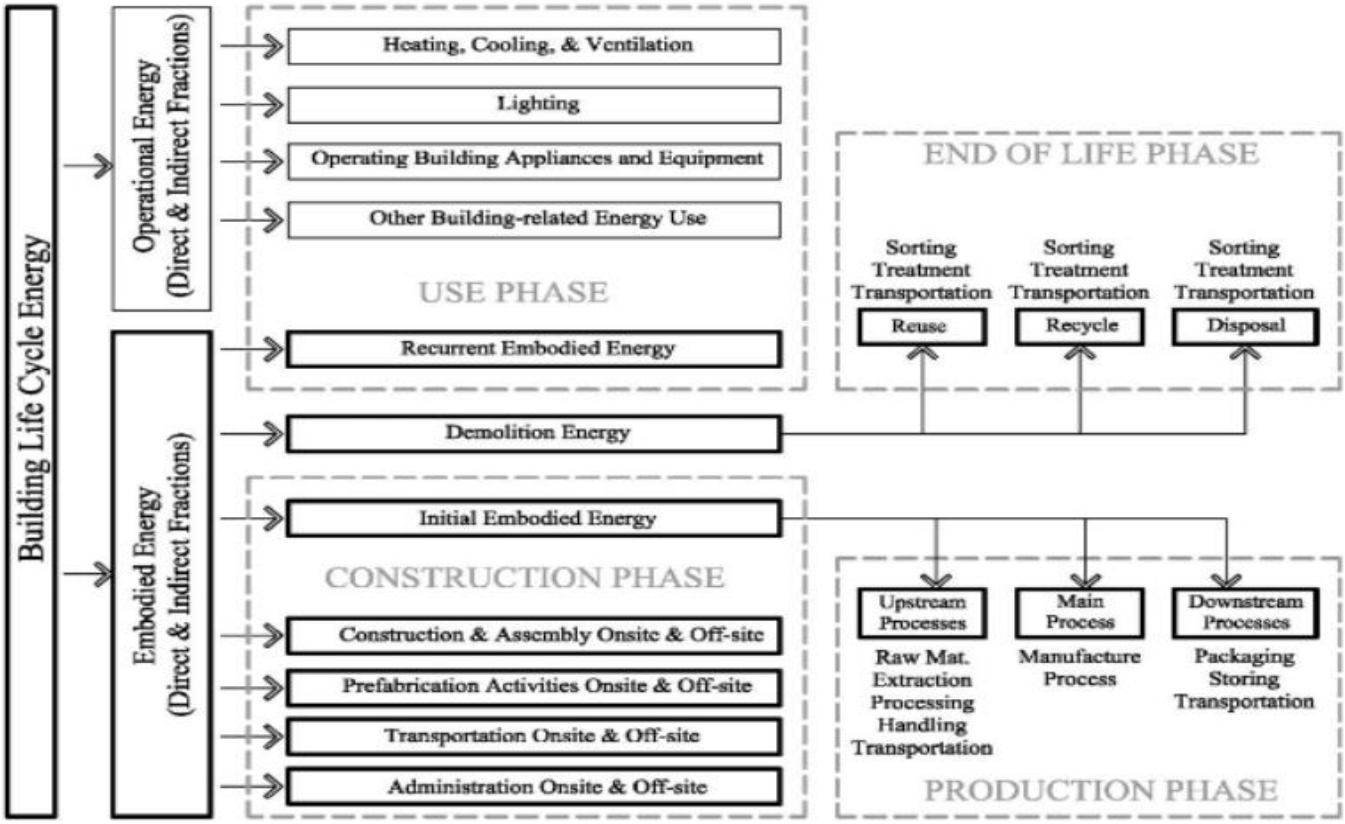

Figure 2 - Embodied Energy model for a building (Dixit, 2013)

The World Green Building Council advocates for ***a "whole life carbon approach" that addresses both operational energy use and embodied carbon***, as can be seen in Figure 3. In order to lower energy demand, this strategy prioritizes energy efficiency and takes into account both on- and off-site renewable energy sources to cover any leftover energy requirements. ***NZCBs are urged to reduce embodied carbon by doing things like using low-carbon building materials***. In order to promote the environmental and social advantages of the shift towards comprehensive sector decarbonization, offsets for any residual emissions must be included (World Green Building Council, 2024).

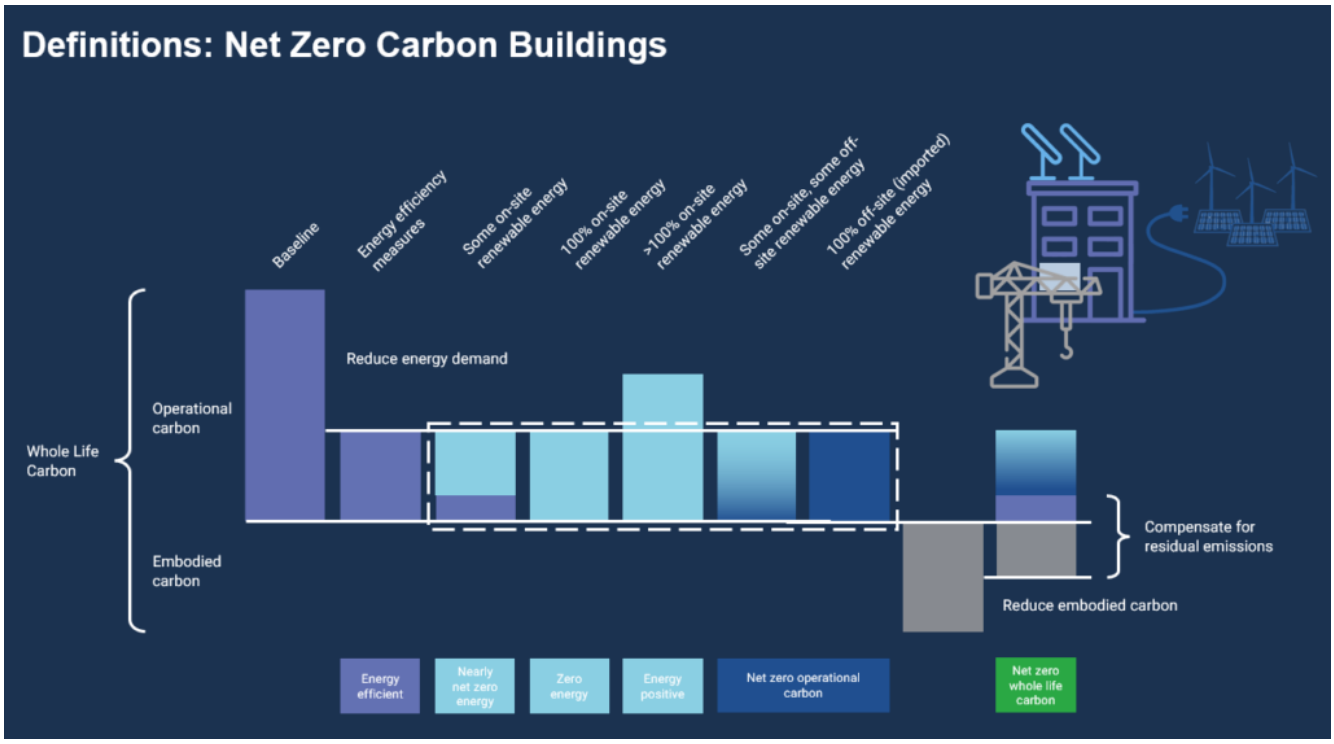

Figure 3 - Definitions Net Zero Carbon Buildings WGBC (World Green Building Council, 2024)

The fact that the WorldGBC definition specifically tackles the embodied carbon of building materials makes it especially relevant to the project. This strategy is essential to the market's adoption of LIMs because it acknowledges that attaining net zero carbon buildings calls for careful consideration of construction materials in addition to operating energy efficiency. The necessity for LIMs with reduced carbon footprints in comparison to conventional construction materials is highlighted by the embodied carbon element. The definition used in this project can be seen below:

"In new building developments, maximum embodied carbon reductions should seek to achieve, for example by choosing to renovate existing buildings or through building material selection. If the remaining residual emissions from embodied carbon and any remaining fossil-fuel use within the building during the operational stage are compensated for, for example through the use of offsets, the building asset is net zero whole life carbon."

Definition according to World Green Building Council (2024)

3.1.1. Embodied Energy: The Critical Role of Materials

An important consideration when evaluating the sustainability of Net Zero Carbon Buildings is the notion of "Embodied Energy". It takes into consideration the whole amount of energy used in all the steps involved in constructing a structure, including raw material extraction and processing, production, transportation, and assembly. Embodied energy must be quantified since, even before a structure is put into service, it contributes significantly to its environmental effect (Hu, 2019). This emphasizes how crucial it is to choose materials with low embodied energy profiles in addition to their practical and aesthetic attributes.

The importance of embodied energy goes beyond the first stages of construction and affects the sustainability of the structure over its whole life. The selection of low-energy building materials and techniques significantly impacts the embodied energy of buildings. Alternative construction materials can reduce embodied energy by approximately 50%, demonstrating a pathway towards reducing greenhouse gas emissions and enhancing energy resource efficiency (B. V. V. Reddy, 2009).

3.1.2. The Quantification of Embodied Energy/Embodied Carbon

The process of quantifying embodied energy necessitates a thorough Life Cycle Assessment (LCA), which is a methodical examination of the energy inputs at each phase of a building's existence. To reduce the environmental effects of building construction and operation, this procedure is crucial for making well-informed judgments on the selection of materials and technologies. An LCA gives a comprehensive picture of the embodied energy of materials and sheds light on areas where energy use might be cut (Khan et al., 2022). In the Netherlands LCA's studies on buildings are communicated within **the 'Milieuprestatie Gebouw' (MPG)**. The MPG indicates the environmental impact of the materials used in a building. It is developed by the Dutch national government to unequivocally and verifiably calculate the material related environmental performance of buildings over their life cycle.

3.2. Social and Market Acceptance

This section delves into the ideas of market and social acceptance, which are essential to comprehending the uptake of LIMs. The definitions and framework used in this chapter are primarily based on the work of Wüstenhagen et al. (2007), as their comprehensive approach to categorizing social acceptance into socio-political acceptance, community acceptance, and market acceptance aligns well with the objectives of this research (Figure 4). Wüstenhagen's model offers a robust structure for analyzing the multi-dimensional nature of acceptance, making it highly suitable for addressing the specific challenges and opportunities related to the integration of LIMs in building practices.

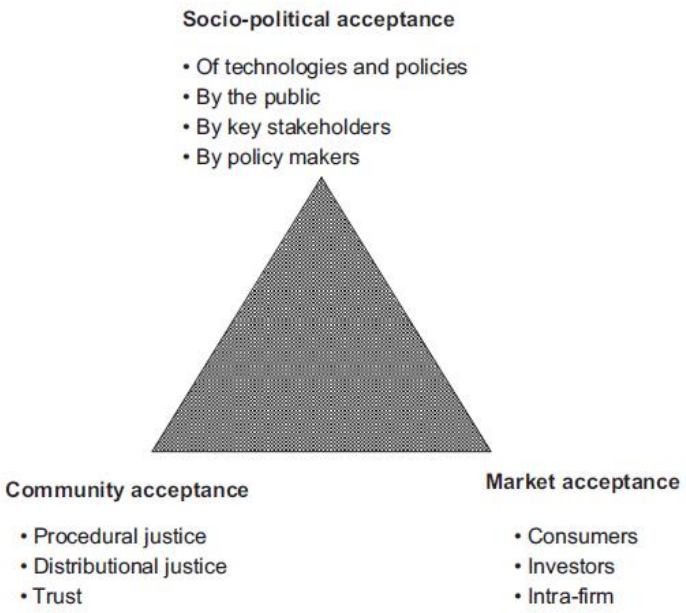

Figure 4 - Categorizing Social Acceptance by Wüstenhagen et al. (2007)

3.2.1. Definitions

Social Acceptance refers to the extent to which new technologies, materials, or practices are embraced by the general public and stakeholders within a specific community or industry. According to Wüstenhagen et al. (2007), social acceptance can be categorized into three dimensions:

- **Socio-political Acceptance:** This dimension involves the acceptance of technologies and practices by the general public, policymakers, and stakeholders. It is often indicated by public support and favorable policies that facilitate the adoption of new technologies.
- **Community Acceptance:** This pertains to the acceptance of specific projects at the local level, including the approval of local communities and the trust itself in a specific project. Key factors influencing community acceptance include procedural justice, distributional justice, and trust. In this project, community acceptance is not taken into consideration so much as the focus is on the main practitioners of the construction industry and not specifically on the final consumers, which are the local communities.
- **Market Acceptance:** Although Wüstenhagen includes market acceptance as a dimension of social acceptance, for this research, we distinguish it separately due to its economic focus, but still consider it as a subset of the overall social acceptance.

Market Acceptance is defined as the degree to which new products, services, or technologies are adopted by the market, driven by economic factors such as cost, performance, availability, and competitive advantage. It encompasses both consumer and investor acceptance. In the case of this project, the investors are the clients/project developers and in some cases the governmental officials in the case of public projects and the consumers are the contractors and the consultants as they are the ones who need to work hands on with the LIMs after the decision of using them by the investors.

- **Consumer Acceptance:** The willingness of consumers to adopt new technologies, influenced by factors like awareness, perceived benefits, and compatibility with existing practices.
- **Investor Acceptance:** The confidence of investors in supporting new technologies, which includes financial investors and consumers who invest in small-scale systems.

3.2.2. Importance to This Research

When analyzing the influence of socio-political and market acceptance on the adoption of LIMs, it becomes evident that both dimensions are interdependent and can significantly influence each other. This interdependence is particularly important to this research, as understanding the dynamics between these dimensions can help identify the most effective strategies for promoting LIMs in the construction industry.

Socio-political Acceptance as a Catalyst: Socio-political acceptance can play a pivotal role in shaping market acceptance. Policies and regulations created due to socio-political acceptance can lead to market incentives, subsidies, and support structures that lower the economic barriers for adopting LIMs. For instance, if policymakers introduce favorable regulations and incentives for sustainable construction, it can lead to increased market confidence and investment in LIMs. For this research, understanding socio-political acceptance is crucial as it can inform the development of policy recommendations and advocacy strategies to promote the use of LIMs.

Market Acceptance Driving Socio-political Change: Conversely, market acceptance can influence socio-political acceptance by demonstrating the viability and benefits of LIMs. As market adoption increases and more successful case studies emerge, public and political support can grow. This market-driven evidence can then feed back into the socio-political realm, leading to further supportive policies and broader acceptance. This research benefits from exploring market acceptance because it provides insights into the economic factors and stakeholder motivations that drive the adoption of LIMs, helping to tailor market strategies and business models.

While both socio-political acceptance and market acceptance are crucial for the adoption of LIMs, socio-political acceptance might be considered slightly more influential initially, as it can create the necessary conditions for market acceptance to thrive. However, the continuous interaction between these two dimensions ensures that as one grows, it reinforces and enhances the other, creating a positive feedback loop that drives the broader acceptance and integration of LIMs in building practices.

3.3. Barriers and Drivers

In the context of this research, understanding the barriers and drivers that influence the adoption of LIMs in the Dutch construction industry, particularly during the design phase, is crucial. Barriers and drivers from a market and social point of view are the factors that respectively hinder or facilitate the acceptance and implementation of new technologies and practices. By examining these elements, this chapter aims to provide a comprehensive view of the challenges and opportunities that exist in integrating LIMs into early design processes.

3.3.1. Definitions

Barriers: Barriers are obstacles that impede the adoption and integration of LIMs in the construction industry. These obstacles can be economic, technological, cultural, or regulatory. Examples of barriers include high initial costs, performance uncertainties, resistance to change, and inadequate policies. Understanding these barriers is essential to develop strategies to overcome them and facilitate the adoption of LIMs (Eze et al., 2023).

Drivers: Drivers are factors that promote and facilitate the adoption of LIMs. They provide motivation, resources, and favorable conditions for change. Drivers can be economic incentives, technological advancements, regulatory support, and cultural shifts towards sustainability. Identifying these drivers helps in leveraging opportunities to encourage the adoption of LIMs (Eze et al., 2023).

3.3.2. Importance to the Design Phase

Understanding barriers and drivers during the design phase and beyond that is essential for several reasons:

1. **Proactive Decision-Making**: Early identification of barriers allows designers and planners to address potential challenges before they become insurmountable. Similarly, recognizing drivers early can help in leveraging them to promote sustainable practices.
2. **Influence on Overall Project**: Decisions made during the design phase have a lasting impact on the entire project lifecycle. Ensuring that sustainability is a priority at this stage can lead to more environmentally friendly and cost-effective outcomes.
3. **Stakeholder Engagement**: Engaging stakeholders early in the design phase can help in understanding their concerns and motivations, leading to better acceptance and smoother implementation of LIMs.
4. **Regulatory Compliance**: Understanding regulatory barriers and drivers can help in aligning design practices with current and anticipated policies, ensuring compliance and potentially benefiting from incentives.

3.4. Definition of Low Impact Materials

In the context of this research, the term "low impact materials" encompasses a broad range of materials used in the construction industry that are designed to minimize environmental harm. This includes circular, recyclable, bio-based, and innovative materials, as well as traditional materials that can be made sustainable by considering their embodied carbon. This chapter defines LIMs and explains the rationale behind using such a diverse pool of materials in this study.

3.4.1. Definition of Low Impact Materials

Low Impact Materials: These are materials that have a reduced environmental footprint compared to conventional materials. The goal is to minimize the negative impacts on the environment throughout the material's lifecycle—from extraction and production to use and disposal. The categories of LIMs include:

1. **Circular Materials**: These materials are designed to be reused and recycled, forming a closed-loop system that reduces waste and the need for virgin materials. Examples include materials that can be easily disassembled and reused in new constructions.
2. **Recyclable Materials**: These are materials that can be processed and used again at the end of their life cycle. This reduces the need for raw material extraction and minimizes waste. Common recyclable materials in construction include metals, certain plastics, and glass.
3. **Bio-based Materials**: These materials are derived from renewable biological sources such as plants and animals. They are often biodegradable and have a lower carbon footprint compared to synthetic materials. Examples include bamboo, hempcrete, and timber.
4. **Innovative Materials**: This category includes new and emerging materials that offer sustainable benefits. These materials often incorporate advanced technologies to improve performance and reduce environmental impact. Examples include carbon capture concrete, self-healing materials, and nanomaterials.
5. **Sustainable Traditional Materials**: Traditional materials such as concrete, steel, and bricks can also be considered low impact if their embodied carbon is minimized through improvements in production processes, use of recycled content, or innovative applications.

3.4.2. Rationale for Including a Wide Range of Materials

Despite each type of low impact material having its own unique characteristics and challenges, this research includes a wide range of materials for several reasons:

1. **Comprehensive Perspectives**: By examining a diverse pool of materials, the research aims to capture a broad spectrum of perspectives from practitioners and literature. This approach helps in understanding the varying challenges and opportunities associated with each type of material.
2. **Macro-Level Insights**: While the materials differ individually, there may be common themes and issues at a macro level that affect their adoption. These include market acceptance, regulatory barriers, economic viability, and social perceptions. Identifying these overarching issues can provide valuable insights for promoting LIMs in general.
3. **Interconnected Solutions**: Solutions that work for one type of low impact material might be applicable to others. For instance, regulatory incentives that promote the use of bio-based materials could also support the adoption of recyclable materials. A holistic approach can help in developing integrated strategies that benefit multiple types of LIMs.

3.5. Conceptual framework

The conceptual framework for this research centers around the critical role of **material choice** in achieving **net zero carbon buildings**. The framework starts with the decision-making process for selecting materials for a single building (depicted on the left side), and it extends to the broader goal of transforming the entire construction industry towards net zero carbon buildings (depicted on the right side). The progression from material choice for one building to the industry-wide adoption of sustainable practices is illustrated by an arrow connecting these two main concepts. This progression underscores the potential of individual material choices to contribute to the overarching goal of sustainability across the industry.

Material Choice represents the decisions made regarding the selection of materials for constructing a building. This singular focus on one building encapsulates the intricate decision-making process involving various factors, stakeholders, and constraints. It highlights the importance of choosing materials that align with sustainability goals, reduce environmental impact, and enhance operational efficiency. Two essential directions within this decision-making process are **Low Impact Materials** and **Accelerating the Adoption** of these materials.

- **Low Impact Materials** focuses on the intrinsic qualities and performance of the materials themselves. Ensuring the low impact of materials involves selecting materials that have a minimal environmental footprint, are high-performance, and are readily available. This includes advancements in Low Impact Materials, enhancements in lifecycle assessment (LCA), and the development of high-performance, low-carbon materials. Reliable supply chain infrastructure and improved material selection processes are also crucial to ensure that Low Impact Materials are consistently available and meet high standards.
- **Accelerating the Adoption** relates to the barriers and drivers associated with stakeholder engagement, financial incentives, skills, and regulatory frameworks. Creating an environment conducive to the widespread acceptance and use of LIMs involves addressing these aspects. This includes regulatory standards and compliance, encouraging market transformation, providing financial incentives to reduce initial costs, enhancing market demand, and fostering stakeholder engagement through public sector leadership and educational programs.

Net Zero Carbon Buildings signify the ultimate objective of achieving a construction industry where buildings contribute no net carbon emissions. This goal is realized through the collective impact of sustainable material choices across many projects. The transition from individual material decisions to industry-wide sustainability practices is essential for mitigating climate change and complying with carbon reduction targets.

3.5.1. Detailed Explanation of Each Component

The conceptual framework breaks down the overarching idea into smaller, interconnected parts that address the fundamental questions of **Why**, **What**, **Who**, **When**, **Where**, **How**, and **So What**. These components help in systematically understanding and addressing the various aspects of material choice and its impact on achieving net zero carbon buildings.

1. **Why**
    a. **Achieving Sustainability Goals:** The motivation behind selecting LIMs is to meet overarching sustainability objectives. This includes reducing carbon emissions, conserving resources, and promoting environmental stewardship.
    b. **Mitigate Climate Change Impacts & Comply with Carbon Reduction Targets:** Sustainable material choices help in mitigating the adverse effects of climate change by reducing the carbon footprint of buildings.
2. **What**
    a. **Factors:** Various factors influence material choices, including cost, availability, performance, and regulatory requirements. Understanding these factors is crucial for making informed decisions that align with sustainability goals.

b. **Barriers/Drivers:** Factors which are unique for a building, become barriers and drivers for the industry and for the whole LCA of a building overall. Identifying barriers such as cost concerns, regulatory hurdles, and lack of information, as well as drivers like technological innovations and financial incentives, is essential for overcoming obstacles and promoting the adoption of LIMs.

3. **Who**
    a. **Actors:** The key stakeholders involved in the material choice of a building process include architects, engineers, contractors, suppliers, governmental officials and clients. Each actor plays a crucial role in influencing decisions and ensuring that sustainability is prioritized.
    b. **Perceptions and Influences:** Understanding the perceptions and influences of different actors helps in addressing resistance and fostering a collaborative approach towards sustainable material choices.
4. **When**
    a. **Design Phase:** The design phase is critical for setting the sustainability trajectory of a project. Decisions made during this phase have a long-lasting impact on the building's environmental footprint and operational efficiency.
    b. **Entire Lifecycle of the Building:** Considering sustainability impacts throughout the entire lifecycle of the building, from construction to operation and eventual demolition, ensures long-term environmental benefits for the project and overall for the industry.
5. **Where**
    a. **A Specific Building:** Focusing on material choices for a specific building provides a tangible example of how decisions are made, and the factors considered.
    b. **Netherlands:** The geographic context, specifically in the Netherlands, provides a localized perspective on material choices and sustainability practices. The framework considers regional regulations, availability of materials, and cultural preferences.
6. **How**
    a. **Decision-Making Processes:** The decision-making process involves evaluating various material options based on their technical performance, cost, availability, and sustainability attributes.
    b. **Integrated Design:** Integrated design approaches involve ensuring that sustainability is considered at every stage of the project. This approach facilitates the alignment of material choices with broader sustainability objectives.
7. **So What**
    a. **Affects the Building's Environmental Footprint and Operational Efficiency:** The choice of materials directly impacts the building's environmental footprint, including its carbon emissions, energy consumption, and resource use. Operational efficiency is also influenced by the durability and performance of the materials used.
    b. **Transform the Built Environment:** By making informed material choices, the construction industry can foster healthier, more sustainable communities with net zero carbon buildings. Sustainable buildings contribute to creating a built environment that supports well-being, conserves resources, and acts as a catalyst for broader environmental change.

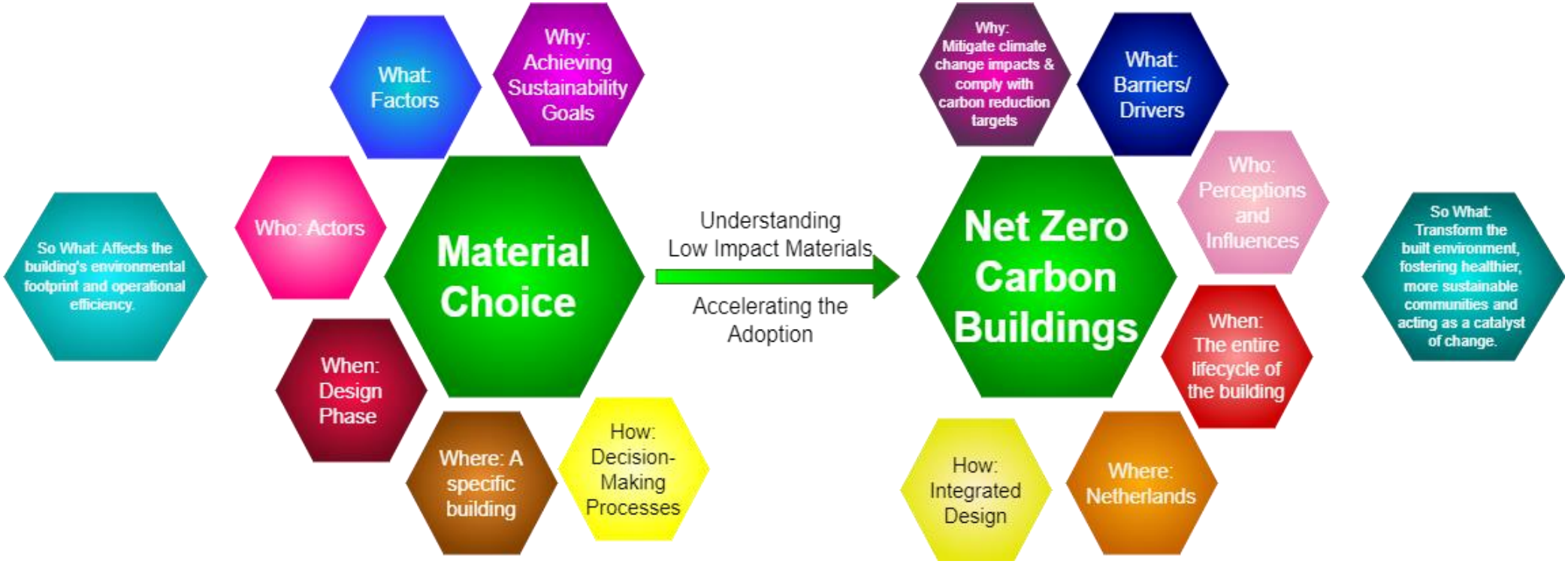

Figure 5 - Conceptual Framework

4. Methodology

4.1. Research Design

This study adopts a qualitative research design to explore the critical factors influencing the adoption of Low Impact Materials (LIMs) in the Dutch construction industry. Given the exploratory nature of the research, a qualitative approach is particularly suited to uncovering the complex and nuanced perspectives of various stakeholders involved in the industry. The primary aim is to understand how these stakeholders perceive and interact with the regulatory frameworks, market incentives, and technical challenges associated with LIMs, thereby addressing the central research question: "**How can the Dutch construction industry accelerate the market acceptance of LIMs to achieve net zero building ambitions**?"

The research is designed to capture in-depth insights from key industry stakeholders, including government officials, clients, contractors, consultants, and suppliers. By focusing on these groups, the study seeks to map out the intricate web of relationships and influences that shape the adoption of LIMs. This qualitative approach allows for a deep exploration of stakeholder perspectives, which is crucial for understanding the barriers and drivers of LIM adoption in a highly regulated and technically complex industry.

A combination of semi-structured interviews and a comprehensive literature review forms the backbone of the data collection process. This dual approach ensures that the research is grounded in both empirical evidence from industry experts and existing academic and professional knowledge. The use of semi-structured interviews is particularly important, as it allows for flexibility in exploring new themes that emerge during the conversations with stakeholders while still maintaining a focus on the key issues identified in the literature review. The research design also incorporates a thematic analysis framework for data interpretation, enabling the identification and categorization of recurring themes related to the adoption of LIMs.

4.2. Data Collection

4.2.1. Literature Review

The literature review focused on the global and European perspectives on adopting LIMs, especially during the design phase. When relevant Dutch-specific papers were found, they were also included. Key resources used for this review included Google Scholar, Scopus, ResearchGate, and Web of Science, as well as general Google searches in the later stages of analysis. Examples of key words that were used to find relevant articles would be: "Low Impact Materials", "Sustainable Construction", "Net Zero Building", "Dutch Construction Industry", "Lifecycle Assessment", "Sustainable Building Practices", "Barriers", "Drivers", ‘Enablers”, “Inhibitors’, "Low Carbon Materials", "Green Building Materials", "Barriers and Drivers", "Circular Economy in Construction", "Construction Industry Collaboration", "Sustainable Design Practices", "Construction Material Standards", "Construction Supply Chain ", "Construction Industry Innovation", "Material Passports", The literature review was pivotal in developing the conceptual framework, terminology, and the initial chapters of the report. It was especially important for identifying barriers and drivers for SQ1. The literature review also helped in developing the interview setup. For SQ1, the saturation method was used to identify when certain themes and ideas began to repeat, indicating sufficient coverage of a topic before moving on to the next.

4.2.2. Semi-Structured Interviews

Insights from the literature review informed the creation of the interview setup. The questions were designed to align with the three sub-questions, ensuring that the interviews provided relevant insights. The sessions were flexible, lasting from 40 minutes to 1 hour 30 minutes, depending on the availability of the practitioners. While all practitioners were asked the main questions, those with more time engaged in deeper discussions. The baseline questions were adapted based on each practitioner's role, company, and specialization. The semi-structured nature of the interviews allowed for open-ended discussions, enabling practitioners to express their views freely.

To recruit interviewees, an administrative search was conducted to identify practitioners across six categories: contractors, engineering/architectural consultants, sustainability consultants, clients/project developers, governmental officials, and suppliers. Invitations were sent via LinkedIn or email to about 150 potential participants, resulting in 18 interviews with 20 practitioners. Despite the broad outreach, no interviews were conducted with suppliers. The interviews were conducted online using Microsoft Teams. To ensure confidentiality, participants were assured that their names and company names would not be disclosed, which encouraged more open and candid discussions.

Table 1 - Interviews Overview

Code	Category	Date
P01	Architectural Consultant	5th of April
P02	Contractor	12th of April
P03	Client	12th of April
P04	Engineering Consultant	15th of April
P05	Contractor	17th of April
P06	Engineering Consultant	17th of April
P07	Sustainability Consultant	18th of April
P08	Contractor	23rd of April
P09	Engineering/Architectural Consultant	24th of April
P10	Sustainability Consultant	24th of April
P11	Engineering Consultant	26th of April
P12	Contractor	26th of April
P13	Architectural Consultant	26th of April
P14	Governmental Official	29th of April
P15	Architectural Consultant	29th of April
P16 & P16b	Client	02nd of May
P17 & P17b	Governmental Official	06th of May
P18	Governmental Official	07th of May

4.2.3. Data Recording and Transcription

All interviews were recorded with the consent of the participants to ensure accurate data capture. The recordings were then transcribed verbatim to facilitate detailed analysis. Transcription was handled using a combination of automated transcription software from Microsoft Teams and manual review to ensure accuracy, particularly in capturing industry-specific terminology and nuances in stakeholder perspectives.

In summary, the data collection process was designed to gather in-depth insights from a wide range of stakeholders while grounding the research in a solid foundation of existing knowledge. The combination of semi-structured interviews and a comprehensive literature review provided a robust dataset that is both rich in qualitative detail and informed by the broader academic and professional context.

4.3. Data Analysis

4.3.1. Thematic Analysis

Thematic analysis was the core method used to analyze both the literature and the qualitative data gathered from the interviews. This method involves several stages:

1. **Familiarization with the Data**: The process began with a thorough review of existing literature to identify recurring themes and patterns related to the barriers and drivers of LIM adoption. Key themes were extracted and used as a foundation for coding and analyzing the interview data. Subsequently, the interview data was transcribed, and the transcripts were closely read to become intimately familiar with the content.

2. **Coding**: After familiarization, the data from both the literature and interviews was systematically coded. Coding involves tagging sections of the data that are relevant to the research questions. For the interview transcripts, each segment of text was highlighted and labeled with codes representing key ideas or concepts, such as "regulatory challenges," "market demand," "innovation barriers," and "collaboration." The themes identified in the literature review served as a basis for these codes, ensuring consistency and alignment between the theoretical background and empirical findings.

3. **Generating Initial Themes**: Once the data was coded, the next step was to identify patterns and group the codes into broader themes. This process involved grouping related codes together to form initial themes that encapsulate the essence of the data. Themes were identified based on their relevance to the research questions and their recurrence across multiple sources.

4. **Defining and Categorizing Themes**: After refining the themes, each one was clearly defined and named. This step involved articulating the essence of each theme and how it relates to the research questions. First the literature themes were identified and then based on those ones, new interview themes have emerged. The initial literature themes were also categorized depending on barriers/drivers' part into 8 and 7 categories considering the themes similarities.

5. **Reviewing and Refining Themes**: The initial themes underwent a thorough review and refinement process. This involved cross-checking the themes derived from the literature with the interview data and the entire dataset. Themes that were either too broad or too narrow were redefined, merged, or divided to ensure they accurately captured the nuances present in the data. Following this refinement, each theme was assigned a distinct classification based on its origin: green themes emerged solely from literature, blue themes were supported by both literature and interview data, and red themes were unique to the interviews. For example, themes such as "Inadequate Technological Infrastructure," "Measurement Uncertainty," and "Greenwashing" illustrate the diversity of insights. The

rationale behind the selection, elimination, and filtering of themes is visually represented in the figure below.

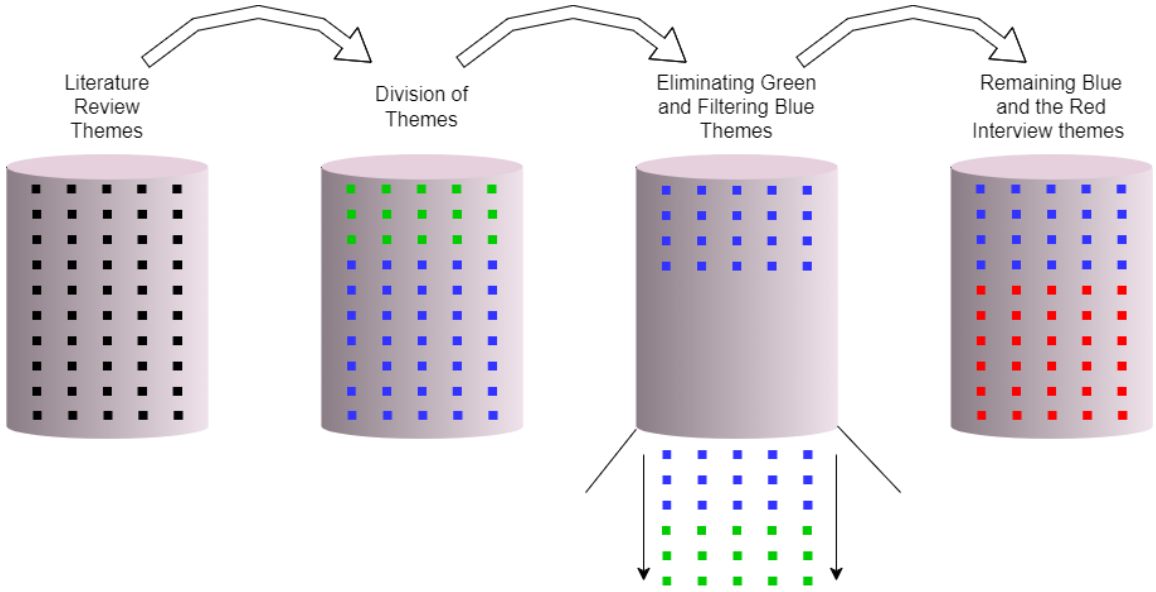

Figure 6 – Steps of Reviewing and Refinement of the Themes

6. **Categorizing the Two Main Directions**: The final set of themes was then systematically categorized into two overarching directions: "Understanding Low Impact Materials" and "Accelerating the Adoption of Low Impact Materials." These categories reflect the dual focus of the research, encapsulating the core areas necessary for driving the adoption of sustainable practices within the Dutch construction industry.

7. **Cross-Sector Analysis**: To provide a comprehensive understanding of the dynamics at play, a cross-sector analysis was conducted. Within each direction, the identified drivers were systematically linked to the barriers they address, highlighting the interdependencies between different themes. This approach not only underscores the complexity of LIM adoption but also illustrates the actionable relationships between overcoming barriers and leveraging drivers across various sectors.

8. **In-Depth Analysis of Each Direction**: After the thematic analysis and cross-sector connections were established, the next step involved delving deeper into each of the two main directions. This in-depth analysis aimed to thoroughly examine the data within each category, enabling a more nuanced understanding of the specific barriers and drivers at play. For "Understanding Low Impact Materials," the analysis focused on the critical information necessary for informed decision-making. In the "Accelerating the Adoption of Low Impact Materials" direction, the analysis centered on the human factors, such as stakeholder interactions, collaboration, and market dynamics. This detailed approach allowed for a comprehensive understanding of the data, ensuring that the conclusions drawn were well-founded and reflective of the multifaceted nature of LIM adoption in the Dutch construction industry.

5. Barriers and Drivers

This part of the study delves into the barriers that impede the selection of low-impact materials during the critical design phase of such buildings and the drivers that promote their adoption. Understanding these barriers and drivers is crucial as the material choices made at this stage have long-lasting impacts on the carbon footprint and sustainability of the built environment. By identifying and analyzing these factors, the research aims to provide insights that can help steer the industry toward more sustainable practices in alignment with the Netherlands' ambitious environmental goals. This chapter's exploration of these barriers and drivers not only highlights the current limitations within the Dutch construction sector but also illuminates the potential pathways to overcoming these challenges and leveraging opportunities.

5.1. Literature Review Barriers

During the literature review for this thesis, several recurring themes emerged in the papers analyzed. These themes, which reflect various challenges and barriers in the field of sustainable construction, were systematically categorized into seven distinct categories. Each category encapsulates specific aspects and thematic elements identified in the literature. In the following section, these themes are discussed in detail, organized by their respective categories and supported by references from key studies where these themes were initially identified. Most of these themes are mentioned across multiple papers, highlighting their pervasive nature in the discourse on sustainable construction. In the table below, the seven categories and the assigned themes can be seen as well as the references and the frequency of references for each category.

Table 2 - Literature Review Barrier Themes Overview

Category	Themes	References	Frequency
Category 1: Economic and Financial Barriers	- High Initial Investment Costs - Long-term Financial Benefits vs. Short-term Costs - Economic Uncertainties and Risk Perception - Organizational and Procedural Costs - High Implementation Costs (BIM)	Munaro and Tavares (2023); Häkkinen and Belloni (2011); Williams and Dair (2006); Chan et al. (2022); Bügl et al. (2009); Ohene et al. (2023); Sahlol et al. (2021); Rissman et al. (2020); V. S. Reddy (2016); Obrecht et al. (2020); Roberts et al. (2020); Chan et al. (2017); Zuo and Zhao (2014)	13
Category 2: Skills and Knowledge Deficiencies	- Skills Gap in the Industry - Educational and Training Barriers - Lack of Continuous Professional Development - Organizational Resistance to Training - Lack of Awareness and Understanding (Stakeholders) - Lack of Awareness and Understanding (BIM)	Williams and Dair (2006); Giorgi et al. (2022); Khalifa et al. (2022); Ohene et al. (2023); Xia et al. (2018); Häkkinen and Belloni (2011); Obrecht et al. (2020); Roberts et al. (2020)	8
Category 3: Regulatory, Compliance and Supply Challenges	- Complexity and Inconsistency in Regulations - Bureaucratic Challenges - Strict and Rigid Regulations - Insufficient Incentives and Support	Giorgi et al. (2022); Munaro and Tavares (2023); Williams and Dair (2006); Bosma et al. (2019); Bügl et al. (2009); Ohene et al. (2023); Xia et al. (2018); Chan et al.	10

		(2022); Bolden et al. (2013); Häkkinen and Belloni (2011)	
Category 4: Quality and Performance Uncertainties	- Uncertainty in New Technologies - Reliability of Assessment Tools - Concerns with Recycled Materials - Variability in Material Quality and Standardization Concerns	Giorgi et al. (2022); Häkkinen and Belloni (2011); Williams and Dair (2006); Sahlol et al. (2021); Bolden et al. (2013); Chan et al. (2022); Munaro and Tavares (2023); Iavicoli et al. (2014)	8
Category 5: Data and Information Gaps	- Inconsistencies in Data Collection and Reporting - Lack of Comprehensive Databases - Measurement Uncertainty - Limited Integration of Data in Decision-Making	Giorgi et al. (2022); Khalifa et al. (2022); Bügl et al. (2009); Williams and Dair (2006); Obrecht et al. (2020); Roberts et al. (2020); Munaro and Tavares (2023)	7
Category 6: Cultural and Behavioral Barriers	- Resistance to Change - Social Norms and Perceptions - Diverse Stakeholder Interests - Insufficient Engagement Strategies	Giorgi et al. (2022); Khalifa et al. (2022); Zhao et al. (2015); Afzal et al. (2017); Williams and Dair (2006); Ohene et al. (2023); Afzal et al. (2017); Xia et al. (2018)	8
Category 7: Supply Chain of Materials	- Lack of Coordination and Integration (Supply) - Inconsistent Supply and Quality of Materials - Supply Chain Disruptions - Scarcity of Low-Carbon Materials	Giorgi et al. (2022); Munaro and Tavares (2023); Rissman et al. (2020); Berawi et al. (2019); Bolden et al. (2013); Häkkinen and Belloni (2011)	7
Category 8: Technological Barriers	- Inadequate Technological Infrastructure - Limited Access to Advanced Technologies - Slow Technological Advancement - Intricacy of LCA Methodologies - Technical Challenges and Integration Issues (BIM)	Munaro and Tavares (2023); Giorgi et al. (2022); Khalifa et al. (2022); Rissman et al. (2020); Häkkinen and Belloni (2011); Obrecht et al. (2020); Roberts et al. (2020); Sahlol et al. (2021)	8

In subsequent sections, each identified theme within these categories is discussed in depth, underpinned by key references that first highlighted these issues, reflecting the extensive scope of research into barriers to sustainable construction. These explanations set the stage for a detailed exploration of how these barriers manifest in the field in the following sections.

5.1.1. Category 1: Economic and Financial Barriers

A common theme in the literature is the **high initial investment required** for sustainable construction practices. According to Reddy (2016), the upfront costs associated with green buildings, including the use of eco-friendly materials and technologies, are perceived as a significant financial burden. Reddy's analysis underscores that although long-term operational savings and increased property values can offset these initial costs, the immediate financial outlay remains a deterrent for many developers. Similarly, Williams and Dair (2006)'s research identifies that stakeholders often perceive sustainable measures as expensive, and this perception is not always backed by thorough cost-benefit analyses.

Rissman et al. (2020) highlight a critical challenge: the difficulty in reconciling **short-term costs with long-term financial benefits**. They argue that while sustainable buildings offer substantial long-term savings in energy, maintenance, and operational costs, these benefits are often discounted by developers focused on immediate financial returns. This short-termism is a significant barrier to the adoption of sustainable practices.

Economic uncertainties and the perceived risks associated with new technologies also play a role in cost concerns. Ohene et al. (2023) point out that the volatility of material costs and the uncertain return on investment in green technologies contribute to a cautious approach among developers. Sahlol (2020) further elaborates on this issue by emphasizing that sustainable building materials often have a reputation for being expensive, which is not always accurate.

Häkkinen and Belloni (2011) explore the **organizational and procedural difficulties** that accompany the adoption of new sustainable methods. They note that resistance to new technologies often stems from the need for process changes, which entail perceived risks and unforeseen costs. They also discuss the **high costs associated with implementing BIM** as a significant barrier. They note that the initial investment in BIM software, training, and infrastructure can be substantial, particularly for small and medium-sized enterprises.

5.1.2. Category 2: Skills and Knowledge Deficiencies

Williams and Dair (2006) highlight the **widespread lack of skills necessary** for implementing sustainable building practices. They note that many construction professionals are not familiar with sustainable techniques and materials, which leads to a reliance on traditional, less sustainable methods. This skills gap results in a hesitance to adopt new practices. They also identify a fundamental challenge in the **lack of awareness and understanding of sustainable practices** among stakeholders. They argue that many stakeholders, including clients, contractors, and end-users, are not fully informed about the benefits and processes of sustainable building.

Giorgi et al. (2022) discuss the barriers related to **education and training**. They emphasize that the existing educational programs do not sufficiently cover the skills needed for sustainable construction. This inadequacy in formal education means that many professionals enter the workforce without the necessary knowledge to implement sustainable practices effectively. They also highlight a fundamental issue of **lack of awareness and understanding of BIM** among stakeholders. They argue that many construction professionals are not fully aware of the potential benefits of BIM for enhancing sustainability. This knowledge gap results in a reluctance to invest in and adopt BIM technologies.

Xia et al. (2018) explore **organizational resistance to training** and skill development in the context of corporate social responsibility (CSR). They note that many companies view training as a cost rather than an investment, leading to insufficient support for skill development initiatives. This organizational resistance further entrenches the skills gap.

5.1.3. Category 3: Regulatory, Compliance and Supply Challenges

A recurring theme in the literature is the **complexity and inconsistency of regulations**. Giorgi et al. (2022) highlight that in the building sector, the varied and sometimes conflicting regulations across regions can create confusion and additional hurdles for developers. This inconsistency often results in delays and increased costs, making sustainable projects less attractive.

Berawi et al. (2019) emphasize the **bureaucratic challenges** that developers face when trying to implement sustainable practices. They note that navigating through complex bureaucratic procedures can be time-consuming and costly, deterring many developers from pursuing sustainable projects.

Ohene et al. (2023) discuss the **stringent building codes**, which, while necessary for ensuring safety and quality, can sometimes be too rigid, preventing the adoption of innovative sustainable practices. These regulations often do not allow for flexibility in design and construction methods, which can stifle innovation and the implementation of sustainable solutions.

Moreover, Berawi et al. (2019) emphasize the **insufficient incentives and support** for green building practices, highlighting that the regulatory environment does not provide enough financial incentives to encourage adoption. The absence of supportive policies and financial incentives makes it challenging for developers to justify the additional costs.

5.1.4. Category 4: Quality and Performance Uncertainties

A recurring theme in the literature is the **uncertainty in new technologies** in the building sector. Giorgi et al. (2022) emphasize that innovative sustainable technologies often lack long-term performance data, making it difficult for stakeholders to predict their effectiveness and reliability. This lack of data can lead to concerns about durability, maintenance, and overall lifecycle performance, discouraging their use in construction projects.

Häkkinen and Belloni (2011) explore the **reliability of assessment tools** used to evaluate the performance of sustainable building practices. They argue that many of these tools are still in development and may not provide accurate or consistent results. This uncertainty in assessment outcomes can undermine confidence in sustainable practices, making it challenging to convince stakeholders of their benefits.

Bolden et al. (2013) address the **uncertainties associated with the use of recycled materials** in construction. They highlight that while recycled materials can reduce environmental impact, there are concerns about their structural integrity and performance. The potential for contaminants and the lack of standardized testing for recycled materials contribute to these uncertainties, limiting their widespread adoption. They further discuss the challenges related to the **quality and standardization** of low-carbon materials. They note that the inconsistent quality of these materials can deter their use in construction projects. The lack of standardized criteria and certification processes for low-carbon materials further complicates their adoption. Sahlol et al. (2021) further discuss the **variability in the quality of sustainable building materials** as a source of technical performance uncertainty. They point out that inconsistencies in the production and supply of these materials can lead to significant differences in performance. This variability can result in unpredictable outcomes, making it difficult for builders to rely on LIMs for consistent results.

5.1.5. Category 5: Data and Information Gaps

Giorgi et al. (2022) highlight **inconsistencies in data collection and reporting** as major obstacles. They argue that the lack of standardized methods for gathering and reporting data on building materials and processes leads to significant variability in results. This inconsistency makes it difficult for stakeholders to compare and evaluate the environmental performance of different projects and materials.

Khalifa et al. (2022) point out that the absence of **comprehensive databases for LIMs** and practices is a significant barrier. They argue that the lack of accessible, reliable data on the environmental performance of materials and technologies prevents developers from making informed decisions.

Bügl et al. (2009) discuss the issue of **measurement uncertainty** in assessing the environmental impacts of buildings. They highlight that the variability in measurement techniques and the lack of precision in data collection can lead to significant discrepancies in the reported impacts. This uncertainty makes it difficult to establish clear benchmarks and targets.

Ohene et al. (2023) emphasize the **limited integration of environmental data** in decision-making processes. They argue that even when data is available, it is often not used effectively to guide design and construction practices. The lack of tools and frameworks for incorporating data into decision-making processes hinders the adoption of sustainable practices.

5.1.6. Category 6: Cultural and Behavioral Barriers

Giorgi et al. (2022) identify **resistance to change** as a major cultural barrier. They argue that many stakeholders in the construction industry are accustomed to traditional building practices and are resistant to adopting new, sustainable methods. This resistance is often rooted in a preference for familiar techniques and a skepticism towards new technologies.

Zhao et al. (2015) explore how **social norms and perceptions** influence sustainable building adoption. They note that societal expectations and peer behaviors can significantly impact individual and organizational decisions. In many cases, there is a perception that sustainable building is more expensive or less reliable, which can deter stakeholders from considering it. Addressing these perceptions through positive reinforcement and showcasing successful sustainable projects can help shift social norms in favor of sustainability.

Afzal et al. (2017) discuss the challenge of balancing **diverse stakeholder interests** in sustainable building projects. They argue that different stakeholders often have varying priorities and levels of interest in sustainability, which can lead to conflicts and compromises that dilute the sustainability outcomes. For instance, financial stakeholders may prioritize cost savings over environmental benefits, while community stakeholders might focus on social impacts.

The literature also highlights the need for more **effective engagement strategies**. Williams and Dair (2006) argue that current engagement practices are often insufficient and do not adequately involve all relevant stakeholders in the decision-making process. They suggest that more inclusive and participatory approaches are needed to ensure that stakeholder voices are heard and considered throughout the project lifecycle.

5.1.7. Category 7: Supply Chain of Materials

Munaro and Tavares (2023) discuss **the lack of coordination and integration within the supply chain** as a primary challenge. They argue that the construction supply chain is often fragmented, with various stakeholders operating independently rather than collaboratively. This fragmentation leads to inefficiencies, increased costs, and difficulties in ensuring the consistent supply of Low Impact Materials. They emphasize that sustainable building projects require close collaboration between suppliers, manufacturers, contractors, and clients.

Chan et al. (2022) explore how **supply chain fragmentation affects the consistency and quality of sustainable building materials**. They note that fragmented supply chains can lead to variability in the availability and quality of materials, making it challenging for builders to source reliable and high-quality LIMs consistently. This inconsistency can deter stakeholders from committing to sustainable practices, as it introduces uncertainty and risk into the project planning and execution phases.

Ohene et al. (2023) add that **supply chain disruptions**, such as those caused by global events or economic fluctuations, can severely impact the availability of low-carbon materials. They argue that the reliance on a limited number of suppliers increases the vulnerability of the supply chain, making it prone to disruptions that can stall sustainable building projects.

A recurring theme in the literature is also the **scarcity of low-carbon materials**. Munaro and Tavares (2023) emphasize the scarcity of low-carbon materials, noting that while demand is growing, the supply remains limited. This scarcity is particularly pronounced for biobased materials, which are often produced in smaller quantities and have not yet reached large-scale production levels. Williams and Dair (2006) discuss the limited availability of Low Impact Materials, particularly recycled materials. They note that the supply of high-quality recycled materials is often geographically restricted, posing logistical challenges and increasing transportation costs.

5.1.8. Category 8: Technological Barriers

Munaro and Tavares (2023) emphasize that the **lack of advanced technological infrastructure** in many regions is a major barrier to sustainable building. They argue that without the necessary tools and technologies, it is challenging for construction projects to incorporate sustainable practices effectively. Giorgi et al. (2022) discuss the **limited access to advanced technologies** as a significant obstacle. They note that sustainable building often requires specialized technologies that are not widely available or affordable.

Khalifa et al. (2022) highlight the **slow pace of technological advancement** as a critical issue. They point out that the construction industry tends to lag behind other sectors in terms of technological innovation. This slow advancement means that many sustainable building technologies are still in their infancy and not yet ready for widespread adoption.

Sahlol et al. (2021) discuss the **inherent complexity of LCA methodologies**, which require detailed data collection and analysis across all stages of a building's life cycle. This complexity can lead to reluctance in adopting LCA practices due to the perceived difficulty and resource requirements.

Obrecht et al. (2020) explore the **technical challenges and integration issues** that hinder the adoption of BIM. They emphasize that integrating BIM with existing workflows and systems can be complex and time-consuming. Additionally, the lack of standardized protocols and interoperability between different BIM software platforms can create further obstacles.

5.2. Interview Barriers

5.2.1. Red/New Barriers

From the interviews new barrier themes have emerged during the discussions with actors. In the table below the themes can be seen as well as quotes related to these themes to show authenticity and the way stakeholders perceive them. These barriers were labelled RED as they are significant

barriers from the field specifically relevant for the practitioners from the Dutch construction industry. These barriers will be categorized into the eight categories later in the process.

Table 3 - Interview Red Barrier Themes

Nr.	Theme	Quote
1	Cost as a Convenient Excuse	"The initial investment for Low Impact Materials is often cited as a major barrier, but in many cases, it's just an excuse to avoid changing established practices." (P12).
2	Reluctance to Pay Upfront Costs	"Clients are reluctant to pay higher initial costs despite potential long-term savings" (P09).
3	Dependency on Government Regulations	"If the government made something mandatory then we just need to comply. So that is easy" (P03). It seemed that couple of opinions of practitioners especially from the clients and contractors' side was that until government makes a move, they will not make a change. The feeling is the same from the consultant's side who are waiting for a push from the governmental side to force the other actors to be more sustainable.
4	Slow Government Action	"Many times the government has goals, but it takes a lot of time to achieve those goals and to get started with what to complete those goals" (P05).
5	Clear Framework from Government	Many practitioners mentioned the lack of a clear view and framework on how to achieve net zero and fully circular goals from the government.
6	Lack of Private Sector Engagement	"The private parties do not join us as often and in as such numbers as we would like to" (P18). This view is from the governmental practitioners who feel the private side does not want to get involved with helping to make the regulations better.
7	Lack of Practical Experience	"We had a project where we did use a new type of wall…we had a lot of resistance because the contractor didn't know how to build those walls" (P01).
8	Limited Access to Training Resources for SME	"Access to training resources and programs is limited, especially for small and medium-sized enterprises" (P12). This closely relates to the skill gap issue of the industry depending on the projects.
9	Fire Hazards and Strength Requirements	"For example, you can say that wooden construction is one of the best options at the moment as opposed to a full block of concrete, but then you have fire safety concerns" (P09). "There's a lot of fear in the market and internally about whether new materials meet regulations and strength requirements" (P17).
10	Lack of Perceived Advantages	"People do not see the direct incentive of those materials. At this moment you only see the problems" (P14).
11	Fear of Experimentation and/or Disqualification from Tenders	Practitioners fear that experimenting with these materials could disqualify them from tenders, especially when competing with companies using traditional materials.
12	Maintenance of Low Impact Materials	"Who will come to take a certain material and recycle it? Does the supplier provide this or the maintenance? Who knows?" (P01).
13	Need for Research on Real Projects and for Pilot Projects	"There is a need for more research on how to implement sustainable technologies not just on prototypes but on real projects" (P07).
14	Greenwashing	"Many materials claim they are sustainable or eco-friendly, but there's no proof to it" (P10). General sentiment about the need for more

		transparency especially with the integration of the materials into the MPG to avoid greenwashing which is existent at the moment.
15	Limiting Supplier Options	"In an early design phase, you commit yourself to a certain supplier, which can limit options later" (P06).
16	Vendor Influence on Material Choice	Suppliers have significant influence over material choices, which can limit the adoption of Low Impact Materials. There is a significant number of suppliers with a lot of influence that are leaning towards pushing for the more traditional materials according to more types of practitioners
17	Fear of Unproven Methods	"There is a fear of unproven methods because people worry about the performance and long-term effects of new materials" (P15).
18	Behavioral Inertia	The general sentiment is that people tend to stick to familiar methods and materials due to comfort and routine, even if new methods are more sustainable.
19	Logistical Challenges	"For the reuse of existing materials, logistics is a challenge because you don't want to create some sort of storage problem." (P18)
20	Certification and Verification for Materials	"The lack of standardized criteria and certification processes for low-carbon materials further complicates their adoption" (P11)

5.2.2. Green/Eliminated Barriers

During the analysis of barriers to the market acceptance of low-impact materials in the Dutch construction industry, it became evident that certain themes identified in the literature were not perceived as significant by the practitioners interviewed. This chapter explores these themes, providing explanations for their lack of relevance in the Dutch context. The insights are drawn from interviews and reflect the unique characteristics of the Dutch construction industry. However, a brief discussion is included for those that may be overlooked by the practitioners and suggestions are done starting from the discussion with the actors.

The theme of **organizational and procedural costs** was not highlighted as a significant barrier. This may be attributed to the efficient organizational structures and streamlined processes within Dutch construction firms, which mitigate the impact of procedural costs. As anticipated, **organizational resistance to training** also proved to be a non-issue, as practitioners showed a strong willingness to learn and advance their knowledge of sustainable practices, reflecting the progressive mindset of Dutch construction firms. Similarly, **educational and training barriers** were not considered significant, suggesting that the Dutch construction sector has effectively integrated sustainability into its educational and training programs, ensuring that professionals are well-prepared. This is further supported by the influx of new personnel over the past 3 to 5 years, who come equipped with a strong background and mindset towards sustainability from universities. In the same way, Lack of Continuous Professional Development was not a significant issue for larger companies, which regularly hold meetings and training workshops to update personnel on sustainability practices.

Concerns about **inadequate technological infrastructure** and **limited access to advanced technologies** were not significant, given the Dutch construction firms' readiness and access to cutting-edge technologies. The industry's dynamic and innovative nature ensures that **technological advancement is not slow**, supported by continuous investments in research and development. Although all of the above seven these themes did not pose serious problems for the

practitioners within the scope of this research, they might still be challenging for less prepared SMEs, as highlighted by one practitioner working on such projects.

Coordination and integration within the supply chain, often a problem elsewhere, did not emerge as a significant barrier in the Dutch context. This is due to the strong connections companies maintain with numerous suppliers, who are integrated into the process. The supply chain issues were found in other parts of the process. **Limited integration of data in decision-making** was not seen as a barrier, indicating that Dutch practitioners effectively use available data to inform their decisions. The primary concern for practitioners regarding decision-making was the lack of sufficient data about materials in most cases.

All themes related to **Building Information Modeling (BIM)** did not present significant challenges in terms of awareness, implementation costs, or technical issues. BIM usage is widespread in the Netherlands, with practitioners at most levels familiar with its application and benefits. The technological infrastructure in the Netherlands supports this widespread adoption, mitigating any potential limitations. The only suggestion in this field was to adopt more BIM in the later stages of projects to enhance the efficiency of the final construction phases, the maintenance and disassembly of buildings.

The intricacy of **Life Cycle Assessment (LCA) methodologies** and the associated **technical expertise and resource requirements** were also not seen as barriers. The Dutch construction industry is well-prepared for conducting LCA, supported by comprehensive training programs and a strong emphasis on professional development. The main issue was the lack of proper data for conducting thorough LCAs for certain materials, given the misleading claims from the market and the unpredictable nature of some materials, particularly recycled and circular materials.

Main takeaways

1. SME challenges
2. Improvement of Supply Chain
3. More Data for Decision-Making
4. Expansion of BIM Usage
5. Better Verification and Standardization of Data for LCA

5.2.3. Remaining Barrier Themes (Blue + Red)

Given the high number of themes, the similarity between some of the blue and red ones, and the desire to focus only on the most relevant and novel themes for this research, a filtering process will be applied to the remaining blue barriers. These blue barriers represent themes that were discussed in both literature and interviews. Some themes were more extensively debated or were more polarizing, while others were straightforward and easily recognizable. The following discussion explains the rationale behind keeping or eliminating each blue barrier. At the end of this section, a table is provided with all the categories, including both blue and red-themed barriers.

Category 1: Economic and Financial Barriers

For this first category, two of the blue themes relate to the initial cost of low-impact materials: **High Initial Investment Costs** and **Long-term Financial Benefits vs. Short-term Costs**. Practitioners extensively discussed their concerns about the large upfront payments required at the beginning of projects. Although both themes are relevant, they are well encapsulated by the red theme **Reluctance to Pay Upfront Costs**, which succinctly summarizes the issue.

Economic Uncertainties and Risk Perception is a more volatile theme, reflecting practitioners' concerns about the fluctuating prices of low-impact materials and navigating misleading claims. Given its close ties to other barrier categories, this theme will be retained.

The other remaining theme in this category, **Cost as a Convenient Excuse**, was frequently noted during interviews cost was the primary barrier cited by practitioners. This is not a critique of the practitioners, as the concern about higher costs is legitimate. However, it seems this ingrained belief might prevent some companies from exploring beyond their current practices.

Category 2: Skills and Knowledge Deficiencies

For this category, the only theme being eliminated is **Skills Gap in the Industry**, which is better described by the two red themes **Lack of Practical Experience** and **Limited Access to Training Resources for SMEs**. The skill gap is primarily observed in terms of practical experience with low-impact materials and the discrepancy between larger companies and smaller ones with limited access to training resources, often due to financial constraints.

As one practitioner mentioned, the demand for skilled personnel exceeds the supply for smaller projects. Smaller projects, often involving individual consumers, may not have the budget for larger companies, or these companies may not be interested in small to medium-sized projects. Over time, this could lead to an unbalanced market as regulations become stricter regarding permissible materials. This can be triggered as well by the **Lack of Continuous Professional Development**, which is not really a problem for the large companies, however it can become a barrier on the long term for SMEs. However, is very unclear if that is really a general problem or just a specific one, so it will not be retained

Lack of Awareness and Understanding is generally not an issue for most actors, though some consultants and contractors emphasized a lack of awareness among some clients. Therefore, this theme will be retained.

Category 3: Regulatory and Compliance Challenges

For this category, three of the blue barriers are interconnected: **Complexity and Inconsistency in Regulations**, **Bureaucratic Challenges**, and **Strict and Rigid Regulations**. These themes were discussed primarily by the private sector, with each company voicing specific complaints about regulatory issues. Consultants are waiting for the government to keep pace with market changes and push for more regulations to foster innovation. Some contractors and clients are waiting for the government to make the first move, showing a lack of initiative. These issues are well encapsulated by the red theme **Dependency on Government Regulations**, as everyone in the Netherlands is largely dependent on governmental action.

Clear Framework from Government also highlights the industry's anticipation for governmental leadership and direction. On the other hand, the government cites a **Lack of Private Sector Engagement**, noting a deficiency of common forums for discussion between the private and public sectors.

The remaining blue theme, **Insufficient Incentives and Support**, is quite polarizing among various actors, irrespective of their market position. Opinions vary widely: some are in favor of incentives, some against, some see them as a necessary evil, and others view them as a long-term problem.

Government representatives feel they are providing sufficient incentives. Due to its importance and the extent of debate around it, this barrier will be retained.

The final red theme in this category, **Slow Government Action**, captures the slow pace of regulatory change and is related to concerns about the slow progress of public projects and pilot initiatives. Practitioners have complained that government projects move too slowly and fail to set a proper example.

Category 4: Quality and Performance Uncertainties

For this category, all the blue themes are relevant, but **Uncertainty in New Technologies** is broad and vague, as most other blue and red themes in this category relate to it. Therefore, it will be eliminated, and the other themes will be kept. **Reliability of Assessment Tools** is particularly important for consultants, who are unsure if the current methods for assessing low-impact materials, including the national MPG, are adequate.

Variability in Material Quality and Standardization Concerns was frequently mentioned by consultants, who strongly advocate for standardization. **Concerns with Recycled Materials** will be assimilated into this theme, as most concerns about material quality variability were specifically directed at recycled and circular materials.

The red themes **Fire Hazards and Strength Requirements**, **Lack of Perceived Advantages**, and **Maintenance of Low Impact Materials** are all highly relevant in the Dutch context and are components of the overall barrier theme of uncertainty in new technologies.

Category 5: Data and Information Gaps

For this category, **Inconsistencies in Data Collection and Reporting** is a broad term encompassing the smaller themes, so it will be eliminated, and the other themes will be kept. **Lack of Comprehensive Databases** was highlighted by consultants working directly with LCA and MPG. The issue is that many materials are not integrated into the MPG, and changes are needed. This is strongly related to the red theme **Certification and Verification for Materials**, which calls for more control over materials through various certifications such as material passports. **Measurement Uncertainty** is also strongly related to the other themes. Consultants emphasized the difficulty in assessing materials long-term and establishing clear targets for buildings using these new materials. **Need for Research on Real Projects and for Pilot Projects** was requested by most stakeholders, particularly for public projects, to serve as examples, but also by major private developers.

Category 6: Cultural and Behavioral Barriers

For this category, **Resistance to Change** is a broad theme encompassing all the other themes, so it will be eliminated. **Social Norms and Perceptions** was not widely discussed, but during some interviews, it was evident that the Dutch background of building with bricks creates reluctance to switch to wood. Practitioners are not used to working with wood, which also brings problems like higher noise thresholds in the Netherlands compared to countries like Sweden. This reluctance extends to other materials and themes such as fear of experimentation, fear of unproven methods, and behavioral inertia, especially among smaller companies that prefer familiar methods.

Fear of Unproven Methods, **Behavioral Inertia**, **Fear of Experimentation and/or Disqualification from Tenders** are all red themes that are sides of the Resistance to Change overall theme.

Altogether they are fears from the market and a desire from certain companies to continue the way they are handling the problems now.

Diverse Stakeholder Interests is an encompassing theme incorporating various stakeholder preferences, such as prioritizing aesthetics over efficiency or sustainability, focusing on process efficiency rather than material efficiency, or catering to niche clients who prefer certain types of materials, making it difficult to switch to low-impact materials.

Insufficient Engagement Strategies is closely related to the **Lack of Private Sector Engagement** from Category 3. There is often a strong disconnect between the private and public sectors regarding exchanging opinions. This theme also relates to the lack of early integration of contractors and suppliers, which could facilitate the process of incorporating low-impact materials. This issue was regularly highlighted by consultants and government officials.

Category 7: Supply Chain of Materials

In this category, the blue barriers are all interlinked, with **Inconsistent Supply and Quality of Materials** being the more encompassing one; however, it does not exclude the relevance of the other themes and the red ones, so it will be eliminated.

Supply Chain Disruptions was not a major issue for practitioners, except during COVID and the beginning of the war in Ukraine, where disruptions were significant at certain points. This led to a reliance on materials in high supply, which are mostly traditional ones. Despite being a background theme, it should be considered.

Scarcity of Low Carbon Materials is primarily related to recycled and circular materials, which do not meet the high demand. This is closely tied to **Logistical Challenges**—practitioners noted that the supply of recycled materials is unstable, and there is a need for storage facilities before installation. Additionally, procuring these materials from distant locations compared to traditional ones poses logistical problems.

Limiting Supplier Options is strongly connected to **Insufficient Engagement Strategies**. Some practitioners complained about being tied to a certain supplier early in the process, limiting their material options. Conversely, some suggested that involving suppliers earlier could help with low-impact material selection, leading to **Vendor Influence on Material Choice**. Certain suppliers have a vested interest in continuing to sell traditional materials and push for them, even when substitutes are available.

Finally, **Greenwashing** was a significant issue highlighted by many actors regarding low-impact materials. They noted that many materials are entered into the MPG with incorrect values and misleading claims, leading to consumer skepticism among the actors.

Category 8: Technological Limitations

After a thorough analysis and elimination process, Category 8: Technological Limitations was found to be redundant. The themes were recognized as not being significant barriers in the Dutch context and being labelled Green, as the construction industry in the Netherlands generally has access to advanced technology and robust infrastructure.

Furthermore, no red themes were identified for this category, indicating that there were no critical technological barriers emerging from the interviews that were not already addressed by other

categories. Additionally, no blue themes remained after the elimination of the green ones, reinforcing the conclusion that technological limitations are not a primary concern.

Final Barrier Themes Overview

Below, in Table 4, the final themes that represent problems for the Dutch Construction Industry regarding the adoption of LIMs can be seen. These will be further analyzed after the driver's chapter and the identification of themes from that chapter. For a complete overview scheme from beginning to end of the barrier themes, check Appendix 1: Complete Overview Scheme Barrier Themes.

Table 4 - Final Barrier Themes

Category	Themes
Category 1: Economic and Financial Barriers	Economic Uncertainties and Risk Perception
	Cost as a Convenient Excuse
	Reluctance to Pay Upfront Costs
Category 2: Skills and Knowledge Deficiencies	Lack of Awareness and Understanding (Stakeholders)
	Limited Access to Training Resources for SME
	Lack of Practical Experience
Category 3: Regulatory and Compliance Challenges	Insufficient Incentives and Support
	Dependency on Government Regulations
	Slow Government Action
	Clear Framework from Government
	Lack of Private Sector Engagement
Category 4: Quality and Performance Uncertainties	Variability in Material Quality and Standardization Concerns
	Reliability of Assessment Tools
	Maintenance of Low Impact Materials
	Lack of Perceived Advantages
	Fire Hazards and Strength Requirements
Category 5: Data and Information Gaps	Lack of Comprehensive Databases
	Measurement Uncertainty
	Certification and Verification for Materials
	Need for Research on Real Projects and for Pilot Projects
Category 6: Cultural and Behavioral Barriers	Social Norms and Perceptions
	Diverse Stakeholder Interests
	Insufficient Engagement Strategies
	Fear of Unproven Methods
	Behavioral Inertia
	Fear of Experimentation and/or Disqualification from Tenders
Category 7: Supply Chain of Materials	Supply Chain Disruptions
	Scarcity of Low-Carbon Materials
	Greenwashing
	Limiting Supplier Options
	Vendor Influence on Material Choice
	Logistical Challenges

5.3. Literature Review Drivers

The process of the drivers from now onwards is really similar to the one of the barriers. It follows the same logic and flow of things. First, the themes were identified from the articles of literature that were read and analyzed. These themes, which reflect various enablers and counterreaction to the barriers were categorized in seven distinct categories. Each category encapsulates specific aspects and thematic elements identified in the literature. In the following section, these themes are discussed in detail, organized by their respective categories and supported by references from key studies where these themes were initially identified. In the table below, the seven categories and the assigned themes can be seen as well as the references and the frequency of references for each category.

Table 5 - Literature Review Driver Themes Overview

Category	Themes	References	Frequency
Category 1: Regulatory, Policy and Standards	- Regulatory Standards and Compliance - Encouraging Market Transformation - Regional and International Policies - Establishing Global Benchmarks	Munaro and Tavares (2023); Häkkinen and Belloni (2011); Giorgi et al. (2022); Berawi et al. (2019); Bügl et al. (2009); Ohene et al. (2023); Lakys et al. (2022); Sahlol et al. (2021); Rissman et al. (2020); Afzal et al. (2017); Xia et al. (2018); Chan et al. (2022)	12
Category 2: Technological and Digital Innovation	- Development of High-Performance, Low-Carbon Materials - Integration of Smart Technologies - Enhancements in Lifecycle Assessment (LCA) - Enhanced Design and Planning (BIM) - Improved Collaboration and Efficient Project Management (BIM)	Munaro and Tavares (2023); Giorgi et al. (2022); Khalifa et al. (2022); Zhao et al. (2015); Ohene et al. (2023); Lakys et al. (2022); Rissman et al. (2020); Afzal et al. (2017); Bolden et al. (2013); Obrecht et al. (2020)	10
Category 3: Financial and Economic Drivers	- Reducing Financial Barriers Through Subsidies and Grants - Encouraging Investment in Sustainable Technologies with Financial Incentives - Long-Term Financial Savings	Häkkinen and Belloni (2011); Khalifa et al. (2022); Ohene et al. (2023); Rissman et al. (2020); Chan et al. (2022); Munaro and Tavares (2023); A. P. C. Chan et al. (2017); Lakys et al. (2022); V. S. Reddy (2016); Gharehbaghi and Georgy (2019)	10
Category 4: Stakeholder Engagement and Public Sector Leadership	- Leading by Example (Public Sector Leadership) - Collaborative Approaches - Addressing Stakeholder Concerns	Afzal et al. (2017); Giorgi et al. (2022); Rissman et al. (2020); Munaro and Tavares (2023); Khalifa et al. (2022); Xia et al. (2018); Bügl et al. (2009); Zhao et al. (2015); Ohene et al. (2023); Lakys et al. (2022)	10
Category 5: Market Demand and Corporate Responsibility	- Consumer Preferences and Market Demand - Corporate and Institutional Demand - Enhancing Corporate Reputation (CSR) - Driving Innovation and Sustainable Practices (CSR)	Häkkinen and Belloni (2011); Bügl et al. (2009); Sahlol et al. (2021); Xia et al. (2018); Bolden et al. (2013); Afzal et al. (2017); Obrecht et al. (2020); V. S. Reddy (2016)	8

Category 6: Educational Programs and Climate Awareness	- Supporting Continuous Professional Development - Facilitating Industry Collaboration - Educational and Awareness Campaigns	Zhao et al. (2015); Ohene et al. (2023); Lakys et al. (2022); Chan et al. (2022); Bolden et al. (2013); Häkkinen and Belloni (2011); Gharehbaghi and Georgy (2019)	7
Category 7: Supply Chain Management	- Reliable Supply Chain Infrastructure - Improved Material Selection Processes - Global and Regional Supply Chain Integration	Chan et al. (2022); Gharehbaghi and Georgy (2019); Reddy (2016); Munaro and Tavares (2023); Obrecht et al. (2020)	5

In subsequent sections, each identified theme within these categories is discussed in depth, underpinned by key references that first highlighted these issues, reflecting the extensive scope of research into drivers to sustainable construction. These explanations set the stage for a detailed exploration of how these drivers manifest in the field in the following sections.

5.3.1. Category 1: Regulatory, Policy and Standards

Häkkinen and Belloni (2011) discuss the impact of **stringent regulatory standards** on driving sustainable building practices. They argue that regulations mandating energy efficiency, waste reduction, and the use of LIMs compel developers to adopt greener practices. Compliance with these standards not only ensures environmental protection but also encourages innovation in building technologies and materials.

Giorgi et al. (2022) discuss how environmental regulations and policies can **stimulate market transformation**. They highlight that by setting higher standards for environmental performance, regulations can create a market demand for Low Impact Materials and technologies. This demand, in turn, encourages manufacturers and suppliers to innovate and develop more sustainable products.

Rissman et al. (2020) discuss the impact of **regional and international policies** on promoting sustainable building practices. They note that international agreements can set ambitious targets for carbon reduction and energy efficiency. These policies often serve as benchmarks for national regulations, thereby driving the global adoption of sustainable practices. Ohene et al. (2023) further explore how regional policies, such as those in the European Union, can drive sustainability. They highlight that stringent environmental regulations at the regional level can compel member states to adopt similar standards.

Giorgi et al. (2022) emphasize the importance of international standards in **establishing global benchmarks** for sustainable building practices. They argue that standards such as ISO 14001 for environmental management systems and BREEAM, LEED, and WELL certifications for green buildings provide clear guidelines and criteria that promote sustainability.

5.3.2. Technological and Digital Innovation

Munaro and Tavares (2023) highlight the **development of high-performance, low-carbon materials** such as bio-based materials, advanced composites, and recycled products, which significantly reduce the environmental impact of construction. Innovations in biodegradable and bio-based materials, as discussed by Giorgi et al. (2022), contribute to a circular economy by

naturally decomposing and reducing waste and pollution. Similarly, advancements in recycling technologies, highlighted by Bolden et al. (2013), enable the repurposing of waste materials into valuable construction products, conserving natural resources and decreasing environmental impact.

Giorgi et al. (2022) discuss the **integration of smart technologies** as a major driver of sustainability in the construction industry. They point out that technologies such as the Internet of Things (IoT), Building Information Modeling (BIM), and smart sensors can enhance the efficiency and sustainability of building operations. These technologies enable real-time monitoring and management of energy use, water consumption, and indoor environmental quality, leading to more sustainable building performance.

Lakys et al. (2022) highlight the **advancements in Lifecycle Assessment (LCA)** tools and methodologies. They note that technological innovations have made LCA more accessible and accurate, allowing for comprehensive assessments of the environmental impacts of building materials and processes. These advancements help stakeholders make better-informed decisions that align with sustainability goals.

Munaro and Tavares (2023) emphasize **the role of BIM in enhancing design and planning processes**. They argue that BIM allows for detailed and accurate modeling of building components, enabling better visualization and analysis of sustainability aspects. By integrating various data sources, BIM helps in optimizing material use from the early stages of design.

Giorgi et al. (2022) discuss how **digital tools facilitate improved collaboration and communication among project stakeholders**. They highlight that BIM and other digital platforms enable real-time sharing of information and collaborative decision-making. This enhanced communication ensures that all stakeholders are aligned with the sustainability goals of the project, leading to more coordinated and effective implementation of green building practices. Khalifa et al. (2022) explore the impact of digital tools on project management efficiency. They note that BIM and other digital tools provide project managers with comprehensive tools for scheduling, cost estimation, and resource management. These tools help in identifying potential issues early and implementing sustainable solutions more efficiently.

5.3.3. Category 3: Financial and Economic Drivers

Häkkinen and Belloni (2011) emphasize the importance of financial incentives in reducing the financial barriers associated with sustainable building. They argue that **subsidies and grants** can offset the higher initial costs of sustainable technologies and materials, making them more accessible to developers and builders. This economic support is essential in encouraging the adoption of sustainable practices, especially in the early stages of project development.

Khalifa et al. (2022) discuss how financial incentives can **encourage investment** in sustainable technologies. They highlight that tax incentives, low-interest loans, and direct subsidies can significantly reduce the financial risks for investors. By lowering the cost of capital, these incentives make it more attractive for companies to invest in sustainable technologies and practices, thus promoting their adoption on a larger scale.

Lakys et al. (2022) emphasize the **long-term financial savings** associated with sustainable building practices. They argue that while the initial costs of implementing green technologies and materials can be high, the operational and maintenance savings over the building's lifespan can be substantial. These savings come from reduced energy consumption, lower maintenance costs, and increased efficiency, making sustainable buildings economically advantageous in the long run. These are advantages are further sustained by the articles of Reddy (2016) and Chan et al. (2022).

5.3.4. Category 4: Stakeholder Engagement and Public Sector Leadership

Giorgi et al. (2022) discuss **how the public sector can lead by example** in the adoption of sustainable building practices. They highlight that government-funded projects and public buildings can serve as models of sustainability. When governments prioritize green building practices in their own projects, it demonstrates the feasibility and benefits of such practices, encouraging private sector adoption.

Munaro and Tavares (2023) emphasize the importance of **collaborative approaches in stakeholder engagement**. They argue that involving all relevant stakeholders in the planning and decision-making processes can lead to more comprehensive and effective sustainable building practices. By fostering collaboration among architects, engineers, contractors, and clients, projects can benefit from diverse perspectives and expertise, which enhances the overall sustainability of the project.

Lakys et al. (2022) explore how **addressing stakeholder concerns** can drive engagement in sustainable building projects. They note that understanding and addressing the concerns and priorities of different stakeholders can lead to more successful and accepted sustainable initiatives. This involves actively listening to stakeholder feedback and making necessary adjustments to align the project with their expectations and values.

5.3.5. Category 5: Market Demand and Corporate Responsibility

Häkkinen and Belloni (2011) discuss the **rising consumer preference** for sustainable buildings as a key driver. They argue that as consumers become more environmentally conscious, their demand for green buildings increases. This shift in consumer preferences encourages developers and builders to adopt sustainable practices to meet market demand and remain competitive. The growing awareness of environmental issues among the public is thus a crucial factor in driving sustainability in construction.

Bügl et al. (2009) highlight the **role of corporate and institutional demand** in promoting sustainable building practices. They note that many companies and institutions are adopting sustainability policies and seeking to reduce their environmental footprint. This corporate demand for green buildings drives developers to incorporate sustainable practices into their projects to attract and retain business clients. The emphasis on corporate social responsibility (CSR) further fuels this demand, making sustainability a priority in the corporate sector.

Afzal et al. (2017) emphasize **the role of CSR in enhancing corporate reputation**. They argue that companies that adopt sustainable building practices as part of their CSR strategies are viewed more favorably by stakeholders, including customers, investors, and employees. This positive perception can lead to increased brand loyalty, investment, and competitive advantage.

Companies committed to sustainability are more likely to attract and retain environmentally conscious clients and partners.

Reddy (2016) highlights how **CSR drives innovation and the adoption of sustainable practices** in the construction industry. He argues that companies with strong CSR commitments are more likely to invest in research and development of new technologies and materials that promote sustainability. This focus on innovation leads to the development of more efficient, durable, and environmentally friendly building solutions, which can set industry benchmarks and inspire broader adoption of sustainable practices.

5.3.6. Category 6: Educational Programs and Climate Awareness

Ohene et al. (2023) emphasize **the role of educational and awareness campaigns** in promoting the understanding of climate change and its impact on the construction industry. They highlight that initiatives aimed at educating stakeholders about the importance of sustainability and the benefits of green building practices are crucial. These campaigns help to raise awareness, change attitudes, and encourage the adoption of sustainable solutions across the industry.

Lakys et al. (2022) highlight the **importance of continuous professional development (CPD)** in driving sustainable building practices. They note that the construction industry is constantly evolving, with new sustainable technologies and methods emerging regularly. CPD programs ensure that professionals stay updated with the latest advancements, enabling them to integrate innovative sustainable solutions into their projects effectively.

Chan et al. (2022) explore how **educational programs can facilitate collaboration** within the construction industry. They argue that training sessions and workshops provide platforms for professionals to share knowledge, best practices, and experiences related to sustainable building. This collaboration fosters a community of practice that supports the widespread adoption of sustainability and encourages the sharing of successful strategies and solutions.

5.3.7. Category 7: Supply Chain Management

Munaro and Tavares (2023) emphasize the importance of a **reliable supply chain infrastructure** in promoting sustainable building practices. They argue that an efficient supply chain ensures the consistent availability of LIMs, which is critical for the timely completion of green building projects. A well-coordinated supply chain reduces delays and minimizes the risk of material shortages, thereby supporting the adoption of sustainable practices.

Gharehbaghi and Georgy (2019) discuss the role of **improved material selection processes** in sustainable construction. They highlight that advancements in material science and better supply chain management have made it easier to source high-quality, Low Impact Materials. The availability of materials such as recycled concrete, steel, and bio-based products has been enhanced by improved logistics and procurement strategies, making sustainable construction more feasible and attractive.

Obrecht et al. (2020) explore **the integration of global and regional supply chains** as a driver of sustainable building practices. They argue that integrating supply chains across different regions ensures a steady flow of materials, even in times of local disruptions. This integration enhances the

resilience of the supply chain and ensures the availability of LIMs, thus supporting continuous and sustainable construction efforts.

5.4. Interview Drivers

5.4.1. Green/Eliminated Drivers

During the analysis of drivers promoting the market acceptance of low-impact materials in the Dutch construction industry, certain themes identified in the literature were not perceived as significant by the practitioners interviewed. This chapter explores these themes, explaining their lack of relevance within the Dutch context. The insights are drawn from interviews and reflect the unique characteristics of the Dutch construction industry. However, a brief discussion is included for those drivers that might be overlooked or underutilized by practitioners, along with suggestions for further improvement.

Integration of Smart Technologies was not highlighted as a significant driver by Dutch practitioners. This is because, according to practitioners, the Dutch construction industry is already highly advanced in adopting smart technologies, to enhance efficiency and sustainability in building operations. The integration of these technologies is well-established, and the industry does not see it as a novel or emerging driver but rather as a standard practice that is already embedded in current construction processes.

Improved Collaboration and Efficient Project Management (BIM) was another driver that did not emerge as a significant focus in the interviews. This can be attributed to the widespread use of BIM across the Dutch construction industry, where it is viewed as a fundamental tool for design and planning. Dutch practitioners are generally well-versed in BIM, and its integration into projects is a given, rather than a challenge or a new opportunity for driving sustainability. The only suggestion again as in the barriers part is that maybe BIM can be used for enhancing the later stages of the construction process.

For last two drivers, these themes can be more beneficial for the SMEs, coming again on top of the green barriers mentioned before where the problem of SMEs was prevalent there as well.

Educational and Awareness Campaigns were not considered a primary driver by the practitioners, possibly because of the high level of awareness and education already prevalent in the Dutch construction sector. The industry has been proactive in implementing educational initiatives over the past years, leading to generally well-informed workforce and public. However, additional campaigns are not seen as redundant or unnecessary in the current context, according to some practitioners who emphasized that client education would still be beneficial.

Global and Regional Supply Chain Integration was not seen as a critical driver, which may be due to the already well-integrated supply chains within the European Union. Dutch companies maintain strong connections with suppliers and benefit from a well-coordinated supply chain infrastructure that supports sustainable construction practices. However, the help of having open borders in EU and having a large pallet of suppliers does not exclude further integration.

Main Takeaways

1. Advanced Adoption of Smart Technologies

2. Established BIM Usage
3. High Level of Awareness and Education
4. Strong Supply Chain Integration
5. SME Focus

5.4.3. Red/New Drivers

From the interviews new driver themes have emerged during the discussions with actors. In the table below the themes can be seen as well as quotes related to these themes to show authenticity and the way stakeholders perceive them. These drivers were labelled RED in the same way as in the barriers part as they are significant barriers from the field specifically relevant for the practitioners from the Dutch construction industry. These drivers will be categorized into the seven categories later in the process.

Table 6 - Interview Red Driver Themes

Nr.	Theme	Quote
1	Need for Practical Implementation	"There is a need for more research on how to implement sustainable technologies not just on prototypes but on real projects" (P07).
2	Reliability and Long-Term Performance Data	The practitioners emphasize the necessity for reliable data on the long-term performance of Low Impact Materials to encourage their adoption.
3	Varied Actor Opinions on Financial Incentives	"Incentives are essential for encouraging the initial switch to Low Impact Materials" (P02) & "I don't believe that much in subsidies because I think it's not the right trigger for the long run. But in the short run, it's good to have it" (P08) & "There are quite a lot of subsidies right now and maybe that could be simplified but yeah there's also the risk that people will stop when the money stops." (P14)
4	Employee Engagement and Retention	"Employee, especially younger ones, feel more engaged and loyal to a company that is committed to CSR and sustainability" (P18).
5	Simplifying Processes by Public Sector Leadership	"Efforts to simplify purchasing and contract management can reduce administrative burdens and promote the use of Low Impact Materials" (P17).
6	Supply Chain Collaboration	"Involving the supply chain earlier in the design and planning stages ensures that Low Impact Materials are considered from the outset" (P18).
7	Local Government Initiatives	"Local government incentives are critical in promoting the adoption of sustainable building practices" (P18).
8	Cross-Sector Collaboration	"Collaboration across different sectors, not just within construction, can lead to more innovative and effective sustainable solutions" (P07).
9	Corporate Initiatives on Climate Awareness	"Many companies are now taking the initiative to educate their employees and stakeholders about climate change and sustainability" (P06).
10	Upgrading the Certifications Thresholds	"The lowest tier of certification, for the BREEAM, for example is quite easily achieved. Upping the threshold for the standards for that would lead to people doing more in terms of sustainability" (P13)
11	Client Education	"Trained professionals can effectively educate clients, increasing demand for sustainable solutions" (P13).
12	Increased Property Value	"Properties built with Low Impact Materials often have a higher market value and attract more buyers" (P05).
13	Supplier Diversity	"Promoting supplier diversity by including small and medium-sized enterprises can drive innovation and sustainability in the supply chain" (P11).

14	Streamlining Material Procurement	"The challenge is always the availability of materials. Circular economy is based on a very tight demand and supply thing and the supply is much more important than it is in the linear economy because supply is huge" (P12).
15	More Standardization	"Standardization in general will be a very important factor in that we need to standardize more and more and more and the more we standardized and more make a product instead of a project." (P12)
16	Update of The Evaluation Frameworks (MPG Primarily)	“MPG does cover everything. It's an amazing idea. It's just executed badly but the idea is really good." (P12)
17	Calculate Residual Value of Materials	"It would be very interesting to calculate some kind of residual value of materials that you can reuse at the end of their life. That’s actually never done, but I think that would be very interesting." (P04)

5.4.4. Remaining Driver Themes (Blue + Red)

Given the high number of themes, the similarity between some of the blue and red ones, and the desire to focus only on the most relevant and impactful drivers for this research, a filtering process will be applied to the remaining blue drivers. These blue drivers represent themes that were discussed in both literature and interviews. Some themes were more extensively debated or proved to be more influential, while others were straightforward and universally recognized. The following discussion explains the rationale behind keeping or eliminating each blue driver. At the end of this section, a table is provided with all the categories, including both blue and red-themed drivers.

Category 1: Regulatory, Policy, and Standards

In this category, the only eliminated blue barrier was **Regulatory Standards and Compliance** as it is too broad, vague and it encapsulates all the other drivers from this category. **Regional and International Policies** were kept due to their significance in aligning Dutch practices with global standards, especially within the European Union, which practitioners emphasized as necessary for having the same thresholds and standards. Also, the red theme of **Local Government Initiatives** was considered essential, as it highlights the role of local authorities in promoting sustainability at the community level—a factor seen as crucial for grassroots adoption.

Establishing Global Benchmarks was also retained, as it underscores the importance of adhering to international standards such as ISO and BREEAM, which guide sustainable practices and ensure quality and consistency in construction. Even though these standards are widely used, they may become mandatory benchmarks in the future. Among the red themes, **Upgrading the Certifications Thresholds** was identified by practitioners as a need to continuously raise the standards for sustainability, driving further innovation and improvement in the industry in order to force actors that are searching for the minimum to update their approach.

Encouraging Market Transformation was retained as a key driver because it encapsulates the essential role of regulatory frameworks in creating a demand for LIMs. Practitioners widely acknowledged that policies setting higher standards for environmental performance are crucial for driving market changes. **Streamlining Material Procurement** can be useful for simplifying the procurement process for LIMs, which was recognized as an area requiring significant improvement. Lastly, **Update of The Evaluation Frameworks** was kept because practitioners agreed on the

necessity of revising and improving sustainability evaluation methods to keep pace with industry advancements and to be sure that greenwashing can be overcome.

Category 2: Technological and Digital Innovation

In the realm of technological and digital innovation, the theme **Development of High-Performance, Low-Carbon Materials** was retained due to its critical importance in advancing sustainable construction. Practitioners highlighted the ongoing need for innovation in material science to meet sustainability goals

In the realm of technological and digital innovation, the themes **Enhanced Design and Planning (BIM)** and **Enhancements in Lifecycle Assessment (LCA)** were eliminated as standalone themes. Instead, these aspects have been incorporated into the broader theme of **Reliability and Long-Term Performance Data**. This decision was made because practitioners emphasized that both BIM and LCA are fundamentally about ensuring accuracy, reliability, and long-term sustainability in construction processes. By integrating these themes into the discussion of reliable data and long-term performance, the analysis better reflects the overarching importance of accurate information and reliable methodologies in driving sustainable construction practice

Red themes such as **Calculate Residual Value of Materials** was also emphasized by practitioners because understanding the end-of-life value of materials is crucial for promoting circular economy practices, a key concern for the industry. **More Standardization** was required by a large amount of consultants to address the need for consistent sustainability standards, which practitioners felt could reduce variability in practices, however this theme should be balanced as it should not be overdone. Additionally, the theme **Need for Practical Implementation** was kept, as it emphasizes the gap between theoretical advancements in LIMs and their practical application, which practitioners recognized as a significant challenge.

Category 3: Financial and Economic Drivers

For financial and economic drivers, **Long-Term Financial Savings** was retained as a core argument for adopting sustainable practices. Practitioners recognized the substantial economic benefits associated with lower operational costs and long-term savings, making this theme particularly relevant. Additionally, **Increased Property Value** is a related theme as it underscores the financial benefits of sustainable buildings in the real estate market, identified by practitioners as a key motivator for adopting green practices.

Varied Actor Opinions on Financial Incentives is a bit of an unusual 'driver' as it does not sound like one. It was one of the most polarizing drivers, as it was mentioned in the barriers part, that was discussed during the interviews, as practitioners had differing views on the effectiveness of financial incentives, highlighting the complexity of financial drivers in promoting sustainability. The other blue themes of **Reducing Financial Barriers Through Subsidies and Grants** and **Encouraging Investment in Sustainable Technologies with Financial Incentives** were eliminated as they are included in the Varied Actor Opinions on Financial Incentives.

Category 4: Stakeholder Engagement and Public Sector Leadership

In the category of stakeholder engagement and public sector leadership, **Leading by Example (Public Sector Leadership)** was retained due to the critical role of the public sector in

demonstrating the viability of sustainable practices. Practitioners emphasized that government projects serve as benchmarks for sustainability, encouraging private sector adoption. **Addressing Stakeholder Concerns** was also kept, as it focuses on the importance of understanding and addressing the concerns of various stakeholders, which can be from a large scope of factors—a key idea for successful implementation of sustainable practices. Practitioners, specially from the clients and governmental side have placed a strong emphasis on having their concerns be placed high up the list of priorities.

Conversely, **Collaborative Approaches** was eliminated as a standalone theme. It was seen as overlapping with other themes like cross-sector collaboration, which better encapsulates the essence of collaboration needed in the industry.

Red themes such as **Cross-Sector Collaboration** was highlighted because of the importance of cooperation between different sectors (e.g., public, private, and non-profit) to drive sustainability—a key area for improvement identified by practitioners. Also, the involvement of different actors earlier in the process, such as contractors and suppliers, was emphasized a lot by practitioners from both private and public sectors. **Simplifying Processes by Public Sector Leadership** was also kept because it reflects the need for the public sector to reduce bureaucratic barriers, which practitioners felt was necessary to accelerate the adoption of sustainable practices. This is closely related to Category 1 of drivers.

Category 5: Market Demand and Corporate Responsibility

Within this category, **Enhancing Corporate Reputation (CSR)** was kept because it emphasizes the role of corporate social responsibility in motivating companies to adopt sustainable practices, a significant motivator acknowledged by practitioners. **Driving Innovation and Sustainable Practices (CSR)** was eliminated because it overlapped with other themes that more specifically addressed the drivers of innovation and sustainability within companies.

The theme **Corporate and Institutional Demand** was also eliminated. This decision was made because its core aspects are effectively captured by other themes. Specifically, **Employee Engagement and Retention** addresses the internal corporate dynamics that drive demand for sustainable practices, highlighting how engaged employees can influence a company's commitment to sustainability. Moreover, the broader consumer trends are well encapsulated by the theme **Consumer Preferences and Market Demand**, which reflects how market forces and consumer expectations are pushing companies and institutions to adopt sustainable practices. By covering both internal and external drivers, these two themes together provide a comprehensive understanding of what **Corporate and Institutional Demand** seeks to address, making the latter redundant.

Category 6: Educational Programs and Climate Awareness

For educational programs and climate awareness, no blue drivers were eliminated. **Supporting Continuous Professional Development** was retained due to its focus on the necessity for ongoing education and training to keep professionals updated on the latest sustainable practices. Practitioners identified this as crucial for staying competitive in the evolving market. **Facilitating Industry Collaboration** was also retained, as it underscores the importance of collaboration within the industry to share knowledge and best practices, which practitioners felt was necessary for

widespread adoption of sustainability. It is closely related to Cross-Sector Collaboration from Category 4.

Red themes like **Corporate Initiatives on Climate Awareness** were highlighted by practitioner for the role of companies in promoting climate awareness through internal and external initiatives. Practitioners recognized this as critical for aligning corporate practices with sustainability goals. **Client Education** was also included as it highlights the need to educate clients on the benefits of sustainable practices, which practitioners felt was essential for increasing demand for low-impact materials.

Category 7: Supply Chain Management

In the final category of supply chain management, no blue drivers were eliminated as well. **Reliable Supply Chain Infrastructure** was retained because of its importance in ensuring the consistent availability of LIMs. Practitioners identified this as critical for the successful implementation of sustainable practices. **Improved Material Selection Processes** was also retained, as it highlights the need for better processes in selecting and procuring LIMs, which practitioners felt was essential for avoiding misleading claims and greenwashing in general.

Red themes such as **Supplier Diversity** were included because they emphasize the need for a broader range of suppliers offering LIMs. Practitioners identified this as necessary for increasing the availability and variety of low-impact materials and to avoid any vendor push-in for not LIMs. Finally, **Supply Chain Collaboration** was included as it focuses on the need for greater collaboration within the supply chain to ensure the timely delivery and quality of LIMs, as well as advice from suppliers on the most feasible materials for the project at hand. This is closely related to the other collaboration drivers which emphasize a greater collaboration in the early phases between actors.

Final Driver Themes Overview

Below, in Table 7, the final themes that represent problems for the Dutch Construction Industry regarding the adoption of LIMs can be seen. These will be further analyzed after the driver's chapter and the identification of themes from that chapter. For a complete overview scheme from beginning to end of the driver themes, check Appendix 2: Complete Overview Scheme Driver Themes.

Table 7 - Final Driver Themes

Category	Theme
Category 1: Regulatory, Policy and Standards	Encouraging Market Transformation
	Regional and International Policies
	Establishing Global Benchmarks
	Upgrading the Certifications Thresholds
	Streamlining Material Procurement
	Local Government Initiatives
	Update of The Evaluation Frameworks
Category 2: Technological and Digital Innovation	Development of High-Performance, Low-Carbon Materials
	Reliability and Long-Term Performance Data
	Calculate Residual Value of Materials
	More Standardization

	Need for Practical Implementation
Category 3: Financial and Economic Drivers	Long-Term Financial Savings
	Varied Actor Opinions on Financial Incentives
	Increased Property Value
Category 4: Stakeholder Engagement and Public Sector Leadership	Leading by Example (Public Sector Leadership)
	Addressing Stakeholder Concerns
	Cross-Sector Collaboration
	Simplifying Processes by Public Sector Leadership
Category 5: Market Demand and Corporate Responsibility	Consumer Preferences and Market Demand
	Enhancing Corporate Reputation (CSR)
	Employee Engagement and Retention
Category 6: Educational Programs and Climate Awareness	Supporting Continuous Professional Development
	Facilitating Industry Collaboration
	Corporate Initiatives on Climate Awareness
	Client Education
Category 7: Supply Chain Management	Reliable Supply Chain Infrastructure
	Improved Material Selection Processes
	Supplier Diversity
	Supply Chain Collaboration

5.5. Dividing the Categories in Two Directions

5.5.1. The Two Directions

In the journey towards achieving Net Zero Carbon Buildings within the Dutch construction industry, it becomes clear that the barriers and drivers to this goal are not solely rooted in technical challenges or straightforward issues like regulations and cost. A closer examination of the final tables of themes for both barriers and drivers reveals that social and market acceptance factors are equally, if not more, critical than the technical aspects. These themes highlight the complexity of achieving widespread adoption of low-impact materials, demonstrating that understanding stakeholder behavior, market dynamics, and cultural attitudes is essential. This recognition underscores the importance of the two directions outlined in this chapter, as they provide a structured approach to tackling both the technical and social dimensions of the problem.

This chapter introduces a focused approach by dividing these barriers and drivers into two primary directions: **Understanding Low-Impact Materials** and **Accelerating the Adoption**. This division aligns with the conceptual framework that underscores the interplay between material choice and stakeholder influence in advancing sustainable building practices from being pilot projects and material choice for one building towards the desired goal of Net Zero Carbon Buildings as a normality.

1. **Understanding Low-Impact Materials**: This direction centers on the technical and informational challenges that influence the selection and utilization of low-impact materials. It encompasses barriers related to data availability, material quality, performance uncertainties, and the infrastructural aspects of the supply chain. These are foundational

issues that need to be addressed to ensure that stakeholders have the necessary knowledge, tools, and resources to make informed decisions during the design phase of construction projects. Additionally, this direction includes drivers that facilitate the gathering, dissemination, and standardization of critical information about low-impact materials. Addressing these factors is crucial because without a deep understanding of the materials, the industry cannot move towards sustainable choices.

2. **Accelerating the Adoption**: The second direction focuses on the human and systemic factors that influence the speed and extent to which low-impact materials are embraced within the industry. This includes barriers related to economic considerations, cultural and behavioral resistance, regulatory challenges, and the knowledge gaps that exist among industry stakeholders. It also considers the drivers that can help overcome these obstacles, such as stakeholder engagement, financial incentives, regulatory frameworks, and educational initiatives. This direction is critical because the adoption of low-impact materials hinges not only on their technical merits but also on the willingness and ability of various actors—such as architects, engineers, developers, policymakers, and clients—to integrate these materials into their projects.

The division into these two directions provides a structured approach to addressing the dual challenges of material understanding and stakeholder adoption. By categorizing the barriers and drivers in this way, the chapter aims to deliver a clear, actionable pathway for overcoming the challenges identified in the study. This structured approach ensures that both the technical and human dimensions are addressed:

Table 8 - The Two Research Directions

Understanding Low-Impact Materials		**Accelerating the Adoption**	
Barriers	Drivers	Barriers	Drivers
- Category 4: Quality and Performance Uncertainties - Category 5: Data and Information Gaps - Category 7: Supply Chain of Materials	- Category 2: Technological and Digital Innovation - Category 7: Supply Chain Management	- Category 1: Economic and Financial Barriers - Category 2: Skills and Knowledge Deficiencies - Category 3: Regulatory and Compliance Challenges - Category 6: Cultural and Behavioral Barriers	- Category 1: Regulatory, Policy, and Standards - Category 4: Stakeholder Engagement and Public Sector Leadership - Category 5: Market Demand and Corporate Responsibility - Category 6: Educational Programs and Climate Awareness

5.5.2. Direction 1: Understanding Low-Impact Materials

Adopting low-impact materials in the construction industry requires overcoming specific technical, informational, and logistical challenges. This sub-chapter explores the interactions between technological innovations and supply chain management (drivers) with barriers such as quality uncertainties, information gaps, and supply chain disruptions.

Diagram of Interactions

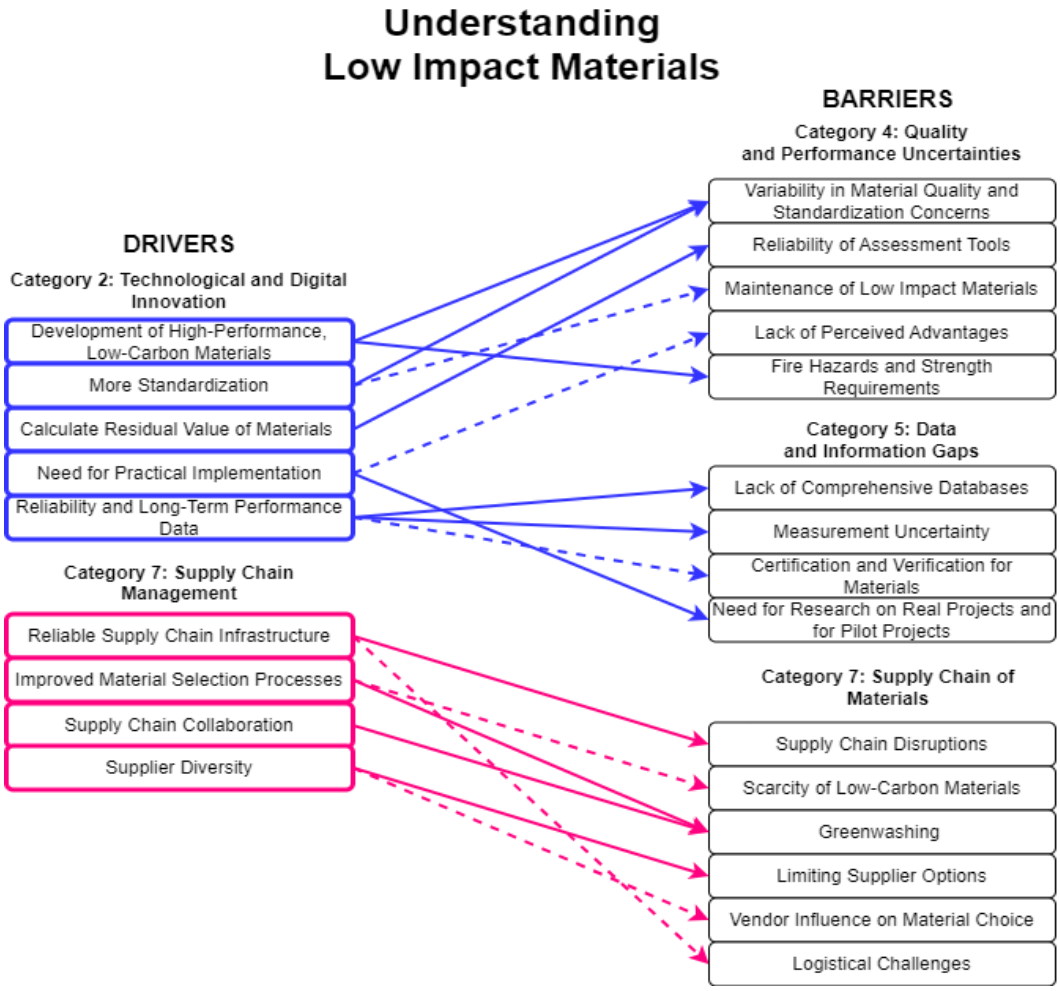

Figure 7 - Interactions of Drivers and Barriers "Understanding LIMs"

In the complex landscape of sustainable construction, understanding the interactions between drivers and barriers is crucial for advancing the adoption of low-impact materials. The diagram (Figure 7) vividly maps out these interactions, using solid and dashed arrows to illustrate the nature and strength of these relationships.

Solid arrows in the diagram represent the most direct and potent influences drivers have on barriers. These connections are akin to striking the heart of the challenge with a well-aimed solution.

Dashed arrows, on the other hand, depict more subtle, indirect interactions where the influence of drivers on barriers is nuanced, requiring a deeper understanding to appreciate fully.

Connection to SQ2: Addressing Critical Information Needs

Before delving deeper, it's important to restate the specific query driving this analysis, as outlined in Sub-Question 2 (SQ2): **"What critical information about low-impact materials is needed to make informed decisions?"** This question underscores the need for a robust understanding of the

material properties, performance metrics, and supply chain dynamics essential for integrating LIMs into construction projects.

The analysis thus far has effectively mapped out the primary barriers and drivers influencing the adoption of low-impact materials, along with illustrating how these elements interact. However, while this framework highlights the relationships between drivers and barriers, it also reveals that further analysis is crucial to fully leverage these interactions and operationalize the drivers effectively.

The interactions identified, particularly those represented by dashed arrows, indicate that some drivers only tangentially address certain barriers. This indirect influence suggests that while the drivers are aligned with overcoming obstacles, their effectiveness may be limited or conditional based on additional factors not fully captured in this initial analysis. For instance, while supply chain collaboration can help improve data accuracy, the extent to which this collaboration effectively addresses measurement uncertainties depends on the specific practices and technologies employed within the supply chain.

Furthermore, the current analysis hints at deeper complexities within each theme that require a more granular examination. Certain aspects, like the reliability of assessment tools or the practical implications of supply chain disruptions, are only scratched on the surface. To truly understand and solve these issues, a detailed exploration in Chapter 6 is necessary.

5.5.3. Accelerating the Adoption

The transition towards sustainable construction not only requires understanding low-impact materials but also effectively implementing strategies to accelerate their adoption. This sub-chapter examines how specific drivers can address and potentially overcome barriers that currently hinder the widespread acceptance and use of these materials within the industry. By exploring the dynamics between economic, knowledge-based, regulatory, and cultural barriers against a backdrop of regulatory policies, stakeholder engagement, market forces, and educational initiatives, we aim to illuminate pathways towards more rapid and widespread adoption of sustainable practices.

Diagram of Interactions

Figure 8 - Interactions of Drivers and Barriers "Accelerating the Adoption"

This section features a diagram illustrating the interactions:

- **Solid lines** will represent direct influences where a driver effectively addresses a barrier.
- **Dashed lines** will indicate more nuanced or indirect influences where a driver supports changes but requires supplementary actions or conditions to fully overcome the barriers.

Connection to SQ3: Stakeholder Perspectives on Accelerating Adoption

As we explore the framework that guides our understanding of accelerating the adoption of low-impact materials, Sub-Question 3 (SQ3) focuses sharply on the real-world implications: **"What are the perspectives of key stakeholders regarding the acceleration of the use of low-impact materials?"** This question is pivotal in shaping the strategies for broader implementation and acceptance of sustainable practices.

The diagram used to visualize the interactions between drivers and barriers lays a foundation for understanding these dynamics. The solid lines indicate direct and impactful connections where drivers robustly address specific barriers. In contrast, the dashed lines suggest interactions where the influence of drivers on barriers, while positive, may require additional support and deeper engagement to fully overcome the challenges presented.

This preliminary mapping of interactions, though insightful, only begins to uncover the complexity of the task at hand. The need for further analysis becomes apparent, particularly in areas marked by dashed lines and in aspects of the framework where barriers may not be fully address by certain drivers (Cost as a Convenient Excuse). This indicates that a more nuanced understanding of stakeholder perspectives is necessary to effectively tailor and implement strategies that can lead to successful outcomes.

To truly respond to SQ3, further detailed analysis in the subsequent chapter will focus on:

- **Deeper Exploration of Stakeholder Views**: Understanding the nuances of how stakeholders interpret these interactions and what barriers they perceive as most critical will be vital. This involves not just identifying barriers and drivers but also understanding the priorities, concerns, and suggestions from those directly impacted by these changes.
- **Refinement of Strategies Based on Feedback**: By integrating stakeholder feedback into the analysis, strategies can be refined to be more effective and responsive to the actual needs and challenges faced in practice

5.6. Conclusions

5.6.1. SQ1

Sub-Question 1 (SQ1) inquires: **" What factors hinder or facilitate the market acceptance of low impact materials in achieving net zero building ambitions?"** The analysis throughout Chapter 5 has focused on the drivers and barriers affecting this adoption from multiple angles. Barriers and drivers were drawn from diverse sources, revealing a rich spectrum of themes across seven categories for each. Pinpointing a single most critical barrier or driver would oversimplify the situation, failing to acknowledge the multitude of underlying factors that either exacerbate or facilitate the issue.

The findings emphasize two primary directions that influence adoption: the technical direction, which includes advancements in material technologies, evaluation of materials and supply chain efficiencies, and the social/market direction, which encompasses regulatory, economic, cultural and educational factors. While technical solutions address surface-level problems such as material performance and logistical challenges, the analysis has shown that these are often

underpinned and kept in place by more complex social issues. The social and market aspects, including stakeholder engagement, market demand, and regulatory frameworks, are critical—often more so than the technical ones—as they influence the broader industry acceptance and integration of these materials. The interplay between these directions highlights that overcoming technical barriers is contingent upon addressing the underlying social dynamics that shape industry practices and perceptions.

5.6.2. Main Takeaways

1. Interconnected Web of Barriers and Drivers

Chapter 5 elucidates a complex and interconnected web of barriers and drivers that collectively dictate the dynamics of adopting low-impact materials within the Dutch construction industry. This analysis has revealed that no single factor operates in isolation; rather, there is a synergistic effect where various elements influence and are influenced by others. Understanding these relationships is critical for developing strategies that effectively address multiple facets of the adoption process simultaneously.

2. Significance of Social/Market Barriers and Drivers

The social and market barriers and drivers are highlighted as being equally, if not more, important than the technical ones. These elements require special attention because they directly influence market acceptance and the broader societal uptake of sustainable practices. Factors such as regulatory policies, market demand, and public sector leadership play pivotal roles in shaping the industry landscape, often determining the success or failure of technical innovations.

3. Two Directions of Analysis

Reflecting the complex nature of the issue, two distinct directions have been developed for further investigation:

- **Understanding Low-Impact Materials**: This direction focuses on the technical aspects of low-impact materials, exploring innovations, material performance, and supply chain logistics.
- **Accelerating the Adoption**: Concentrates on the acceleration of market acceptance through regulatory influence, stakeholder engagement, and the cultivation of market demand.

These two directions not only categorize the thematic focus areas but also guide the detailed discussions in the next two chapters, each dedicated to diving deeper into these specified aspects.

4. Regulatory Factors as Central Discussion Points

Regulations, both as barriers and as drivers, have emerged as the most discussed and debated aspects of the adoption process. The prominence of regulatory discussions highlights their critical role in the ecosystem of adoption, serving as both facilitators and obstacles. This focus reveals that while regulatory policies can pave the way for the introduction and integration of sustainable practices, they can also pose significant challenges if not aligned with technological advancements and market needs. Governmental officials, recognized as initiators and key stakeholders in this process, are crucial in both setting and navigating the regulatory framework. The complexities and the central role of regulations will be the subject of more detailed discussions in Chapter 7.

6. Critical Information Regarding Materials

Chapter 5 concluded with a robust discussion on the diverse barriers and drivers shaping the adoption of low-impact materials in the Dutch construction industry. It highlighted the necessity of moving beyond simple identification to a deeper understanding of these materials and their broader impact. Chapter 6 responds to this need by delving into the essential details that influence design phase decisions, directly tackling Sub-Question 2 (SQ2): "**What critical information about low-impact materials is needed to make informed decisions?**"

This chapter will unfold through a structured discussion on several key areas: the narrative of the materials' origins and lifecycle, the application of evaluative frameworks culminating in the MilieuPrestatie Gebouwen (MPG), the crucial role of standardization, the long-term impacts of material usage, and the dynamics of the supply chain. Each section is designed to not only inform but also empower industry professionals by providing the critical information necessary to influence design phase decisions positively. By integrating these diverse aspects, Chapter 6 aims to equip industry professionals with the knowledge to make informed, sustainable decisions during the design phase, ultimately contributing to a more resilient and eco-friendlier built environment.

6.1. Understanding Low Impact Materials

6.1.1. Materials Background

Before delving into the critical information needed for understanding materials, it is essential to understand the background and context of the materials themselves. Each material has a unique story, encompassing its origin, lifecycle, and impact on the environment. These materials have unique properties that contribute to sustainability, but they also come with specific challenges that must be understood and addressed to facilitate their widespread adoption.

"***Is that circular or can I refurbish it and make a new material out? Is that also circular? There is no definition as far as I know what a fully circular economy means. We need to define what it means, but this is where the government needs to step up. Alright, let's work towards it, we can do it. They just said they want to be circular, but not what they mean by it.***" (P12)

Questions like this reflect the ongoing debate and the need for clear definitions and guidelines. The ambiguity surrounding what constitutes a fully circular material or what constitutes a sustainable or not sustainable material underscores the necessity for standardized criteria and definitions. Understanding the broader context of sustainability is also vital. Sustainability encompasses various aspects, including biobased materials, reuse, circularity, and carbon neutrality. Each of these subsets has its own unique story and set of challenges.

"***Sustainability is such a wide definition, and making a distinction between various subsets like biobased, reuse, circularity, and carbon-neutral is important as they all have their own stories.***" (P17)

6.1.2. Broader Context

The role of government in defining and regulating these definitions and guidelines is crucial. Clear definitions and regulations can guide the industry towards consistent and effective implementation

of sustainable principles. This includes addressing fire hazards and strength requirements, which are critical for the safe use of these materials in construction.

Governmental institutions stress the importance of industry-wide understanding of these distinctions. Recognizing these distinctions enables practitioners to make informed material choices that align with specific sustainability goals. During discussions with practitioners from the governmental side, it was revealed that frameworks and roadmaps for sustainable buildings are in place. However, they were surprised to learn that many private sector practitioners were unaware of these resources. For example, the RVB has published documents like Roadmap 2.0 and the Roadmap for Sustainability, which address sustainability themes, including circular and biobased materials (Rijksvastgoedbedrijf, 2023; Rijksvastgoedbedrijf, 2023b).

This lack of awareness underscores a significant disconnect between the public and private sectors. Although these roadmaps and frameworks are available at national and European levels, their effectiveness and suitability for various types of businesses remain uncertain. The surprise expressed by government practitioners about the private sector's ignorance of these documents further emphasizes the communication gap and the lack of common discussions between these sectors. Bridging this gap is crucial for aligning efforts and making substantial progress in sustainable practices across the industry.

6.2. Standardization

Understanding the story behind each material becomes fundamental to make informed, sustainable choices in the construction industry. The concepts of circular economy, sustainability, and material lifecycle play a pivotal role in this process. Clear definitions, robust regulations, and a comprehensive understanding of material flows are essential to navigate the complexities of the supply chain and achieve sustainability goals. It is also essential to understand the story of the materials to have a clear understanding of balancing the standardization.

6.2.1. Impact of Standardization

The social value of standardization in the construction industry is a complex and multifaceted issue that deserves thorough consideration. While standardization can offer significant benefits by simplifying workflows for contractors, consultants, and government officials, and transforming project development into a more product-oriented approach, it also poses potential long-term challenges. These challenges particularly affect project developers, clients, and the general public, as standardization might lead to a loss of architectural diversity and individuality in our built environment.

Benefits for Industry Professionals

From the perspective of contractors, consultants, and government officials, standardization can bring about several advantages:

1. **Efficiency and Simplification:** Standardization can streamline construction processes, making them more predictable and manageable. This can reduce errors, lower costs, and shorten project timelines (Gibb, 2001; Rocha et al., 2022).

2. **Integration of Sustainable Practices**: Integrating sustainable practices from the early stages of design and feasibility studies is essential. Addressing sustainability requires standardizing processes and materials to ensure quality and performance throughout a building's lifecycle. "A comprehensive review of sustainability in construction projects highlights the importance of integrating sustainable practices from the early stages of design and feasibility studies. Addressing sustainability requires not only ecological and environmental considerations but also economic and technical sustainability, which includes standardizing processes and materials." (Wei et al., 2024)

3. **Product Development:** Shifting from project development to product development can foster innovations in construction techniques and materials. Prefabrication and modular construction methods, which rely heavily on standardization, can improve sustainability, productivity, and quality (Rocha et al., 2022).

One quote that highlights the mentioned benefits is the following one: "***Standardization in general will be a very important factor in that we need to standardize more and more and more and the more we standardized and more make a product instead of a project we generally just make projects in the Netherlands and actually everywhere in the construction world we make projects and a project means that you're already thinking it from scratch and a product means you're taking something and putting it there. The more products we make the more effective we can do it and the less CO2 emissions and everything we can reduce because we can optimize our product. But it's really hard to optimize a project***" (P12)

Challenges for Developers and the Public

However, for project developers, clients, and the general public, the push towards standardization can be overwhelming and potentially damaging in the long term:

1. **Loss of Architectural Diversity:** Over-standardization can result in monotonous and uninspired architectural designs. Historically, different regions and countries have had unique architectural styles reflecting their cultural, historical, and environmental contexts. Standardized buildings risk erasing these distinctions, leading to homogenous and dull neighborhoods (Gibb, 2001; Demirkesen & Tezel, 2021).

2. **Psychological Impact:** The aesthetic quality of our surroundings significantly influences our mental health and well-being. Uniform, uninspired architecture can contribute to a sense of alienation and dissatisfaction among residents, negatively impacting their quality of life (Gibb, 2001; Demirkesen & Tezel, 2021).

3. **Cultural Erosion:** Standardization can erode cultural identity and heritage, making cities and towns indistinguishable from one another. This can weaken community ties and local pride, as unique characteristics that foster a sense of place are lost (Gibb, 2001).

4. **Resistance to Change:** For developers focused on creating unique buildings, standardization can be seen as restrictive and stifling creativity, leading to resistance against adopting standardized methods and materials (Gibb, 2001; Albalkhy & Sweis, 2020)

Historical and Contemporary Examples

The negative impacts of over-standardization are evident in historical and contemporary examples. During the Baby Boom era in countries like Romania and the former Eastern Bloc, the mass construction of Brutalist-style apartment blocks resulted in gray, uninspiring neighborhoods. These areas, characterized by their uniformity and lack of aesthetic appeal, had negative psychological and social impacts on residents.

In modern times, the trend towards standardized, energy-efficient buildings is visible in many new developments, with similar architectural styles appearing regardless of location. For instance, new neighborhoods in the Netherlands and Italy, countries with historically distinct architectural styles, now display similar, sustainable designs. While these buildings meet high sustainability standards, their lack of originality and aesthetic diversity is concerning.

6.2.2. Finding a Balance

The key challenge is determining the appropriate extent of standardization. While standardizing processes and material supply is crucial for achieving sustainability goals, it is essential to avoid over-standardizing the built environment to the point where architectural diversity and creativity are sacrificed.

1. **Standardizing Processes and Materials:** Focus on creating standardized processes and material specifications that enhance sustainability and efficiency without dictating specific design outcomes. This approach allows architects and designers the flexibility to innovate within a standardized framework**.**
2. **Regional Adaptations:** Promote regional adaptations of standardized practices to reflect local cultural, historical, and environmental contexts. This can help preserve the unique character of different regions while benefiting from the efficiencies of standardization.
3. **Stakeholder Engagement:** Engage a wide range of stakeholders, including architects, urban planners, community groups, and residents, to develop standards that balance efficiency with creativity. This collaborative approach can help ensure that standardization efforts are broadly accepted and effectively implemented.

6.2.3. Addressing Barriers Through Proper Standardization

When executed correctly, standardization can play a significant role in addressing many of the barriers identified in the "Understanding Low Impact Materials" direction. For instance, the challenges related to the variability in material quality and standardization concerns could be mitigated through the development of comprehensive, widely accepted standards that ensure consistent quality across materials.

Moreover, proper standardization can help overcome issues related to the reliability of assessment tools and the maintenance of low-impact materials. By establishing clear guidelines and standardized methodologies for material assessment, the industry can ensure that all materials are evaluated on a level playing field, providing more reliable and comparable data. This, in turn, can lead to more informed decision-making and better long-term maintenance strategies.

Standardization can also address supply chain disruptions and logistical challenges by creating more predictable and streamlined processes for material procurement and distribution. By establishing clear standards for material production and supply chain operations, the industry can reduce the likelihood of disruptions and ensure that materials are available when and where they are needed.

In summary, while standardization must be carefully balanced to avoid stifling creativity and cultural diversity, its proper implementation offers a powerful tool for overcoming many of the barriers to the adoption of low-impact materials.

6.3. Methods of Evaluating Materials

The effective evaluation of materials is crucial for informed decision-making during the design phase of construction projects. This section explores various methods and tools used by industry professionals to assess the sustainability, performance, and overall suitability of low-impact materials. Understanding these methods is essential for ensuring that the materials chosen not only to meet the project's immediate needs but also align with long-term sustainability goals.

6.3.1. Evaluative Frameworks

One primary method for evaluating construction materials involves using internal structured frameworks created by companies. These tools help systematically assess various aspects of a material, such as recyclability, origin, installation process, and overall quality. By providing a way to compare materials, these frameworks help identify the strengths and weaknesses of different materials, facilitating relatively informed decisions. Such frameworks are essential for developing a comprehensive understanding of each material's characteristics. They help identify the strengths and weaknesses of different materials, facilitating informed decisions that consider both environmental and practical considerations.

"***We made a list of questions, if a material is recyclable, how you install it... And then we made different levels of the material quality and installment method, and then you can see how it is scoring on both of those parameters.***" (P01)

However, one of the problems with these frameworks is that they can be too generic and might not capture all the nuances of specific materials or project requirements. This can lead to oversimplified evaluations that do not fully reflect the real-world performance of the materials. Moreover, the development and implementation of these frameworks require significant effort and expertise, which can be a barrier for smaller firms or projects with limited resources (Thomas et al., 2023). Additionally, these frameworks are not universally applicable to all types of materials, and different companies may evaluate the same materials in entirely different ways. Therefore, it is important to note that these methods are not necessarily the most accurate.

6.3.2. LCA

Lifecycle assessments evaluate the environmental impacts of a material from extraction to disposal. This comprehensive approach ensures that the selection of materials is based on their overall sustainability rather than just their initial cost or performance. LCAs consider various factors, including energy consumption, carbon footprint, and potential for pollution, providing a holistic view of a material's environmental impact (Huijts et al., 2012).

One problem with LCAs is the complexity and cost associated with conducting them. They require detailed data collection and analysis, which can be resource intensive. Additionally, there is often a lack of standardized methodologies, leading to inconsistent results that can be difficult to compare across different projects or materials.

"***The carbon stored in biobased materials is not taken into account in environmental effect calculations, which is a limitation.***" (P18)

Despite these challenges, LCAs are invaluable for making decisions that favor materials with lower overall environmental impacts and they stay at the base of MPG. This method also supports regulatory compliance, as many building codes and standards increasingly require or recommend the use of LCAs for material selection.

6.3.3. Importance of Environmental Product Declarations (EPDs)

Environmental Product Declarations (EPDs) play a crucial role in material evaluation by providing third-party verified data on the environmental impact of materials. EPDs offer transparency and reliability, making them a valuable resource for professionals aiming to make informed, sustainable choices (Wüstenhagen et al., 2007).

"***Environmental product declarations (EPDs) are crucial. They provide third-party verified data, and we rely on them heavily. For us, the EPDs show everything: the energy used in producing materials, the source of the materials, material health, and more.***" (P10)

This comprehensive data allows professionals to compare materials on a like-for-like basis, ensuring that decisions are based on reliable, standardized information. However, there are challenges with EPDs as well. Obtaining an EPD can be a costly and time-consuming process for manufacturers, which can limit the availability of EPDs for certain materials.

6.3.4. Overview

In summary, the evaluation of materials involves a combination of structured frameworks, lifecycle assessments, and environmental product declarations. These tools provide a comprehensive approach to assessing the sustainability and performance of materials, ensuring that informed decisions can be made during the design phase. By incorporating these methods, industry professionals can select materials that not only meet immediate project needs but also contribute to long-term sustainability goals.

However, each method has its challenges. Evaluative frameworks can be overly generic, LCAs are complex and costly, EPDs can be difficult to obtain and assessing residual value and recyclability lacks standardization. By acknowledging and addressing these problems, the industry can improve these evaluation methods and better integrate LIMs into construction projects.

6.4. MPG

In the Dutch construction industry, the MilieuPrestatie Gebouwen (MPG) calculation tool plays a pivotal role in evaluating the environmental performance of buildings. This section examines the MPG tool, its significance, the challenges associated with its use, and the broader context of calculation tools in material evaluation.

6.4.1. Overview of MPG and Its Importance

The MPG is a standardized method for assessing the environmental impact of building materials throughout the lifecycle of a building. It considers various factors, including resource extraction, manufacturing, transportation, use, and end-of-life disposal (RVO, 2017). By providing a comprehensive view of a building's environmental footprint, the MPG helps architects, engineers, and developers make more informed decisions about material selection.

"***So in the Netherlands there is only one or one rule on this. There's only one answer. That's the MPG. Because that is the only legal rule in the Netherlands that is actually calculating the sustainability***." (P12)

The importance of the MPG tool lies in its ability to standardize sustainability metrics across the industry, ensuring that all projects are evaluated using the same criteria. This consistency is crucial for regulatory compliance and for promoting transparency and accountability in the industry. By providing a uniform framework for evaluating materials, the MPG aims to help to eliminate confusion and discrepancies that can arise from using different evaluation methods.

6.4.2. Challenges with the MPG Tool

"*MPG does cover everything. It's an amazing idea. It's just executed badly but the idea is really good.*" (P12)

Despite its benefits, the MPG tool is not without its challenges. One significant issue is the complexity and lack of user-friendliness of the tool, which can make it difficult for practitioners to use effectively. The tool requires detailed data inputs and a thorough understanding of lifecycle assessment methodologies, which can be a barrier for smaller firms or those with limited expertise in sustainability assessments.

"***The difficulty with MPG is that again the database we mentioned before it's really ****** and you can play around with it and nobody really understands it. So it's lacking a lot of things. That's why I'm saying the MPG is a shady number but it's the only number and we're all doing the same number.***" (P12)

The complexity of the MPG tool can lead to inconsistent application and potential errors in data entry and interpretation. This can undermine the accuracy of the assessments and reduce the overall effectiveness of the tool in promoting sustainable practices. Additionally, the current MPG database is not comprehensive, with many manufacturers not including their products in the database. This limits the range of materials that can be accurately assessed using the MPG tool, potentially biasing decisions towards materials that are included in the database, regardless of whether they are the most sustainable options available. The limited scope of the MPG database can lead to a narrow focus on certain materials, potentially overlooking innovative or less common materials that may offer superior sustainability benefits.

"***There's a problem because very little suppliers actually have their product inside this database (MPG). We need more manufacturers of products to enter this database of environmental impact data, that's very important.***" (P04)

6.4.3. Addressing Greenwashing and Data Accuracy

Another significant challenge is the issue of greenwashing, where manufacturers may present misleading claims about the sustainability of their products. Ensuring data accuracy and reliability is crucial for the MPG tool to provide meaningful assessments. This requires rigorous third-party verification and the inclusion of comprehensive data on all relevant environmental impacts.

"***To prevent greenwashing and you know to actually give like advice what data we have this and MPG calculations the basically behind every building material there's a whole life cycle assessment of the environmental impacts.***" (P04)

Greenwashing undermines the credibility of sustainability claims and can lead to the adoption of materials that do not genuinely contribute to environmental goal. To combat this, it is essential to have robust verification processes that can detect and prevent greenwashing. This includes stringent criteria for data inclusion in the MPG database and regular audits to ensure compliance with these criteria. Also, as the practitioners mentioned, making the MPG database mandatory for every supplier.

"***I think the government needs to make this MPG database mandatory for all manufacturers to create a level playing field.***" (P04)

Addressing the challenges associated with the MPG tool is crucial for improving its effectiveness and reliability. Enhancing user-friendliness, expanding the database, and ensuring data accuracy through rigorous verification processes can significantly improve the tool's utility. By overcoming these barriers, the industry can better leverage the MPG tool to make informed, sustainable choices in material selection.

6.5. Long Term Impact of Materials

The long-term impact of materials is a critical factor in sustainable construction. This section explores the importance of considering the long-term performance, durability, and potential for reuse and recycling of materials used in building projects. It delves into the methods used to assess these impacts and discusses the challenges and potential solutions.

"***We are looking at long-term performance and reliability of materials, but it's difficult to know how a material will evolve over time.***" (P08)

6.5.1. Residual Value and Recyclability

Evaluating the residual value and recyclability of materials at the end of their lifecycle is one important consideration. This aspect of material evaluation looks at the potential for materials to be reused or recycled, reducing waste and promoting a circular economy.

"***It would be very interesting to calculate some kind of residual value of materials that you can reuse at the end of their life. That's actually never done, but I think that would be very interesting.***" (P04)

Materials with high residual value can significantly reduce the environmental impact of construction projects by minimizing waste and conserving resources. Recyclability also contributes to the circular economy, where materials are continuously reused and repurposed

rather than being discarded. This not only has environmental benefits but can also result in cost savings over the long term.

"***In order to facilitate more use of Low Impact Materials, looking more at the value of materials at the end of the life cycle is important.***" (P01)

A major problem with evaluating residual value and recyclability is the lack of standardized methods and metrics. This makes it difficult to compare materials accurately and can lead to inconsistent decision-making. Additionally, there may be technical and logistical challenges in implementing recycling programs, such as the need for specialized equipment or processes to reclaim and reuse materials.

Despite these challenges, considering the end-of-life value of materials ensures that sustainability is a key factor from the beginning to the end of a project. Integrating these considerations into the material selection process helps to support long-term environmental goals and can enhance the overall sustainability of construction projects.

6.5.2. Material Passports

Material passports are tools that support this approach by documenting the materials used in a building, their properties, and their potential for reuse and recycling. Material passports provide detailed information about each material, including its origin, composition, and potential applications after the building's lifecycle ends.

"***We are developing now a material passport for our projects to give a second life to the products.***" (P15)

Madaster is an example of an organization actively working on the implementation of material passports. They create detailed digital records of materials used in buildings, documenting their quality, origin, and potential for reuse. Practitioners have mentioned Madaster as a valuable resource for enhancing the traceability and management of building materials. Material passports provide a structured way to manage material data throughout the lifecycle of a building. They help ensure that materials retain their value and can be efficiently repurposed or recycled at the end of their initial use.

6.5.3. Challenges in Assessing Long-Term Impact

Despite the importance of assessing the long-term impact of materials, practitioners face several significant challenges. One major challenge is the lack of real-life examples and long-term data on the performance of new LIMs. Many materials, such as biobased, recycled, and circular materials, have not been in use long enough to provide empirical data on their long-term performance.

"***We don't know yet. We cannot assess it. There are some tests that you can do in such a way that you test the life expectancy, but there I also know that there are tests that you simply just must wait. You can't speed up.***" (P06)

The absence of long-term data means that practitioners often must rely on simulations and short-term tests, which may not accurately predict real-world performance over extended periods. This

uncertainty makes it difficult to confidently select and promote these materials, especially when stakeholders demand assurances of their durability and environmental benefits.

Moreover, existing tools and methods, such as Environmental Product Declarations (EPDs) and Lifecycle Assessments (LCAs), while invaluable, have their limitations. EPDs, for example, provide third-party verified data on the environmental impact of materials but may not cover all aspects of long-term performance. However, these declarations often fall short when it comes to assessing how materials will hold up over time in different environments.

The variability in material performance adds another layer of complexity. Materials that perform well in one environment may not do so in another, making it challenging to generalize findings. Additionally, the current system of measuring and judging circularity and environmental effects does not always favor biobased materials.

6.5.4. The Role of Pilot Projects Research

Given these challenges, pilot projects emerge as a crucial strategy to bridge the gap between theoretical assessments and real-world performance. These projects serve as testing grounds where materials can be observed under real-world conditions, providing insights that are impossible to obtain through simulations or short-term tests alone.

To tackle the need for real-world projects, the construction industry should prioritize funding and support for pilot projects. Collaboration between material manufacturers, construction companies, government bodies, and small and medium-sized enterprises (SMEs) is essential to ensure these projects are well-resourced and effectively monitored. SMEs, in particular, can play a crucial role in this process by testing new materials on smaller-scale projects. These smaller projects provide a more manageable environment for initial testing, where the risks associated with using new materials are lower and more easily controlled.

Moreover, involving SMEs in pilot projects can democratize the innovation process, allowing smaller players in the industry to contribute to and benefit from advancements in sustainable construction. This approach also helps to distribute the knowledge gained from these projects more widely across the industry, as SMEs are often closely connected to local communities and networks. By sharing the findings from pilot projects within these networks, the adoption of successful materials can be accelerated across different regions and types of construction projects. Ultimately, the integration of SMEs in pilot projects not only supports the broader adoption of low-impact materials but also strengthens the overall resilience and adaptability of the construction industry

6.6. Supply Chain Considerations

The supply chain plays a crucial role in the adoption of LIMs in the construction industry. Understanding the dynamics, challenges, and opportunities within the supply chain is essential for making informed decisions during the design phase. This section explores the critical aspects of the supply chain that influence the selection and use of low-impact materials, including availability, reliability, and logistics.

6.6.1. Availability of Materials

The availability of LIMs is a primary concern for practitioners. Ensuring a steady supply of materials such as biobased, recycled, and circular materials is essential to meet the growing demand for sustainable construction. Availability often dictates whether these materials can be integrated into projects on a large scale.

"***The supply chain for wood is already established and can be easily enlarged, unlike more sustainable concrete which requires a new supply chain.***" (P18)

Practitioners have highlighted that while some materials, like wood, have well-established supply chains, others, like sustainable concrete, still face significant challenges in scaling up. Ensuring the availability of these materials involves developing robust supply chains that can meet demand consistently. Additionally, there are instances where local availability plays a crucial role**.**

"***The main thing for us is it needs to be locally available. If you need to transport it all over the country, it's not worth the effort.***" (P16)

The practitioner was discussing a case involving the transportation of materials in the USA, where the distances are much greater. In the Netherlands, it would be more ideal for materials to be sourced from the EU or at least from Europe. One practitioner mentioned that the origin of materials, particularly steel, can be misleading:

"***No, we don't construct such a huge complex building that we can't source enough steel from the Dutch market. Even if we use a Dutch supplier, the steel often comes from Eastern Europe. For example, the steel mill might be in Romania or Bulgaria, and then the steel is transported to the Netherlands for final processing, after which it's labeled as Dutch steel. But it never really is.***" (P12)

In this scenario, the supply chain is feasible since it's within the EU. However, for other materials, it can be more difficult to trace their origins and determine if they are worth the effort. Local sourcing not only reduces transportation costs and carbon emissions but also supports local economies. This, however, requires an efficient and adaptable supply chain that can handle fluctuating demand and regional constraints, and also ensure transparency and honesty about the materials' origins.

6.6.2. Logistics and Storage

Logistics and storage are also significant considerations. The process of transporting and storing Low Impact Materials can be complex, particularly for materials that require specific conditions to maintain their integrity.

"***For the reuse of existing materials, logistics is a challenge because you don't want to create some sort of storage problem.***" (P18)

Effective logistics management is essential to ensure that materials are available when needed and in the right condition. This includes planning for the transportation and storage of materials, considering factors such as space, temperature, and handling requirements. Poor logistics can lead to delays and increased costs, undermining the benefits of using Low Impact Materials.

"***Can you take it out and can you make it in such a way that you can take it out in time again? When is it available and does that match your project? Or should you have storage place? And then there's stuff that we designers and builders don't really like that's signing and making contracts for storage places or and writing. It's not our happy place, so we try to avoid it and because you can also get to the situation, a lot of building projects get delayed. And so, then you have to make sure that the storage is still available. There is a lot of uncertainty there.***" (P11)

This quote highlights the complexities involved in logistics and storage for recycled materials. Ensuring the availability of storage, managing contracts for storage spaces, and dealing with project delays add layers of uncertainty that need to be managed effectively economy.

6.6.3. Impact of External Factors

External disruptions such as geopolitical events and global pandemics have highlighted the vulnerabilities in supply chains. These events can cause significant delays and unpredictability in material availability, further emphasizing the need for robust logistics and contingency planning. The war in Ukraine, for instance, has influenced the supply chain dynamics for certain materials.

"***Well, the COVID crisis and the war outbreak in Russia-Ukraine, then we faced more issues regarding lead times of materials.***" (P13)

Understanding and anticipating the impact of external factors can help practitioners develop more resilient supply chains that can adapt to changing conditions. This includes developing contingency plans and diversifying supply sources to mitigate risks. The ability to quickly adapt to changes in material availability due to external factors is crucial for maintaining project timelines and ensuring the continuous use of LIMs.

6.6.4. Supply Chain Transparency

Transparency within the supply chain is essential for making informed decisions about material selection. This involves having access to detailed information about the sourcing, production, and environmental impact of materials. Transparent supply chains enable practitioners to evaluate the sustainability credentials of materials accurately and ensure they align with project goals and regulatory requirements.

"***There should be at least a European or even a national standard and collaboration between the private and public sectors to create a database of materials.***" (P13)

Creating standardized and accessible databases that provide comprehensive information about materials can significantly enhance supply chain transparency. Practitioners have stressed the need for such databases to be integrated into existing tools and systems for seamless access.

6.6.5. Addressing Vendor Lock-In through a Robust Supply Chain

A robust and transparent supply chain is not only critical for ensuring the availability, reliability, and quality of LIMs but also plays a significant role in mitigating vendor lock-in. By developing a robust supply chain, companies can reduce their dependency on a small number of suppliers. This approach not only enhances supply chain resilience but also promotes competitive pricing and innovation.

"Reliable sourcing of materials involves establishing long-term relationships with suppliers and ensuring that materials meet the necessary quality standards. However, vendor lock-in should be avoided." (P17)

A well-developed supply chain enhances a company's flexibility in material selection and strengthens its negotiation power with suppliers. This can lead to cost savings and improved material quality. A diversified supply chain encourages innovation and competitiveness among suppliers. This dynamic can lead to the development of more advanced and LIMs.

"The Low Impact Materials need to become cheaper and easier to deliver to reach a tipping point where clients and suppliers choose these materials." (P13)

6.7. Synthesis

This section synthesizes the insights gathered from the preceding sections. Section 6.7.1 outlines the main takeaways that highlight the essential elements needed to drive progress. Following these insights, Section 6.7.2 delves deeper into answering SQ2: "What critical information about material supply is necessary for design phase decisions?".

6.7.1. Main takeaways

- *Need for Definitions and Guidelines for Different Types of Materials*
- *Need for Improved Communication and Alignment Between Public and Private Sectors on Frameworks*
- *Standardization is essential for progress; however, balance needs to be found*
- *Combining different evaluation methods enhances material selection but requires addressing each method's limitations.*
- *MPG is deficient, complex and limited in scope*
- *MPG database should be stricter and more mandatory*
- *Long Term Impact of Materials can be evaluated more clearly by calculating residual value and Recyclability, Using Material Passports and More Pilot Projects Research*
- *Need for Validation of New Materials through Pilot Projects*
- *Involving SMEs in pilot projects democratizes innovation, accelerates the adoption of Low Impact Materials, and enhances the construction industry's resilience and adaptability.*
- *Need for consistent, locally sourced supply of low impact materials, coupled with effective logistics and storage management for recycled materials, is essential for large-scale adoption and maintaining material integrity.*
- *Need for robust contingency planning for future external supply chain disruptions*
- *A transparent supply chain empowers informed decision-making, reduces dependency on single suppliers, and fosters innovation in Low Impact Materials.*

6.7.2. Answering SQ2

To answer SQ2, "**What critical information about low-impact materials is needed to make informed decisions?**", it's important to consider several key aspects that guide sustainable choices in the construction industry.

Firstly, understanding the **origins and lifecycle** of low-impact materials is crucial. Knowing what materials are available, where they originate, how they are produced, and their environmental

footprint throughout their lifecycle means grasping the full story of the material. Secondly, **balanced standardization and collaboration** are essential. Clear definitions and industry-wide standards for low-impact materials ensure consistency and reliability in their use, making it easier to compare materials on an equal basis. **Enhanced communication between the private and public sectors** would accelerate the development of definitions and frameworks that serve both sides effectively.

Properly utilizing **material evaluation tools**, whether individually or in combination, is indispensable for informed decision-making. These tools, with their limitations in mind, culminate in the use of **MPG**, the legal framework in the Dutch construction industry. However, MPG is complex and often restricts innovation while being lenient toward suppliers regarding material transparency. Stricter and more mandatory regulations would strengthen the MPG framework.

The long-term performance and durability of low-impact materials must be thoroughly tested and sustained through various methods, such as **calculating residual values, developing material passports, and conducting comprehensive pilot project research**. These efforts would be most efficient if all stakeholders, especially SMEs, were involved, as they often bring innovative ideas to the table.

Lastly, **supply chain transparency** is critical. Understanding the **availability, sourcing, and logistics** of low-impact materials ensures they can be delivered on time and meet the project's sustainability standards. Transparency within the supply chain allows for informed decisions about material selection, ensuring that every aspect of the material's journey—from production to delivery—is aligned with the project's goals. This includes assessing supplier reliability, tracking material origins, and anticipating potential risks that could impact availability.

6.7.3. Transition to Actor Perspectives

In this chapter, we explored the critical information needed for the effective incorporation of LIMs in the Dutch construction industry, addressing the second sub-question. It became evident that even the technical and logistical details crucial to material selection are deeply intertwined with the perspectives and actions of key stakeholders. This highlights that the social and collaborative aspects are often more significant than the technical ones in driving the adoption of LIMs.

The successful integration of these materials depends not just on understanding their properties and supply chains but also on the attitudes, motivations, and cooperation of the actors involved. Recognizing this, Chapter 7 will address the third sub-question: "**What are the perspectives of key stakeholders regarding the use of LIMs?**" This chapter will delve into the barriers and drivers discussed earlier, providing insights into the motivations, challenges, and recommendations from various stakeholders within the construction process. By examining their perspectives, we aim to uncover the socio-economic factors that influence the adoption of LIMs and identify strategies to enhance collaboration and commitment towards achieving sustainability goals.

7. Perspectives of Actors

The successful adoption of Low Impact Materials in the Dutch construction industry hinges not only on technical and logistical factors but also on the perspectives, attitudes, and collaboration of key stakeholders. As highlighted in previous chapters, particularly in the discussion of regulatory factors, it is evident that regulations play a central role in both facilitating and hindering the integration of sustainable practices. The prominence of regulatory discussions underscores the importance of understanding how these policies interact with technological advancements and market needs, further emphasizing the influence of governmental officials as both initiators and key stakeholders in this process.

This chapter aims to address the third sub-question: "**What are the perspectives of key stakeholders regarding the acceleration of use of low-impact materials?**" By gathering and analyzing the viewpoints of various stakeholders, we can identify the critical factors that influence decision-making processes and highlight the barriers that need to be addressed to facilitate the widespread adoption of LIMs. Through in-depth interviews and analysis, this chapter delves into the insights from real estate developers, contractors, consultants, government officials, and other interested parties such as clients and end-users. Each stakeholder group offers unique perspectives on the challenges and opportunities associated with LIMs, providing a comprehensive understanding of the industry landscape.

7.1. Governmental Officials: Setting the Stage

7.1.1. The Role of Governmental Officials

Governmental officials hold a pivotal role in shaping the regulatory environment that governs the adoption of LIMs in the Dutch construction industry. As the architects of the policies and regulations that define the playing field, they are instrumental in both driving and sometimes hindering the integration of these materials into mainstream practices. Their influence extends far beyond mere enforcement; they are the gatekeepers who **set the stage** for the construction industry's sustainability journey.

7.1.2. Challenges Faced by Governmental Officials

One of the most mentioned pressing issues is the need to keep regulations up to date with the rapid advancements in LIMs and construction technologies. The pace of innovation in this field often outstrips the speed at which regulations can be revised, leading to a regulatory environment that may not fully support the latest sustainable practices. One obvious example, mentioned in chapter 6 is the MPG, which has been regularly criticized by the consultants especially for its complexity, limited scope and being too lenient on the suppliers regarding the database.

Furthermore, governmental officials must navigate the complexities of stakeholder alignment. They are tasked with creating regulations that satisfy a wide range of interests, including those of environmental advocates, industry leaders, and the general public. This balancing act is made even more challenging by the fact that different stakeholders often have conflicting priorities, which in turn, according to practitioners from the public side lead to longer and longer time from developing new regulations.

Another challenge closely tied to the previous ones is the dependency of all stakeholders on governmental regulations. The industry often waits for clear and decisive governmental actions to guide their sustainability efforts. For instance, many industry professionals emphasize that without clear regulations and policies, the private sector remains hesitant to fully commit to Low Impact Materials. As one participant noted, "**The major shift will happen only if there's a change in the policy and if there's a change in rules and regulations enforcing people to use it**" (P02). This sentiment is echoed across the sector, as another respondent mentioned, "**The government is always one or two steps behind the market, but on the other hand, the market needs the government to improve**" (P12). The need for a clear and enforceable framework is critical. Stakeholders across the board recognize that without a well-defined regulatory environment, the push for sustainability may stall. As one participant succinctly put it, "**More clear regulations would speed up this development for sure**" (P01).

7.1.3. Interaction with Other Stakeholders

This section explores how governmental officials interact with other key actors—contractors, clients, consultants, and suppliers—and how these stakeholders perceive the influence and effectiveness of governmental actions.

Governmental Officials' Perception of Other Stakeholders

Governmental officials are primarily focused on ensuring that contractors, clients, and suppliers adhere to sustainability standards while effectively managing the economic and logistical challenges inherent in the construction industry. A key challenge they perceive is the resistance from both contractors and clients towards regulatory changes, often due to the associated costs and practical difficulties. Officials recognize the necessity of encouraging compliance, but they also see the need to provide support to ease the transition towards sustainable practices. As one official emphasized, "**Contractors need to be more accountable to sustainability standards set by the government**" (P14). This highlights the ongoing struggle to enforce standards while considering the realities faced by contractors.

Similarly, governmental officials view clients as requiring strong and clear regulatory frameworks to motivate them towards adopting sustainable practices. Without such robust regulations, there is a concern that clients might prioritize short-term financial benefits over long-term sustainability goals. As one official noted, "**Clients often need more than just incentives; they need strong regulations to adopt sustainable practices**" (P17). This perspective underscores the importance of a dual approach that combines regulatory mandates with financial incentives to guide client behavior towards sustainability. However, there is a belief among some governmental officials that the current level of financial incentives is sufficient, as reflected in one practitioner's remark: "**I think we did €11 billion last year in subsidies. So I think that's quite a lot. Personally, I'm opposed to subsidies in new builds but I think in the existing housing stock it's necessary**" (P14). This suggests a nuanced view within the government about balancing incentives and regulatory enforcement.

When it comes to suppliers, governmental officials express concern over the pace of innovation and the consistency of material quality. There is a clear recognition of the need for stricter regulations to ensure that suppliers deliver certified, high-quality LIMs. One official articulated this need,

stating, "**We need to enforce stricter regulations on suppliers to ensure material quality and sustainability**" (P18).

Moreover, governmental officials have noted a concerning lack of engagement from private stakeholders in public commissions, particularly in the context of knowledge exchange. As one official pointed out, "**The private parties do not join us as often and in as such numbers as we would like to**" (P18). This lack of engagement is closely linked to the government's worry that private entities are not fully engaging with the frameworks that the government develops, potentially hampering the effectiveness of these initiatives.

Other Stakeholders' Perception of Governmental Officials

The perception of governmental officials by other stakeholders varies, often reflecting the complexities of the construction industry and the challenges of implementing sustainability initiatives.

Contractors generally view governmental regulations as both a necessary guide and a potential burden. They often express frustration with the practical challenges these rules can impose. "**Regulations need to be more in tune with on-ground realities of construction**," one contractor noted (P12). This sentiment reflects a broader concern that governmental policies, while well-intentioned, sometimes fail to account for the practical difficulties faced on construction sites.

Clients also hold mixed views on governmental officials. On one hand, they recognize the critical role of regulations in setting industry standards and driving sustainability. On the other hand, they often feel that these regulations are not always aligned with the financial realities of development projects. Clients express a need for more robust governmental support, not just through regulations but also through incentives that make sustainable practices financially viable. "**Regulatory requirements need to be more aligned with the realities faced by developers**" commented a client (P16). This reflects a demand for regulations that are not only stringent but also practical and supportive of long-term financial planning.

Consultants, including both engineering/architectural consultants and sustainability consultants, generally support the role of governmental officials in promoting sustainability but often find themselves caught between the ideals of policy and the practicalities of implementation. Sustainability consultants, in particular, are vocal about the need for regulatory frameworks to keep pace with emerging sustainability practices. "**Regulations sometimes do not reflect the latest sustainability practices, making it hard to comply and innovate simultaneously**", stated a sustainability consultant (P04). This highlights a key concern that governmental policies may lag behind the cutting-edge innovations that consultants are trying to implement, creating a disconnect between policy and practice.

7.1.4. Addressing Challenges

Addressing the Slow Pace of Regulatory Updates

To address this issue, governmental officials must prioritize the continuous review and updating of regulations to ensure they remain relevant and supportive of innovation. This could involve the establishment of dedicated task forces or advisory panels that include representatives from across

the industry, tasked with monitoring developments in LIMs and recommending regulatory adjustments as needed.

Moreover, fostering greater collaboration between the public and private sectors is essential for ensuring that regulatory updates are both timely and effective. By engaging with industry stakeholders throughout the regulatory process, governmental officials can create a more dynamic and responsive regulatory environment that supports the adoption of Low Impact Materials while also addressing the practical concerns of those who must implement these changes.

The Need for Incentives and Support

The effectiveness of these incentives depends on how well they are targeted and implemented. Overly generous incentives might encourage compliance but could also lead to market distortions or over-reliance on government support. On the other hand, insufficient incentives may fail to drive the necessary level of adoption. A balanced approach is required, one that motivates stakeholders without creating dependencies or inefficiencies in the market.

Governmental officials also need to ensure that these incentives are accessible to a broad range of stakeholders, including small and medium-sized enterprises (SMEs), which may lack the resources to compete with larger firms in the adoption of sustainable practices. By providing targeted support to SMEs, governmental officials can foster innovation and ensure that the benefits of sustainability are distributed across the entire industry.

7.1.5. The Strategic Role of Governmental Officials

The interaction between governmental officials and other stakeholders is characterized by a complex dynamic of influence and cooperation. Governmental officials wield significant power through their ability to create and enforce regulations, but their effectiveness depends heavily on how well these regulations are received and implemented by contractors, clients, consultants, and suppliers.

For successful adoption of LIMs, there must be a continuous feedback loop between governmental officials and other stakeholders. This means that governmental policies should be informed by the practical experiences of those on the ground, while stakeholders must be willing to engage with and adapt to regulatory frameworks. The quotes from various stakeholders highlight the importance of a collaborative approach where each actor not only understands but actively contributes to the regulatory environment.

In conclusion, the interaction between governmental officials and other stakeholders is a defining factor in the adoption of Low Impact Materials. While governmental officials set the regulatory stage, the success of their efforts depends on the cooperation and buy-in from contractors, clients, consultants, and suppliers. Also, these efforts must be continuously updated and refined in response to technological advancements and market dynamics. By fostering a more collaborative and responsive regulatory process, governmental officials can better align their policies with the needs and realities of the construction industry, ultimately driving more effective and widespread adoption of LIMs.

7.2. Consultants (Architects/Engineers): Facilitators and Advocates

7.2.1. The Role of Consultants

Consultants, encompassing both engineering/architectural and sustainability specialists, serve as crucial facilitators in the adoption of Low Impact Materials within the Dutch construction industry. Their dual role as technical experts and sustainability advocates positions them uniquely to bridge the gap between policy and practice. Architects and engineers, in particular, act as **facilitators**, translating regulatory frameworks into actionable strategies and guiding project teams through the complexities of sustainable construction. Meanwhile, sustainability consultants **advocate** for higher environmental standards and push the industry towards greater sustainability.

Engineering and architectural consultants focus on the practical and structural aspects of integrating LIMs into building designs. They assess the feasibility of using innovative materials and methods, ensuring that these align with both client expectations and regulatory requirements. On the other hand, sustainability consultants concentrate on the environmental impact of materials and practices, driving projects towards higher standards and helping projects achieve certifications that demonstrate their environmental credentials.

7.2.2. Challenges Faced by Consultants

One of the primary challenges faced by consultants is the integration of sustainable practices from the earliest stages of design and planning. Sustainability is often viewed as an add-on rather than a core principle, making it challenging for architects and engineers, who facilitate these projects, to advocate for these practices in a cost-driven industry. As one consultant highlighted, "**Sustainability should not be an afterthought but an integral part of the planning process**" (P01). This sentiment underscores the difficulty facilitators face when attempting to shift the mindset of clients and contractors who may prioritize immediate costs over long-term sustainability benefits.

Consultants also grapple with the lack of standardization in LIMs. This absence of uniform standards complicates the process of evaluating and selecting materials, leading to inconsistencies in project outcomes. As a result, facilitators often advocate for more robust standardization to ensure that materials meet consistent quality and performance benchmarks.

Moreover, consultants are often caught between the conflicting demands of clients and contractors. Clients may push for cost-effective solutions, while contractors might resist changes to established practices, particularly if they perceive sustainable alternatives as more costly or challenging to implement. This tension requires architects and engineers to act as mediators, finding a middle ground that satisfies both parties while still advancing sustainability goals.

7.2.3. Interaction with Other Stakeholders

Consultants' Perception of Other Stakeholders

Consultants often view their role as that of a mediator or translator, helping to align the objectives of various stakeholders with the overarching goal of sustainability. However, they also encounter significant challenges in this role, particularly in their interactions with clients and contractors.

Clients: Architects and engineers, as facilitators, perceive clients as one of the biggest obstacles to the adoption of sustainable practices, primarily due to the latter's focus on upfront costs rather than long-term benefits. One consultant noted, "**Clients are more concerned about upfront costs rather than long-term benefits of Low Impact Materials**" (P09). This cost-driven mindset and using the cost as an excuse can make it difficult for facilitators to advocate for the use of innovative, low impact materials.

Furthermore, advocates feel that many clients lack a deep understanding of the potential advantages of LIMs, which can lead to hesitancy in embracing new technologies or approaches. To counter this, facilitators often emphasize the need for more education and awareness among clients, which could shift their focus towards the broader benefits of sustainability.

Contractors: Consultants, particularly those in engineering and architecture, express concerns about the willingness of contractors to engage with sustainable practices. Contractors may prefer to stick with familiar materials and methods, viewing sustainability as an added complexity rather than a core component of their work. "**Contractors tend to go for materials that are readily available and cheaper, which can compromise sustainability goals**" (P04). This reluctance to adopt sustainable alternatives can pose significant challenges for facilitators who are trying to integrate these practices into project designs.

Additionally, sustainability consultants are wary of the skills gap that exists among contractors. Many contractors lack the training or experience needed to effectively implement LIMs, leading to potential quality issues and project delays. This gap not only complicates the facilitator's role but also undermines the overall goal of achieving sustainability in construction.

Suppliers: Rather than simply relying on suppliers for the availability and quality of LIMs, consultants increasingly recognize the importance of involving suppliers earlier in the project lifecycle. Early engagement with suppliers can help ensure that the materials selected are not only sustainable but also fit seamlessly into the project's design and construction processes. "**Involving suppliers from the beginning allows us to tailor material choices to the specific needs of the project, reducing the risk of later complications**" one consultant explained (P07). By bringing suppliers into the discussion early on, facilitators can better align material innovation with project requirements.

Other Stakeholders' Perception of Consultants

Clients: From the clients' perspective, consultants are seen as essential guides in the complex world of sustainable construction. Clients rely on facilitators to provide expert advice on the best materials and practices to use, but they also sometimes perceive facilitators as overly focused on idealistic sustainability goals that may not align with project budgets or timelines. This perception can lead to tension, especially when facilitators push for solutions that are seen as costly or impractical.

Contractors: Contractors often view consultants, especially those acting as facilitators, as intermediaries who impose additional demands on their already challenging work. While they recognize the importance of sustainability, they may see facilitators as out of touch with the on-the-ground realities of construction. This perception can create friction, especially when facilitators

advocate for materials or methods that contractors find difficult or costly to implement. "**Consultants need to be more aware of the practical challenges we face on-site**" noted one contractor (P05).

Perception Between Themselves

There is a recognition among engineering and architectural consultants that sustainability consultants play a crucial role as advocates, driving the industry towards greener practices. However, there can also be a perception that sustainability consultants are sometimes too focused on ideal outcomes, without enough consideration for the practical constraints of projects. This can lead to differences in priorities and approaches between the two groups of consultants.

7.2.4. Addressing Challenges

Bridging the Communication Gap with Clients and Contractors

Consultants face the dual challenge of educating clients about the long-term benefits of LIMs while also convincing contractors to adopt new practices. To address these challenges, consultants must play a more proactive role. This could involve providing comprehensive cost-benefit analyses that demonstrate the long-term savings and environmental benefits of LIMs to clients. At the same time, consultants should advocate for continuous professional development among contractors to equip them with the necessary skills and knowledge.

Promoting Early Involvement of Suppliers

A significant challenge that consultants face is the need for early involvement of suppliers in the design and planning stages of projects. This early involvement helps to mitigate the risk of later complications, such as material availability issues or quality concerns, and ensures that sustainable practices are integrated from the outset

Enhancing Collaboration and Knowledge Sharing

Finally, consultants, including both facilitators and advocates, have a key role to play in shaping the regulatory environment. By working closely with governmental officials, they can ensure that regulations are both practical and supportive of innovation. This collaboration could lead to the development of more flexible and responsive regulatory frameworks that better align with the realities of sustainable construction.

7.2.5. The Strategic Role of Consultants

Consultants, as both facilitators and advocates, are the linchpin that connects policy with practice in the adoption of LIMs. Their ability to translate regulatory requirements into practical, actionable strategies makes them indispensable in the push towards sustainability. However, to maximize their impact, consultants must navigate the complex dynamics between clients, contractors, and suppliers, ensuring that all stakeholders are aligned with the shared goal of sustainability. By acting as the central point of communication between clients, contractors, and suppliers, consultants can facilitate a more integrated approach to project development. This collaboration is essential for overcoming the challenges associated with sustainable construction, such as the skills gap among contractors or the need for clients to understand the long-term benefits of sustainability.

7.3. Clients/Project Developers: Driving the Demand

7.3.1. The Role of Clients/Project Developers

Clients and project developers play a pivotal role in the construction industry's shift toward sustainable practices. As the primary decision-makers and financiers of construction projects, their preferences and demands significantly influence the adoption of low-impact materials. These stakeholders are in a unique position to **drive the market** toward sustainability by prioritizing environmentally friendly materials and methods in their projects. Their choices not only set the tone for the construction process but also send a strong signal to the rest of the industry, including contractors, consultants, and suppliers, about the importance of sustainability.

7.3.2. Challenges Faced by Clients/Project Developers

Balancing Cost with Sustainability

One of the most significant challenges for clients and project developers is the perceived conflict between sustainability and cost. LIMs often come with higher upfront costs, which can be a deterrent for developers focused on immediate financial returns. This short-term focus can lead to a reluctance to invest in innovative materials, even when the long-term benefits, such as reduced operational costs and increased property value, are clear. As one developer noted, "**Clients often overlook the long-term benefits in favor of short-term cost savings**" (P10).

Influencing Market Demand

Clients and project developers are also responsible for influencing market demand for LIMs. Their choices can drive suppliers and contractors to prioritize sustainability, creating a ripple effect throughout the industry. However, achieving this influence requires a shift in mindset, both within their organizations and across the broader market. One significant barrier is the existing market's lack of emphasis on sustainability, which can make it challenging for developers to justify the additional costs associated with LIMs. "**There is still a lot of resistance in the market because people are used to doing things a certain way, and it's hard to change that mindset**" observed one developer (P11).

7.3.3. Interaction with Other Stakeholders

Clients' Perception of Other Stakeholders

Contractors: Clients often view contractors as key players in the implementation of sustainable practices but are also aware of the practical challenges contractors face. Many clients express concerns about contractors' willingness and ability to adopt new materials and methods, especially when these involve higher costs or require specialized skills. As one client noted, "**We need contractors who are committed to sustainability and can deliver on our expectations**" (P03). This highlights the need for close collaboration between clients and contractors to ensure that sustainability goals are met without compromising the quality or feasibility of the project.

Suppliers: There is a growing acknowledgment among clients of the need to involve suppliers earlier in the project lifecycle, same as the consultants. Early supplier involvement can help to address potential supply chain issues and ensure that the materials chosen are not only sustainable but also suited to the specific needs of the project. "**By bringing suppliers into the process earlier, we can avoid a lot of the headaches that come later on with material**

availability and quality" (P06). This proactive approach can also encourage suppliers to innovate and align their offerings more closely with the evolving demands of sustainable construction.

Other Stakeholders' Perception of Clients

Contractors see clients as the initiators of sustainability efforts but often feel that these efforts are undermined by cost constraints. They appreciate when clients are willing to invest in sustainability but express concern when clients prioritize budget over environmental impact. "**Clients set the tone for sustainability, but if they're not willing to spend, it can be hard to meet those goals**" (P02). This perception highlights the need for clients to balance cost considerations with their sustainability objectives.

7.3.4. Addressing Challenges

Investing in Innovative and Low-Impact Materials

To overcome the reluctance to invest in sustainability, clients and project developers need to shift their focus towards embracing innovative and low-impact materials, even if these require higher initial investments. Rather than being deterred by the upfront costs, clients should recognize the potential long-term advantages that such materials can bring, not just in terms of environmental benefits but also in terms of market differentiation and future-proofing their assets.

Engaging Suppliers Early

A key strategy for addressing supply chain challenges is the early involvement of suppliers in the project planning stages. By engaging suppliers from the outset, clients can ensure that the materials chosen are aligned with the project's sustainability goals and are available when needed.

Creating Feedback Loops with Governmental Officials

Clients and project developers should engage in continuous dialogue with governmental officials to navigate the complexities of the regulatory environment effectively. This involves more than just staying informed about regulatory changes; it requires an active back-and-forth communication process where clients provide feedback on what is and is not working within current regulations. When clients encounter regulatory obstacles, they should proactively communicate these issues to the government, advocating for adjustments or additional incentives that would make sustainable practices more feasible. In turn, the government can respond by refining regulations and offering targeted incentives to support proactive clients.

Being Receptive to Consultant-Led Sustainability Education

To foster a culture of sustainability within their organizations, clients and project developers should remain open to the education and guidance provided by consultants, particularly those with expertise in sustainability. This involves actively seeking out and incorporating the latest knowledge and best practices into their projects, rather than viewing sustainability as a checkbox or an afterthought. This receptiveness to education not only enhances the sustainability outcomes of individual projects but also contributes to the broader industry movement towards more sustainable construction practices.

7.3.5. The Strategic Role of Clients and Project Developers

Clients and project developers occupy a strategic position in the construction industry, where their decisions have far-reaching implications. Their role extends beyond merely commissioning

projects; they are pivotal in setting the agenda for sustainable practices within the industry. Clients and project developers are not just participants in the construction process; they are key drivers of change. By setting high standards for sustainability, engaging in strategic collaboration and feedback loops with governmental officials, and fostering a culture of sustainability within their organizations, they can significantly influence the adoption of LIMs and practices across the industry.

7.4. Contractors: Implementers

7.4.1. The Role of Contractors

Contractors play a vital role in the construction industry as the primary **implementers** of sustainable practices on the ground. Contractors are the link between the theoretical aspects of sustainable design and the tangible outcomes seen in the built environment. Contractors have the unique responsibility of bridging the gap between the conceptual sustainability goals set by clients and consultants and the practical realities of construction.

7.4.2. Challenges Faced by Contractors

Logistical and Material Challenges

One of the primary challenges contractors face is the logistical complexity of sourcing, storing, and using LIMs. Unlike conventional materials, LIMs often require specific handling and storage conditions to maintain their integrity, which can complicate the construction process. Additionally, LIMs may not always be readily available in the quantities required, leading to potential delays and increased costs. As one contractor noted, "**Delays in material supply can disrupt the entire construction schedule**" (P05).

Resistance to Change within the Workforce

Implementing sustainable practices often requires changes in standard operating procedures, which can be met with resistance from the workforce. Long-standing practices and the use of traditional materials are deeply ingrained in the construction industry. Convincing workers to adopt new methods and materials, especially when they involve additional training or changes in workflow, can be a significant challenge. Resistance to change can slow down the adoption of sustainable practices, reduce efficiency, and lead to potential conflicts within the team. This is more so evident with smaller contractors which as one practitioner stated, the demand is much higher for skilled workers than compared to the supply of prepared workers.

Managing Client Expectations

Clients may have high expectations for sustainability outcomes without fully understanding the complexities and challenges involved in implementing such practices. They may expect contractors to achieve ambitious sustainability goals within tight budgets and timelines, without appreciating the potential trade-offs in terms of costs, material availability, or project duration. Contractors need to manage these expectations by communicating the realities of sustainable construction clearly and setting achievable goals from the outset.

7.4.3. Interaction with Other Stakeholders

The Contractor's perception of the other stakeholders was presented in the earlier chapters, so only the perception of the other stakeholders towards contractors will be summarized below.

Perception of Contractors by Other Stakeholders

Other stakeholders generally view contractors as essential implementers of sustainability initiatives but also as a potential bottleneck if they are not fully committed to sustainable practices. Consultants often express concerns that contractors may prioritize cost savings over sustainability, which can undermine the overall goals of the project. However, they also recognize that contractors are under significant pressure to deliver projects on time and within budget, which can sometimes lead to difficult compromises. Governmental officials view contractors as the front-line enforcers of sustainability regulations and standards, emphasizing the need for contractors to adhere strictly to these guidelines to ensure that projects meet regulatory requirements.

7.4.4. Addressing Challenges

Enhancing Logistics and Material Management

To overcome the logistical and material challenges associated with sustainable construction, contractors should establish strong relationships with multiple suppliers to ensure a steady and reliable supply of materials. Additionally, incorporating flexibility into project schedules to accommodate potential delays in material delivery can help mitigate disruptions. As one practitioner emphasized, "**We need to anticipate supply chain disruptions and be ready to adapt quickly**" (P07). Also, the support of earlier supplier involvement in the process, as emphasized by consultants as well can be a great improvement towards any supply chain disruptions.

Fostering Workforce Adaptability

Addressing resistance to change within the workforce requires a concerted effort to shift organizational culture toward sustainability. Contractors can achieve this by providing continuous education and training programs that emphasize the benefits and importance of sustainable practices. These programs should be designed to not only enhance technical skills but also to foster a mindset open to innovation and change. As one contractor noted, "**It's about getting everyone on board**" (P10). This also involves trusting younger professionals more on the side of sustainability, as the mindset of the employees coming in the last years from universities is more developed on being open towards this transition.

Managing and Aligning Client Expectations

To effectively manage client expectations, contractors must engage in transparent and proactive communication from the outset of a project. Contractors should work closely with clients as well as with the consultants and suppliers to develop a shared understanding of the project's sustainability objectives and ensure that these are achievable within the given constraints. By aligning expectations early, contractors can avoid misunderstandings and ensure that clients are satisfied with the project's outcomes.

7.4.5. The Strategic Role of Contractors

Contractors are the linchpin in the successful implementation of sustainable practices in the construction industry. Their ability to translate sustainability goals into practical, on-the-ground outcomes makes them critical players in the industry's shift towards greener practices. As sustainability becomes increasingly important in the construction industry, contractors who excel in this area will gain a competitive advantage. Clients and developers are likely to favor contractors who can deliver projects that meet high sustainability standards, recognizing the long-term value of

such investments. By investing in skills and training, collaborating early with suppliers, and working closely with clients and consultants, contractors can overcome the challenges they face and become leaders in the sustainable construction movement.

7.5. Suppliers: Innovators & Providers

7.5.1. The Role of Suppliers

As the providers of these materials, suppliers hold a unique position of influence within the supply chain as **innovators and providers**. Their role is not merely transactional; they are the creators of the very products that shape the sustainability of construction projects. Suppliers drive the development of new materials, meet quality standards, and ensure that LIMs are available to meet the growing demand in the industry. Although the direct perspective of suppliers was not captured in the interviews conducted for this study, their influence and the challenges they face can be inferred from the perspectives of other stakeholders.

7.5.2. Challenges Faced by Suppliers

Development of LIMs

One of the primary challenges suppliers face is the continuous need for innovation in developing Low Impact Materials. The construction industry is increasingly demanding materials that not only meet environmental standards but also perform on par with or better than traditional materials. This demand requires suppliers to invest heavily in research and development (R&D) to create materials that are both sustainable and viable in a competitive market.

Meeting Quality and Standardization Expectations

Suppliers are also under pressure to meet stringent quality and standardization expectations. As more projects incorporate Low Impact Materials, there is a growing need for consistency in quality to ensure that these materials can be reliably used across various projects and conditions. This expectation for high standards extends not just to the final product but also to the processes used in material production, including sourcing, manufacturing, and transportation.

Supply Chain and Logistical Complexities

The logistical challenges of providing LIMs are another significant concern for suppliers. As sustainability becomes a central focus, suppliers must ensure that their materials are sourced responsibly and transported in ways that minimize environmental impact. This includes managing supply chains that are often global, ensuring that materials arrive on time and in the condition required for their intended use. The complexity of these supply chains can lead to disruptions, especially when external factors such as geopolitical events or global pandemics impact the flow of goods. Also, for recycled and circular materials there are other logistical problems such as storing, not enough materials, maintenance uncertainties, quality differentials being just examples of variables.

7.5.3. Interaction with Other Stakeholders

While direct interviews with suppliers were not conducted, it is evident from the perspectives of other stakeholders that suppliers are seen as crucial partners in the innovation process. Consultants, contractors, and clients alike depend on suppliers to bring new and improved sustainable materials to the market. However, there is a clear call for earlier and more consistent

involvement of suppliers in the design and planning phases of construction projects. This involvement is crucial for ensuring that the materials developed meet the specific needs and constraints of each project.

One of the significant concerns raised by other stakeholders, particularly consultants and contractors, is the issue of greenwashing by certain suppliers. Stakeholders have expressed frustration over suppliers who exaggerate the sustainability credentials of their materials without providing sufficient evidence or transparency. This lack of transparency creates challenges for consultants and contractors who rely on accurate and honest information to make informed decisions about material selection. As one consultant mentioned, "**We need reliable data from suppliers to ensure that the materials we choose truly meet the standards required**" (P04).

7.5.4. Addressing the Challenges

Enhancing Collaboration with Stakeholders

For suppliers to effectively overcome the challenges they face, it is crucial to enhance collaboration with other stakeholders in the construction process. This means engaging more actively with consultants and contractors early in the project lifecycle to ensure that their materials meet the specific requirements and sustainability goals of each project. Additionally, suppliers should work closely with governmental officials to ensure their materials comply with current and upcoming regulations. By being actively involved in discussions around regulatory changes and sustainability standards, suppliers can influence the development of policies that are both realistic and supportive of innovation.

Improving Transparency and Combating Greenwashing

To address the challenges related to greenwashing and the lack of transparency, suppliers must commit to providing clear, verifiable data about their materials. This includes full disclosure of the material's lifecycle, environmental impact, and compliance with sustainability standards. By adopting third-party certifications and engaging in rigorous, transparent testing processes, suppliers can build trust with contractors, consultants, and clients. Suppliers should focus on developing clear and accessible Environmental Product Declarations (EPDs) that provide all stakeholders with reliable data, thereby reducing skepticism and enabling informed decision-making. By prioritizing transparency, suppliers can distinguish themselves from competitors who may resort to greenwashing, thus fostering stronger relationships within the supply chain.

Driving Innovation in Material Development

Suppliers need to focus on continuous innovation to meet the evolving demands of the construction industry. This involves not only developing new sustainable materials but also improving the performance and scalability of existing ones. Additionally, by involving themselves earlier in the design phase of projects, suppliers can better align their material offerings with the specific needs of each project, ensuring that their innovations are practical and widely applicable.

7.5.5. The Strategic Role of Suppliers

Suppliers are at the forefront of driving innovation and providing sustainable materials. Their ability to innovate, maintain transparency, and ensure material availability directly impacts the success of sustainable construction projects. However, the strategic importance of suppliers extends beyond merely providing materials; it encompasses their influence on shaping industry standards and

fostering collaboration among all stakeholders. Suppliers who prioritize transparency and engage in open, honest communication with contractors, consultants, and clients are more likely to build long-term, trust-based relationships. By providing clear, verifiable data on their materials, and working closely with other stakeholders from the early stages of projects, suppliers can ensure that their materials are not only compliant with regulations but also meet the specific needs of each project. By addressing their challenges and leveraging their strategic importance, suppliers can help accelerate the adoption of sustainable materials, ensuring that they become a standard, rather than an exception, in construction projects.

7.6. SMEs: The Sideline Innovators

Small and Medium-sized Enterprises (SMEs) play a unique and often underappreciated role in the adoption of sustainable materials within the construction industry. While they may not have the same level of influence or resources as larger firms, their agility and innovative spirit allow them to be significant contributors to sustainability efforts, often acting as early adopters and testers of new materials and methods.

7.6.1. Role and Influence of SMEs

SMEs are frequently at the forefront of innovation due to their smaller scale, which allows them to experiment with sustainable materials and practices more freely than larger firms, which may be more risk averse. By integrating these new materials into smaller projects, SMEs can provide valuable feedback to suppliers, governmental officials and larger industry players, helping to refine and improve sustainable solutions before they are adopted on a larger scale. Moreover, SMEs often bring fresh perspectives and creative approaches to problem-solving, which can lead to the discovery of novel applications for sustainable materials. This innovative mindset is essential for pushing the boundaries of what is possible in sustainable construction.

7.6.2. Challenges Faced by SMEs

Despite their potential, SMEs face several challenges in contributing to the sustainability agenda. Limited financial resources and access to advanced technologies can hinder their ability to fully engage with the latest sustainable practices. Additionally, SMEs may struggle with navigating the complex regulatory environment, which is often designed with larger firms in mind. Moreover, the impact of their innovations may be limited by their smaller project sizes and lack of visibility in the broader industry. This can make it difficult for SMEs to scale their innovations or influence industry-wide practices significantly. Another challenge may be the lack of personnel given the demand necessary for their type of projects.

7.6.3. Strategic Importance of SMEs

Despite these challenges, the role of SMEs should not be underestimated. Their contributions may become vital in testing and refining sustainable materials. By collaborating with suppliers and participating in pilot projects, SMEs can help accelerate the adoption of low-impact materials across the industry. To maximize their impact, it is crucial that SMEs receive targeted support, including access to funding, technology, and training. Additionally, fostering partnerships between SMEs and larger firms or governmental bodies can help bridge the gap between innovation and implementation, ensuring that the sustainability innovations pioneered by SMEs can be scaled and

integrated into mainstream construction practices. In conclusion, while SMEs may operate on the sidelines, their role as innovators in the construction industry is essential.

7.7. Integrating Perspectives: Demonstrating the Ecosystem

The successful adoption of Low Impact Materials (LIMs) in the Dutch construction industry relies on the complex and dynamic interactions between various stakeholders, each playing a distinct yet interconnected role in driving or hindering sustainable practices. To encapsulate these relationships, the spider diagram has been developed, offering a visual representation of the roles, interactions, and influence of each actor within the sustainability ecosystem. This diagram serves as a comprehensive overview, synthesizing the key insights drawn from the preceding sections.

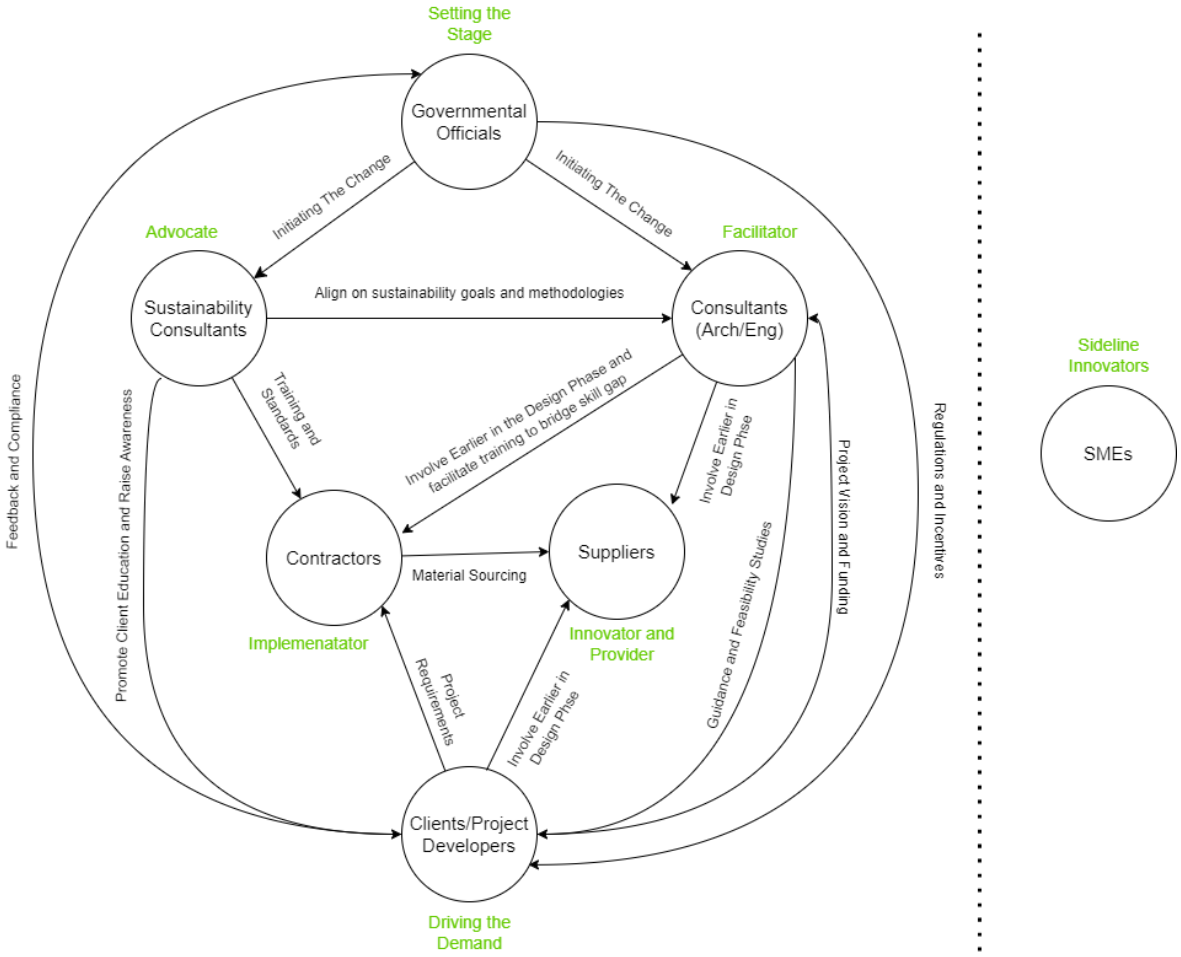

Figure 9 - Spider Diagram Actor Interactions

7.7.1. The Central Role of Governmental Officials

At the top of the diagram are the **Governmental Officials**, who "Set the Stage" for the entire industry. Their role is critical as they establish the regulatory frameworks that dictate the pace and direction of sustainability initiatives. They are the ones who can push the process and make certain “wheels” to start moving towards desired purposes. Through their regulations, incentives, and

policies, they influence every other actor, underscoring their central position in the ecosystem. However, their effectiveness is often tempered by the complexity of balancing competing interests and keeping pace with rapid technological advancements. The feedback loop between governmental officials and other stakeholders, particularly clients, is crucial.

7.7.2. Consultants as Facilitators and Advocates

Positioned as **Facilitators**, **Architects and Engineers** bridge the gap between regulatory frameworks and practical implementation, translating policies into actionable strategies. Their collaboration with **Sustainability Consultants**, who are labeled as **Advocates**, further enhances this process by pushing for higher environmental standards and guiding projects toward certification and compliance. Together, they ensure that LIMs are integrated effectively into construction projects, influencing both the initial design and long-term sustainability of buildings. The diagram highlights the critical connection between consultants and other stakeholders, particularly suppliers and clients. The need for early supplier involvement is emphasized, as it helps align material selection with project requirements.

7.7.3. Clients/Project Developers as the Drivers of Demand

Clients and Project Developers are positioned at the bottom of the diagram, **driving demand** for sustainable practices. They hold significant power in the decision-making process, as their preferences and willingness to invest in sustainability set the tone for the entire project lifecycle. Their interaction with governmental officials is particularly vital; by providing feedback and advocating for clear, supportive regulations, clients can help shape a regulatory environment. Moreover, their relationship with contractors, consultants and suppliers is essential for ensuring that LIMs are selected and implemented effectively.

7.7.4. Contractors: Implementers

Contractors, as the **Implementers**, are directly responsible for executing sustainable practices on the ground. Their relationship with suppliers is crucial, as the availability and quality of LIMs directly impact their ability to meet sustainability targets. The diagram reinforces the importance of contractors collaborating closely with both suppliers and consultants to overcome these challenges and ensure the successful implementation of the desires of clients.

7.7.5. Suppliers: Innovators & Providers

Suppliers are identified as **Innovators and Providers**, at the heart of material development and supply. They drive the creation of new LIMs and are responsible for meeting the industry's growing demand for high-quality, standardized materials. Their strategic role is underscored by the need for transparency and early involvement in project planning, ensuring that their innovations align with industry needs and regulatory requirements.

7.7.6. SMEs: Sideline Innovators

While **SMEs** are positioned on the periphery of the diagram as **Sideline Innovators**, their role is far from marginal. SMEs can bring agility and creativity to the sustainability landscape, maybe acting as early adopters and testers of new materials. Their smaller scale allows them to experiment more freely, providing valuable feedback to larger firms and suppliers. However, their influence is often

limited by their scale and resources, making it essential for them to receive targeted support to maximize their impact on the industry's sustainability goals. They are the “Wildcard” of the industry.

7.7.7. Conclusion: Answering SQ3

The spider diagram, therefore, serves as a synthesis of the complex interrelations between these key stakeholders, and through this analysis, it becomes clear that the perspectives and interactions of these actors are central to understanding how to accelerate the adoption of LIMs. Each actor's role is interconnected with others, creating a web of influence that determines the success of sustainable practices within the industry. The diagram illustrates not only the flow of influence—such as how governmental policies impact all other stakeholders—but also the importance of collaboration across different roles to overcome challenges and drive the adoption of LIMs.

In conclusion, this chapter effectively answers SQ3 by mapping out the perspectives of key stakeholders regarding the acceleration of LIMs. The interactions and roles depicted in the diagram emphasize that the adoption of sustainable materials is not driven by a single. Certain stakeholders such as governmental officials and clients have more power than the others, hence the positioning in the diagram at the top and bottom of it, however they cannot make the process work individually. By understanding and leveraging these relationships, the construction industry can move toward a more sustainable future, where LIMs are not just an option but a standard.

8. Conclusion

This research aimed to explore the critical factors influencing the adoption of LIMs in the Dutch construction industry. The central research question guiding this study was: "***How can the Dutch construction industry accelerate the market acceptance of low impact materials to achieve net zero building ambitions?***" To answer this overarching question, three sub-questions were addressed. This chapter provides an overview of how each sub-question was answered and synthesizes the findings to draw overall conclusions.

8.1. Answering Sub-Question 1

" What factors hinder or facilitate the market acceptance of low impact materials in achieving net zero building ambitions?"

Main Takeaway: Social and market themes are as relevant if not more relevant than the surface themes such as cost, regulations or technical issues. This underscores the importance of addressing the human element in sustainability initiatives. Without changing mindsets and fostering a culture that values sustainability, other efforts may fall short.

This has resulted in the development of two primary directions that influence adoption: the technical direction “understanding low impact materials”, which includes advancements in material technologies, evaluation of materials and supply chain efficiencies, and the social/market direction “accelerating the adoption”, which encompasses regulatory, economic, cultural and educational factors. The interplay between these directions highlights that overcoming technical barriers is contingent upon addressing the underlying social dynamics that shape industry practices and perceptions.

8.2. Answering Sub-Question 2

"What critical information about low-impact materials is needed to make informed decisions?"

Main Takeaway: Transparency in material information, communication between public and private sector, combined with rigorous evaluation methods and robust supply chain management, are crucial for making suitable, sustainable decisions in the construction industry.

Diving deeper into the "Understanding Low Impact Materials" direction, it became evident that making informed decisions about these materials requires a thorough understanding of their "story". The importance of clear definitions and industry-wide standards for Low Impact Materials (LIMs) was underscored as essential for ensuring consistency and comparability. However, while standardization is crucial, it must be carefully balanced to avoid hindering innovation.

Additionally, stakeholders need access to detailed and comprehensive data on the environmental impacts of materials, supported by tools such as LCAs and EPDs. Moreover, the chapter highlights the need for a future, more stringent, and mandatory version of the MPG, aimed at making the framework more reliable and transparent, thereby bolstering trust in sustainable practices.

Furthermore, the involvement of all relevant actors, including SMEs, in pilot projects is emphasized as a key strategy for validating new materials. This collaborative approach not only assesses the practical application of LIMs but also democratizes the innovation process, ensuring that a broader spectrum of knowledge and experience contributes to the industry's sustainability efforts.

8.3. Answering Sub-Question 3

"What are the perspectives of key stakeholders regarding the use of Low Impact Materials?"

Main Takeaway: The adoption of sustainable materials hinges on a complex web of influence where every actor plays a vital role. While governmental officials and clients hold significant power, their efforts alone are not enough. It is the synergy between all stakeholders that transforms LIMs from an option into the industry standard. By leveraging these dynamic relationships, the construction industry can propel itself into a future where sustainability is the norm, not the exception.

The analysis of the second direction of “Accelerating the Adoption” demonstrated that collaboration across these groups is vital. A notable insight was the critical role of collaborative platforms that enable stakeholders to share knowledge, experiences, and best practices. Creating such platforms can bridge the gap between different actors, fostering a more unified approach to overcoming barriers and promoting the use of Low Impact Materials.

8.4. Answering Main Question

Throughout this research, a profound shift in understanding has emerged, revealing that the social and market dynamics—the human interactions—are not merely another factor among many but the very backbone of the conclusions drawn for all three research questions. In an industry as technically driven as construction, it might seem intuitive to assume that the solution to accelerating the adoption of Low Impact Materials (LIMs) would be rooted in technical advancements or substantial financial investments. While these elements certainly play a crucial

role, the analysis has shown that the most important driver is something far less tangible but infinitely more powerful: collaboration.

Collaboration, transparency, and communication have surfaced as the essential pillars needed to bridge the gap between ambition and action in the Dutch construction industry. There is no single driver that can resolve all the challenges, just as there is no singular barrier that stands in the way. However, by fostering genuine collaboration across all stakeholders—government officials, clients, contractors, suppliers, consultants, and SMEs—the industry can begin to break down the silos that often impede progress. Transparency and open communication must permeate every layer of interaction, ensuring that all parties are working towards the same sustainability goals with a shared understanding.

A fitting parallel to this collaborative approach can be drawn from the Dutch "polder model," a governance and consensus model deeply ingrained in Dutch culture. The polder model is characterized by "a pragmatic recognition of pluriformity" and the ability to achieve "cooperation despite differences." It is precisely this spirit of cooperation and mutual respect for differing perspectives that the Dutch construction industry must embrace to accelerate the adoption of LIMs. By recognizing the pluriformity within the industry and working together towards a common goal, stakeholders can overcome the complexities and challenges that come with implementing sustainable practices.

In answering the central research question—"How can the Dutch construction industry accelerate the market acceptance of low impact materials to achieve net zero building ambitions?"—the conclusion is clear: it is not through singular, isolated efforts but through a collective, coordinated approach that success will be achieved. The industry must "just do it"—not in a rushed, haphazard manner but through deliberate, well-coordinated actions that leverage the strengths of every stakeholder. This proactive mindset, supported by collaboration, transparency, and communication, will propel the Dutch construction industry towards its net zero building ambitions.

As one stakeholder aptly put it, "**Just do it. I think it's the best approach to accelerate the adoption of Low Impact Materials in the Dutch construction industry**" (P08). This ethos captures the essence of moving from intention to action, from individual efforts to collective progress. By working together, the industry can overcome the NIMBY (Not In My Back Yard) mentality and move towards a future where sustainability is not just a goal but a standard practice across the board.

9. Discussion

9.1. Limitation of the Project and Future Research Recommendations

Despite the comprehensive approach taken in this research, several limitations were encountered that should be acknowledged:

1. **Scope and Generalizability**: The study focused on the Dutch construction industry, which may limit the generalizability of the findings to other regions, even specific regions in Netherlands or countries. Different regulatory environments, cultural contexts, and market conditions could affect the applicability of the results elsewhere.
2. **Sample Size and Representation**: The research relied on interviews with a limited number of stakeholders. While efforts were made to include diverse perspectives, the sample size may not fully capture the entire spectrum of views within the industry. Future studies with larger and more representative samples could provide a more comprehensive understanding.
3. **Self-Reported Data**: The data collected through interviews are based on self-reported information, which may be subject to biases such as social desirability or selective memory. Participants might have presented their perspectives in a way that aligns with perceived expectations or industry norms.
4. **Evolving Industry Dynamics**: The construction industry is rapidly evolving, particularly regarding sustainability practices. The findings of this study reflect the state of the industry at the time of research. Changes in regulations, technological advancements, and market conditions could influence the relevance of the results over time.
5. **Focus on Qualitative Data**: This research primarily employed qualitative methods to gather insights from stakeholders. While this approach provided in-depth understanding, it may lack the quantitative rigor needed to generalize findings across a larger population. Future research could benefit from combining qualitative and quantitative methods.
6. **Limited Focus on Specific Materials**: Although the study explored LIMs in general, it did not delve deeply into specific types of materials or technologies. A more detailed examination of LIMs and their unique challenges and benefits could provide more actionable insights.
7. **Potential Biases in Interviewee Selection**: The selection of interviewees was based on their availability and willingness to participate. This could introduce selection bias, as those who chose to participate might have more favorable views towards sustainability. Including stakeholders with more critical perspectives could offer a more balanced view.
8. **Economic and Financial Constraints**: The study did not extensively explore the economic and financial constraints faced by small to medium-sized enterprises (SMEs) within the industry, only one practitioner working directly on these types of projects. SMEs often encounter unique challenges that differ from larger firms, and these constraints might significantly impact their ability to adopt LIMs.
9. **Temporal Limitations**: The research was conducted over a specific period, which might not capture long-term trends and developments in the industry. The timing of the study could influence the findings, particularly in a rapidly changing field like sustainable construction.

9.2. Reflection

Embarking on this research journey has been a transformative experience, not just academically but also personally. My initial perception of the sustainable construction industry was rather simplistic. I viewed it as a straightforward transition from traditional to LIMs driven by clear regulations and economic incentives. Given my background of five years in university (4,5 at the point of the start of the project) I believed that given the number of projects we did during university with a large focus on sustainability in general, I believed that the real-world projects are already leaning towards those values. This is not 100% not true as there many projects and practitioners which encapsulate the value of sustainability as a must, however there is a large side of the market that is not like this. As the project unfolded, I realized that the landscape is far more complex, requiring a multifaceted approach that addresses various technical, economic, social, and regulatory challenges.

The project scope, direction, and focus underwent numerous changes from the initial proposal to my chairman, resulting in a continual process of back-and-forth adjustments and trial and error. This necessitated a far more extensive literature review than I had anticipated, especially compared to my Bachelor's Thesis, which was much more straightforward. This iterative process proved to be both challenging and frustrating at times. However, I am immensely grateful for the experience. There were many progress meetings with one or both of my supervisors where I felt certain that my current approach was "the one." Yet, often, it was demonstrated that further adjustments were needed or that the direction was not feasible.

Throughout the project, my chairman would often ask, "How do you feel about the project?" Coming from a technical background with a straightforward, quantitative bachelor's thesis, I initially assumed this project would follow a similar path. Early on, my response was, "So and so, but very confident in the outcome." As the project progressed, my answer evolved to, "Really happy about it but sometimes confused about the outcome."

Reflecting on the journey, I can confidently say I've learned an immense amount and grown significantly in my field. However, I find myself more curious and eager to learn about certain aspects than ever before, which is a good thing. If asked the same question now, I would respond, "I am so enthusiastic about this project, but I remain curious about so many things." Given more time, I would delve deeper into several areas. Nonetheless, I am thrilled to have answered all my research questions and contributed a new, objective perspective to a critical and timely issue in our industry. As a sidenote, Mr. Chan, I hope I can proudly say I brought a "small research dot" to our discussions from a few months ago.

During the interview phase, I was pleasantly surprised by the number of responses I received to my emails and messages. It was encouraging to see so many people genuinely interested in my research topic, willing to spend considerable time answering all my questions and providing valuable insights. This part of the project was particularly exciting as I had to adapt the interview setup each time to accommodate the diverse backgrounds of the practitioners. Each interview brought unique perspectives, enriching the research with a variety of viewpoints. The only disappointment was my inability to secure an interview with a supplier, the only category of stakeholder missing from my research. Despite this, the enthusiasm and engagement from other

participants more than made up for it, highlighting the collective interest in advancing sustainable practices in the construction industry.

The most challenging aspect of the current research and report was determining what information was essential and novel and making sense of the vast amount of data from both literature and interviews, which predominantly came together in Chapter 5 on barriers and drivers. This chapter underwent numerous iterations, complicating the writing of subsequent chapters since everything hinged on Chapter 5's conclusions and insights. This process deepened my understanding of the multifaceted nature of problems, revealing that no single barrier or driver alone dictates the process. The interconnectedness of various factors—ranging from social and technical to economic and regulatory—became evident.

From Chapters 6 and 7, I learned that logistical and technical aspects of a material cannot be addressed in isolation from the social aspects, and vice versa. It is crucial to understand the material's intended use, procurement, and evaluation while ensuring all stakeholders are aligned. Transparency and collaboration emerged as key themes from these chapters. A significant realization from Chapter 7 was that the transition to sustainable practices cannot be achieved by any single actor alone; it requires a collective effort, despite the varying influence of different stakeholders. The knowledge gap among stakeholders and lack of communication are significant impediments to this transition.

In conclusion, this research project has profoundly changed my perception of the sustainable construction industry. It has highlighted the complexity of the challenges involved and the need for a holistic, coordinated approach that addresses regulatory, technical, financial, cultural, and educational barriers. The insights gained have underscored the importance of government action, stakeholder collaboration, cultural change, and transparency in driving the adoption of sustainable practices. As I reflect on this journey, I am more convinced than ever that achieving sustainability in construction is not just a technical challenge but a multifaceted endeavor that requires the collective effort and commitment of all stakeholders. This realization has not only enriched my understanding but also reinforced my passion for contributing to this critical field.

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Appendix 1: Complete Overview Scheme Barrier Themes

	Initial Themes Literature Review	Identification Green and Blue Barriers	Filtering Blue Themes
Category 1: Economic and Financial Barriers	- High Initial Investment Costs	- High Initial Investment Costs	~~- High Initial Investment Costs~~
	- Long-term Financial Benefits vs. Short-term Costs	- Long-term Financial Benefits vs. Short-term Costs	~~- Long-term Financial Benefits vs. Short-term Costs~~
	- Economic Uncertainties and Risk Perception	- Economic Uncertainties and Risk Perception	- Economic Uncertainties and Risk Perception
	- Organizational and Procedural Costs	~~- Organizational and Procedural Costs~~	
	- High Implementation Costs (BIM)	~~- High Implementation Costs (BIM)~~	
Category 2: Skills and Knowledge Deficiencies	- Skills Gap in the Industry	- Skills Gap in the Industry	~~- Skills Gap in the Industry~~
	- Educational and Training Barriers	~~- Educational and Training Barriers~~	~~- Lack of Continuous Professional Development~~
	- Lack of Continuous Professional Development	- Lack of Continuous Professional Development	- Lack of Awareness and Understanding (Stakeholders)
	- Organizational Resistance to Training	~~- Organizational Resistance to Training~~	
	- Lack of Awareness and Understanding (Stakeholders)	- Lack of Awareness and Understanding (Stakeholders)	
	- Lack of Awareness and Understanding (BIM)	~~- Lack of Awareness and Understanding (BIM)~~	
Category 3: Regulatory and Compliance Challenges	- Complexity and Inconsistency in Regulations	- Complexity and Inconsistency in Regulations	~~- Complexity and Inconsistency in Regulations~~
	- Bureaucratic Challenges	- Bureaucratic Challenges	~~- Bureaucratic Challenges~~
	- Strict and Rigid Regulations	- Strict and Rigid Regulations	~~- Strict and Rigid Regulations~~
	- Insufficient Incentives and Support	- Insufficient Incentives and Support	- Insufficient Incentives and Support
Category 4: Quality and Performance Uncertainties	- Uncertainty in New Technologies	- Uncertainty in New Technologies	~~- Uncertainty in New Technologies~~
	- Reliability of Assessment Tools	- Reliability of Assessment Tools	- Reliability of Assessment Tools
	- Variability in Material Quality and Standardization Concerns	- Variability in Material Quality and Standardization Concerns	- Variability in Material Quality and Standardization Concerns
	- Concerns with Recycled Materials	- Concerns with Recycled Materials	~~- Concerns with Recycled Materials~~
Category 5: Data and Information Gaps	- Inconsistencies in Data Collection and Reporting	- Inconsistencies in Data Collection and Reporting	~~- Inconsistencies in Data Collection and Reporting~~
	- Lack of Comprehensive Databases	- Lack of Comprehensive Databases	- Lack of Comprehensive Databases
	- Measurement Uncertainty	- Measurement Uncertainty	- Measurement Uncertainty
	- Limited Integration of Data in Decision-Making	~~- Limited Integration of Data in Decision-Making~~	
Category 6: Cultural and Behavioral Barriers	- Resistance to Change	- Resistance to Change	~~- Resistance to Change~~
	- Social Norms and Perceptions	- Social Norms and Perceptions	- Social Norms and Perceptions
	- Diverse Stakeholder Interests	- Diverse Stakeholder Interests	- Diverse Stakeholder Interests
	- Insufficient Engagement Strategies	- Insufficient Engagement Strategies	- Insufficient Engagement Strategies
Category 7: Supply Chain of Materials	- Lack of Coordination and Integration (Supply)	~~- Lack of Coordination and Integration (Supply)~~	~~- Inconsistent Supply and Quality of Materials~~
	- Inconsistent Supply and Quality of Materials	- Inconsistent Supply and Quality of Materials	- Supply Chain Disruptions
	- Supply Chain Disruptions	- Supply Chain Disruptions	- Scarcity of Low-Carbon Materials
	- Scarcity of Low-Carbon Materials	- Scarcity of Low-Carbon Materials	
Category 8: Technological Barriers	- Inadequate Technological Infrastructure	~~- Inadequate Technological Infrastructure~~	
	- Limited Access to Advanced Technologies	~~- Limited Access to Advanced Technologies~~	
	- Slow Technological Advancement	~~- Slow Technological Advancement~~	
	- Intricacy of LCA Methodologies	~~- Intricacy of LCA Methodologies~~	
	- Technical Challenges and Integration Issues (BIM)	~~- Technical Challenges and Integration Issues (BIM)~~	

	Final Barrier Themes Blue + Red
Category 1: Economic and Financial Barriers	Economic Uncertainties and Risk Perception
	Cost as a Convenient Excuse
	Reluctance to Pay Upfront Costs
Category 2: Skills and Knowledge Deficiencies	Lack of Awareness and Understanding (Stakeholders)
	Lack of Practical Experience
	Limited Access to Training Resources for SME
Category 3: Regulatory and Compliance Challenges	Insufficient Incentives and Support
	Dependency on Government Regulations
	Slow Government Action
	Clear Framework from Government
	Lack of Private Sector Engagement
Category 4: Quality and Performance Uncertainties	Reliability of Assessment Tools
	Variability in Material Quality and Standardization Concerns
	Fire Hazards and Strength Requirements
	Lack of Perceived Advantages
	Maintenance of Low Impact Materials
Category 5: Data and Information Gaps	Lack of Comprehensive Databases
	Measurement Uncertainty
	Need for Research on Real Projects and for Pilot Projects
	Certification and Verification for Materials
Category 6: Cultural and Behavioral Barriers	Social Norms and Perceptions
	Diverse Stakeholder Interests
	Insufficient Engagement Strategies
	Fear of Unproven Methods
	Behavioral Inertia
	Fear of Experimentation and/or Disqualification from Tenders
Category 7: Supply Chain of Materials	Supply Chain Disruptions
	Scarcity of Low-Carbon Materials
	Greenwashing
	Limiting Supplier Options
	Vendor Influence on Material Choice
	Logistical Challenges

Figure 10 - Complete Overview Scheme Barrier Themes

Appendix 2: Complete Overview Scheme Driver Themes

	Initial Themes Literature Review	Identification Green and Blue Drivers	Filtering Blue Themes
Category 1: Regulations, Policy and Standards	- Regulatory Standards and Compliance	- Regulatory Standards and Compliance	~~- Regulatory Standards and Compliance~~
	- Encouraging Market Transformation	- Encouraging Market Transformation	- Encouraging Market Transformation
	- Regional and International Policies	- Regional and International Policies	- Regional and International Policies
	- Establishing Global Benchmarks	- Establishing Global Benchmarks	- Establishing Global Benchmarks
Category 2: Technological and Digital Innovation	- Development of High-Performance, Low-Carbon Materials	- Development of High-Performance, Low-Carbon Materials	- Development of High-Performance, Low-Carbon Materials
	- Integration of Smart Technologies	~~- Integration of Smart Technologies~~	~~- Enhancements in Lifecycle Assessment (LCA)~~
	- Enhancements in Lifecycle Assessment (LCA)	- Enhancements in Lifecycle Assessment (LCA)	~~- Enhanced Design and Planning (BIM)~~
	- Enhanced Design and Planning (BIM)	- Enhanced Design and Planning (BIM)	
	- Improved Collaboration and Efficient Project Management (BIM)	~~- Improved Collaboration and Efficient Project Management (BIM)~~	
Category 3: Financial and Economic Drivers	- Reducing Financial Barriers Through Subsidies and Grants	- Reducing Financial Barriers Through Subsidies and Grants	~~- Reducing Financial Barriers Through Subsidies and Grants~~
	- Encouraging Investment in Sustainable Technologies with Financial Incentives	- Encouraging Investment in Sustainable Technologies with Financial Incentives	~~- Encouraging Investment in Sustainable Technologies with Financial Incentives~~
	- Long-Term Financial Savings	- Long-Term Financial Savings	- Long-Term Financial Savings
	- Insufficient Incentives and Support	- Insufficient Incentives and Support	~~- Insufficient Incentives and Support~~
Category 4: Stakeholder Eng. & Public Sector Leadership	- Leading by Example (Public Sector Leadership)	- Leading by Example (Public Sector Leadership)	- Leading by Example (Public Sector Leadership)
	- Collaborative Approaches	- Collaborative Approaches	~~- Collaborative Approaches~~
	- Addressing Stakeholder Concerns	- Addressing Stakeholder Concerns	- Addressing Stakeholder Concerns
Category 5: Market Demand and CSR	- Consumer Preferences and Market Demand	- Consumer Preferences and Market Demand	- Consumer Preferences and Market Demand
	- Corporate and Institutional Demand	- Corporate and Institutional Demand	~~- Corporate and Institutional Demand~~
	- Enhancing Corporate Reputation (CSR)	- Enhancing Corporate Reputation (CSR)	- Enhancing Corporate Reputation (CSR)
	- Driving Innovation and Sustainable Practices (CSR)	- Driving Innovation and Sustainable Practices (CSR)	~~- Driving Innovation and Sustainable Practices (CSR)~~
Category 6: Educ. Programs and Climate Awar.	- Supporting Continuous Professional Development	- Supporting Continuous Professional Development	- Supporting Continuous Professional Development
	- Facilitating Industry Collaboration	- Facilitating Industry Collaboration	- Facilitating Industry Collaboration
	- Educational and Awareness Campaigns	~~- Educational and Awareness Campaigns~~	
Category 7: Supply Chain Management	- Reliable Supply Chain Infrastructure	- Reliable Supply Chain Infrastructure	- Reliable Supply Chain Infrastructure
	- Improved Material Selection Processes	- Improved Material Selection Processes	- Improved Material Selection Processes
	- Global and Regional Supply Chain Integration	~~- Global and Regional Supply Chain Integration~~	

	Final Driver Themes Blue + Red
Category 1: Regulations, Policy and Standards	Encouraging Market Transformation
	Regional and International Policies
	Establishing Global Benchmarks
	Upgrading the Certifications Thresholds
	Streamlining Material Procurement
	Local Government Initiatives
	More Standardization
	Update of The Evaluation Frameworks
Category 2: Technological and Digital Innovation	Development of High-Performance, Low-Carbon Materials
	Reliability and Long-Term Performance Data
	Calculate Residual Value of Materials
	Need for Practical Implementation
Category 3: Financial and Economic Drivers	Long-Term Financial Savings
	Varied Actor Opinions on Financial Incentives
	Increased Property Value
Category 4: Stakeholder Engagement & Public Sector Leadership	Leading by Example (Public Sector Leadership)
	Addressing Stakeholder Concerns
	Cross-Sector Collaboration
	Simplifying Processes by Public Sector Leadership
Category 5: Market Demand and CSR	Consumer Preferences and Market Demand
	Enhancing Corporate Reputation (CSR)
	Employee Engagement and Retention
Category 6: Educational Programs and Climate Awareness	Supporting Continuous Professional Development
	Facilitating Industry Collaboration
	Corporate Initiatives on Climate Awareness
	Client Education
Category 7: Supply Chain Management	Reliable Supply Chain Infrastructure
	Improved Material Selection Processes
	Supplier Diversity
	Supply Chain Collaboration

Figure 11 - Complete Overview Scheme Driver Themes