Timber in Transition: Examining Socio-Technical and Enabling Processes in Residential Construction from a TIS framework perspective

A qualitative socio-technical study of the key factors, market actors and strategies that are required for a large-scale diffusion of timber building concepts

Master Thesis

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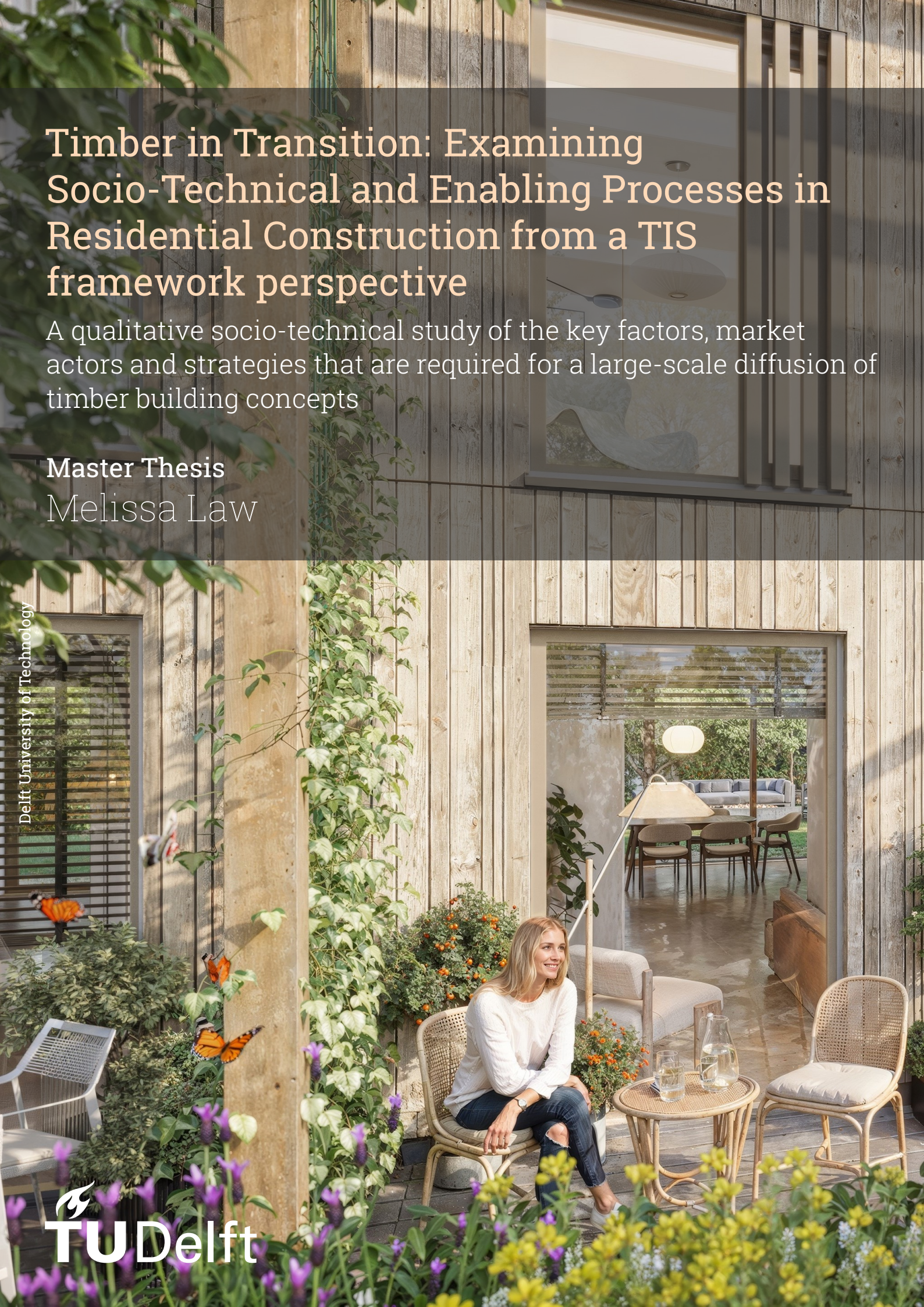
Delft University of Technology



TU Delft

Timber in Transition: Examining Socio-Technical and Enabling Processes in Residential Construction from a TIS framework perspective

A qualitative socio-technical study of the key factors, market actors and strategies that are required for a large-scale diffusion of timber building concepts

by

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bam wonen

Preface

This thesis presents the final part of my master's degree in Construction, Management & Engineering (CME) at the Faculty of Civil Engineering at Delft University of Technology. Herein the specialization of Projects & People aligns with the thesis topic, where the interaction between the development of innovations regarding building structures, designed from mostly a technical perspective, interfaces with the social aspect of the involved actors and their needs and wishes.

Over the past couple of months, I have dived into the unknown with regard to the transition toward timer buildings. These sustainable building practices are currently a hot topic in the Netherlands, but they also turn out to be sensitive due to the inherently competitive position construction companies currently have. Conducting this research and gathering the data was therefore quite dynamic and interesting but also rather challenging.

Through the extended support of my graduation committee from the TU Delft, I was able to take on this challenge. Dear committee, instead of just being my supervisors, it felt like you were my mentors along the process. Personally, I thrive in environments where I feel supported and encouraged and each of you created that environment for me throughout this thesis journey, for which I am extremely grateful.

Hans, thank you for your guidance, warm attitude, and constructive feedback during the meetings. Pierre, I want to thank you for sharing your fascinating, and often surprising, insights with me. It elevated the research to a new level. I also remember you saying 'The strongest trees don't grow the fastest; they stand the longest', which made me realize that growth isn't always about speed or size, but about the strength and stability one cultivates over time.

Many thanks to Johan for giving me that extra push and practical advice whenever I needed it. I always looked forward to our meetings, since I knew I would walk out of the room with my thoughts a bit more structured than when I walked in.

Lennert, thank you for your always positive attitude and for seeing opportunities where others might see challenges. I'm also deeply grateful for the freedom and opportunities you have given me to develop myself, both personally and professionally. It has been incredibly valuable (and pleasant) to have you at my side as my first company supervisor.

A special shout-out should go to Imke, thank you for your intelligent insights, helpful guidance, but most importantly your never-ending support. Without you, I would have never been able to present my research to so many people within BAM Group already. Thank you for providing these opportunities to me.

I would like to express my appreciation to BAM Wonen, for providing me with the opportunity to conduct this interesting and rather new topic within the organization. Through making space for such research, the company has shown its courage and moreover intrinsic motivation towards becoming a more green contractor which inherently aligns with the mission: Building a sustainable tomorrow.

My personal goal for this research was to bring light to innovative and new topics within the construction industry and at the same time go the extra mile. This involved providing new insights through filling scientific research gaps, crafting and leaving something practical and valuable for the thesis company, but most importantly going through a process where I learned a lot more about myself and which I could proudly look back to. This also presents therefore the grand finale of my studies.

I hope you find this work as insightful and engaging as the journey to create it has been.

Melissa Law

Delft, September 2024

Summary

As environmental concerns intensify and regulations evolve, the construction industry seeks innovative and competitive solutions. To mitigate climate change and to reach Dutch targets to reduce greenhouse gas emissions of 55% by 2030, emissions by the construction industry must be lowered. Developments regarding mass timber construction have increased the potential to do so.

This report addresses the problem that the opportunity to reduce CO_2 emissions by constructing in timber is not utilized to its full potential. Timber can contribute to reducing gas emissions because the production of structural timber elements is less carbon-intensive compared to concrete, the most used structural building material in the Netherlands. Additionally, timber can capture and store carbon.

The transition towards timber building practices can be seen as a socio-technical system transition. Therefore, in this research, the TIS framework of Ortt and Kamp, 2022, wherein the importance of adopting a company perspective is emphasized, and the framework proposes strategies to enhance the chances of successful innovation deployment of timber building practices. The TIS analysis framework consists of a total of seven building blocks ranging from the innovation product itself to network formation and important actors in the market, which together represent all important dimensions within the socio-technical system.

This report aims to identify the key socio-technical factors and essential actors, that influence the large-scale implementation of new timber-building practices in The Netherlands, by taking a market perspective. The methodology that was used for this research is the combination of a literature review, case study research, and semi-structured interviews. This approach will provide valuable insights into the current drawbacks and challenges of using timber in buildings by taking a socio-technical perspective and therefore identifies the key factors and essential actors, that are crucial to initiate the large-scale deployment of timber in the residential sector.

The scientific relevance of this study lies in expanding the TIS framework by the application it in the residential construction industry, but also the development of the innovation over time and the outlook towards expanding the innovation concept to the next development level. The practical relevance for BAM Wonen is that the thesis company plays a pivotal role in the Dutch transition journey by transitioning towards sustainable timber building practices and therefore this research would offer the company suitable niche introduction strategies by giving a selection of the various types of timber building practices, the scale and timing of the implementation of the innovation in order to penetrate the market, the essential actors needed, and recommended enabling steps to bring about the transition. This will essentially contribute to the strategic incentives of construction companies to realize the big-scale deployment of timber building concepts and give insights into taking the next step towards mid-rise timber buildings.

In Part I, the introduction and methodology of this research will be given. Thereafter in Part II, the Definition Phase of this thesis, extensive literature research has been conducted to portray the current problem context with regard to each key element of the subjects mentioned in the main research question. This involves the subjects of the current state of the residential construction industry, essential market actors within the building network, the perceived drivers, but also challenges of building with timber, and the technical advancement of industrializing conceptual building. Herein the first sub-question will be answered, which reads as follows: 'What are the main key factors, conditions, and actors leading towards implementation of timber building practices in The Netherlands'.
In addition, the Definition Phase also outlines the relevant socio-technical systems frameworks, and especially the TIS framework of Ortt and Kamp, 2022, that will be modified and applied in this thesis. Herein the key factors identified in the literature will form the building blocks where the framework will be implemented and assessed on.

The main findings from the Definition Phase are firstly the urgency and priority of the construction industry of reducing both embodied and operational carbon emissions in order to reach the set targets,

both national and internationally. The main focus in the past decades has been on reducing operational carbon emissions, however in order to achieve net-zero buildings the embodied carbon emissions are equally important, which unfortunately have been neglected in both research and practice. It is found that the reduction of buildings' environmental impact especially in terms of embodied carbon can only be achieved by increasing the proportion of wood-based materials in the main building structures relative to concrete materials, where the design choices on materials should already be made in the very early stages of a building tender or project. Over the lifecycle of wood-framed buildings, the substitution potential of logging, processing, construction, and demolition residues is greater than the fossil energy inputs to material production, leading to substantial savings of 43% of embodied energy and 68% of carbon savings when utilized to its full potential.

Currently the market including developers, contractors, builders, and politicians does not have the full incentive and willingness to shift from the familiar common traditional building approach towards the innovative building structures of timber construction, which is seen as too complex and too risky. The evolution of developing and implementing timber building practices in The Netherlands can be described according to the innovative product diffusion theory of Rogers et al., 2014 and with the landscape of transition and interaction between three nested hierarchical levels. Currently, the innovation of timber building practices is still in the early phase of predevelopment and take-off at the regime level. Herein the market stake is assigned to the early adaptors and majority, which points out that timber construction is still relatively new and lacks standardization, wherein the exchange of information and value chain partnerships between stakeholders are crucial to safeguard themselves and lower risks and uncertainties.

Furthermore, the implementation of timber comes with benefits on the triple bottom line aspects with regard to social, economic, and technical factors. The main beneficial characteristics of timber are that the material has the potential to minimize its environmental impact throughout the materials whole lifecycle, also timber is renewable and due to the technical advancement of producing wood into timber-engineered products, the economic surplus value and therefore the important trade-off between cost and quality is becoming increasingly tangible and promising.

The main barriers for constructing in timber are located at in all the phases in a typical construction project, herein the importance on decision-making in the acquisition phase has been undermined. The main barriers with regard to the perception of clients and consumers on timber can be concluded to be the newness of the technology in the whole value chain from laws and regulations, towards limited experience in the design, supply, and value chain, which poses immense uncertainties and risks with regard to operational costs, but moreover the ambiguous maintenance costs.

As of today, the construction industry needs to move away from a project-based approach, where specially designed structures are worked out on-site, by steering towards a product-based construction process, where standardized sub-elements and building blocks are designed like functions, manufactured separately, and combined with branding characters and customization options, in order pushover the leap in the market of utilizing timber buildings in the residential sector. Herein the integrated design approach is essential, by industrializing, standardizing, and digitizing the value chain of producing and assembling timber construction projects while incorporating the needs and wishes of clients.

In part III three timber case studies and a total set of seventeen semi-structured interviews have been executed with the focus on participants in the transition towards timber. The data and findings from these methods have been analyzed and merged in order to find the overarching categories and characteristics that result in the key factors that influence the transition towards timber.

The first finding is that the instances can be divided into a matrix of four quadrants. This crafted matrix is useful for practitioners to bring about transition since it helps organizations prioritize their actions based on the level of control and impact the instruments have on the success of the timber building project. The four quadrants in this matrix are defined as shown below.

1. Quadrant 1 'Monitor': instances with low control and low impact
2. Quadrant 2 'Manage': instances with high impact, but low control
3. Quadrant 3 'Optimize': instances with low impact, but high control
4. Quadrant 4 'Focus': instances with high impact and high control

Herein the instances and measures situated in Quadrant 4 'Focus', are examples of key factors in the

transition towards timber, due to the fact that these instances are in high control of the project's team and at the same time result in high impact and influence on the project's outcome.

Thereafter a total set of instances has been crafted and analyzed. As a result of the analysis, the researcher extracted the instances into findings that are categorized and characterized accordingly. The overarching categories found with the instances are: leadership, managerial levers, and business processes, as shown in FIGURE below. In line with the characterizations of the findings, the researcher formulated a total set of 10 characteristics. Whereas leadership remains one overarching category, and both managerial lever as well as business processes consist of five sub-categories (characteristics). It can be pointed out that both the categorizations as well as these characteristics are not mutually exclusive, resulting in that instances can occur in more than one category or characteristic at one time and that the list might not necessarily be limited to the ten characteristics. The final set of characteristics are the following:

Managerial lever

- Mission, goals & strategy
- Structure & systems
- Resource allocation
- Organizational learning & knowledge
- Organizational culture

Business processes

- Initiation & decision-making
- Portfolio management
- Development & implementation
- Project management
- Commercialization

It is found that the instances with the highest impact and within the control of a project's team upon proceeding with a timber project are situated in several characterizations, respectively mission, goals & strategy, organizational learning & knowledge, development & implementation, and project management. It can be concluded that none of the instances within the identified categories dominate and therefore vary in the four identified categories. Herein the condition is found that a push-and-pull strategy is inherently important for these 'Focus' categories where simultaneous alignment and development have shown to be effective through a project's success. Upon adjustment or enhancement of one of the characteristics, the interrelated characteristics are subject to change (either for the bad or good).

The vast majority of instances that are highly impactful for a timber project but are rather low in control by the project's team are situated in the category of business processes. Therefrom it can be concluded that the most determining key factors in a timber project are the categories of project management and commercialization.

The fewest instances found in the whole set of findings are allocated in Quadrant 1 (low impact - low control), therefrom only a couple of leadership instances and portfolio management related to decision-making of timber projects within an organization are found in the total set. Nevertheless, it can be said that leadership performance in managing the portfolio of a construction company highly influences the initiation & decision-making on whether to proceed with timber projects and the pace and likewise timing of upscaling timber projects within the organization's portfolio.

Project management has shown to be the most determining sub-category within the timber cases, which can be concluded from the allocation of the majority of instances in both Quadrant 2 (low control

- high impact) and Quadrant 4 (high control - high impact). It is found that project management has a direct influence on the so-called 'rotary knobs' of a project where feasibility and affordability have been identified as key factors. These rotary knobs are technically (tangible) from nature, e.g. scope, planning, cost, quality, and risks that need to be aligned with the project's objectives, but are also directly influenced by social aspects, especially in the alignment of scope between client's requirements with the feasibility of the project

Upon this analysis, a model has been crafted that integrates the determining characteristics as found in this study and highlights the key factors influencing the transition towards timber in the residential construction industry. This model aims to provide actionable outcomes through the phenomenon of open dialogue. The actionable recommendations or in this case the considered triggering questions leading towards actions that can be asked through each of the influencing conditions, which leads to the desired innovation outcomes can be set up. These type of questions has the aim of creating space for holding an open dialogue that allows the personnel within an organization to discuss either the barriers or opportunities they see in incorporating timber in projects throughout the project's lifecycle (e.g. from acquisition towards project management and upon delivery of the timber project).

With regard to further research, the following recommendations are given. This study mainly focused on the tender phase and design phase upon collecting the instances from practice. In order to broaden the perspective on these key factors and the categorizations with the detailed characteristics it would be interesting to take the operational phase upon delivery into consideration and analyse these stages. Subsequently, as the crafted TIS model consists of a total of three overarching socio-technical factors (e.g. leadership, managerial levers, and business processes) and five enabling processes of innovation (e.g. resource allocation, commercialization, portfolio management, structure & systems, and project management) it is relevant to conduct further research on the evolvement of these identified socio-technical factors and enabling processes that have not yet been analyzed for their dynamic nature over time. Besides it would be of relevance to broaden the perspective of the framework by incorporating the interplay of the so-called triple bottom line interdependency of socio-technical-economic factors. In addition to this recommendation, monetizing and evaluating the impact of the factors through tangible data in the timber cases would enhance the reliability of the results in this research.

The most important and recommended actions for the contractors that are currently deploying timber building practices are firstly several quick wins which are performing a (detailed) risk analysis and assessment considering the risk matrix adjusted towards timber building practices derived from the previous pilot projects, and in line with this ensure compliance with Dutch Building Codes when optimizing the timber design by identifying at the start of the project the needed documents to provide evidence of compliance with local regulations on the performance and quality of the building. In addition, it is recommended to put forward driven leaders and on top of that change and key-account managers who can create alignment within the organization and alignment with clients.

Another quick win is investing more time in defining the clear allocation of shifts in responsibilities of the (new) product owner and designated communication channels between project teams and the industrialization team in the new process of working. In line with inter-organizational processes is to make sure to involve the commercial organization in the upcoming development initiatives on the timber concept and moreover in the development of a new midrise with conceptual building. Secondly, several focus points are pointed out, and the main recommendations are investigating a viable timber business case from a broader perspective and putting effort into developing a roadmap through feedback loops that incorporate regular evaluation and adjustment of the roadmap based on progress and monitoring.

Besides it is recommended to in all cases ensure an open dialogue between the contractor-client relation upon acquiring a timber project and along the project execution. Lastly, there have been advised that acceptance that the industry currently is in this early adaptors phase, where the company is now building up learning capacity for pilot projects and that setbacks or investment costs are part of it, and subsequently it is crucial to not lose the innovative learning capacity within the organization.

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List Of Abbreviations

CLT	Cross Laminated Timber
GHG	Green House Gas
SDG	Sustainability Development Goals
STS	Socio-Technical System
TIS	Technical Innovation System

PART I
INTRODUCTION AND METHODOLOGY

1

Introduction

The transition towards timber involves several motivations of the construction industry to deploy new techniques and commence with such an innovative trajectory from an early adaptors phase. In order to understand these motives and the context of where the transition of timber originates from, it is crucial to have background knowledge. This chapter therefore discusses in Section 1.1 the motive of the industry, whereafter in Section 1.2 the State of art will be given and in Section 1.3 the problem statement is explained.

1.1. Research Motive

As environmental concerns intensify and regulations evolve, the construction industry seeks innovative and competitive solutions. The effects that climate change has around the world are becoming more visible and will have serious consequences on buildings and their occupants. Moreover, the more frequent occurrence of extreme weather and climate events will have a substantial impact on building performance and the energy consumption of the construction industry.

When looking at the energy consumption of the construction industry, according to UNEP (2020) in 2019 the total global energy-related CO_2 emissions of the building sector accounted for 38%. From this percentage around 10% of all global emissions were attributed to the manufacturing of building construction materials (UNEP, 2020), which indicates that the biggest part of the CO_2 emissions are due to the production and manufacturing of materials. Herefrom can be concluded that reducing the emissions of CO_2 in the construction industry and specifically the reduction of emissions for construction materials, will have a significant influence on mitigating climate change.

In order to cope with these concerns in 2015 a total of 90 countries have committed to actions for addressing buildings-related emissions or improving energy efficiency. This has been stipulated and addressed in each of the country's Nationally Determined Contributions (NDCs) under the Paris Agreement. The goals in the Paris Agreement have been set with the following targets: by 2030 the built environment should have its emissions, whereby 100% of new buildings must be net zero carbon in operation. Furthermore, by 2050, at the latest, all new and existing assets must be net zero across the whole building's life cycle, which includes operational and embodied emissions (European Parliament, n.d.).

According to Plan Radar (n.d.) the decarbonization of the construction industry throughout its life cycle can be achieved by adopting a triple strategy, which holds a combination of reducing energy demand (behaviour change and energy efficiency), decarbonizing the power supply (e.g., shift towards electrification through renewable sources and increased use of other zero-carbon heating technologies) and addressing embodied carbon stored in building materials. The first two measures in the triple strategy will help in eliminating carbon emissions from building operations by 2050, whereas the main challenges lay in emissions from materials and construction processes. In order to concur with this challenge, it is necessary to incorporate lean construction and maximize the use of low-carbon and therefore sustainable materials in buildings by assessing every design decision using a whole life-cycle approach and avoid future embodied carbon during and after the building's life by considering

future adaptation and circularity. These prospects must be urgently addressed and tended to achieve the Sustainable Development Goals (SDGs) as defined by the United Nations, especially SDG 11 on sustainable cities and communities and SDG 13 on climate action – by providing residential housing for all, having cleaner and resilient cities, protecting and enhancing health, and supporting economic prosperity and to ensure that the buildings being built today are optimized for low-carbon solutions across the full life cycle of buildings in the future.

1.1.1. State Of Art: Timber Use in The Netherlands

When considering the needed triple strategy of reducing energy demand, decarbonizing the power supply, and addressing the footprint of construction materials, it is striking that bio-based building materials are under-addressed in the committing countries' NDCs (the earlier mentioned national contributions as agreed upon in the Paris Agreement), including The Netherlands. The ambition expressed by the Dutch government is to realize at least 30% of newly built houses by using at least 30% bio-based materials by 2030 and to reach the goal of 50% reduction of CO_2 emissions by 2030 in order to reduce the impact of the construction industry on the climate (Rijksoverheid, n.d.-b). However, if the Dutch construction industry operates at the current speed as it is now, these goals will notably not be achievable in the given time frame without causing severe damage to the building environment and the citizens due to climate change.

Currently the governmental tension between major societal problems and the sustainability goals set for 2030 is evident in The Netherlands. On the one hand, the Dutch government needs to deal with the residential shortage and therefore has set out the construction target of 100,000 newly-built homes per year. This will lead to an increase in the annual construction production means, which ultimately clashes with on the other hand the ambitious climate targets regarding the reduction of CO_2 and nitrogen emissions and also enhancing the circular economy.

Given that the residential sector constitutes 75% of the European building stock and that residential properties demonstrated to be responsible for 22% of a European household's carbon footprint as stated by Ivanova et al. (2017), it is safe to say that residential housing is in itself a pivotal contributor to climate change in the European context (Economidou et al., 2011). Even more so considering that Europe is witnessing an increase in the total number of households, primarily composed of one to two persons, leading to an increase in residential demand (Ellsworth-Krebs, 2020). This highlights another growing gap, this time between residential demand and residential supply (Jović et al., 2022). These trends are also occurring in the Dutch residential demand and growth whereas The Netherlands is currently facing a growing residential shortage necessitating the construction of new-build dwellings to address this pressing issue. Thus, the residential sector's dominance in The Netherlands, coupled with a growing residential shortage, presents a dual challenge. On the one hand, there is an urgent need for the built environment to expedite its transition toward a net-zero emissions scenario to combat climate change and, on the other hand, future residential needs render the generation of added emissions inevitable. Overall, this amplifies the pressure on new-build dwellings to enhance their energy efficiency performance (IEA, 2019).

The study of Copper8 and Metabolic-consulting (n.d.) has outlined the needed change scenario in order to solve the residential shortage, but at the same time achieve as close as possible in the climate objectives. This change scenario, as showcased in Figure figure 1.1 expresses the need for the following four major shifts in the construction sector:

1. High-quality reuse of materials;
2. Utilization of building with bio-based materials;
3. Efficient allocation use of small households;
4. Topping & transforming current buildings.

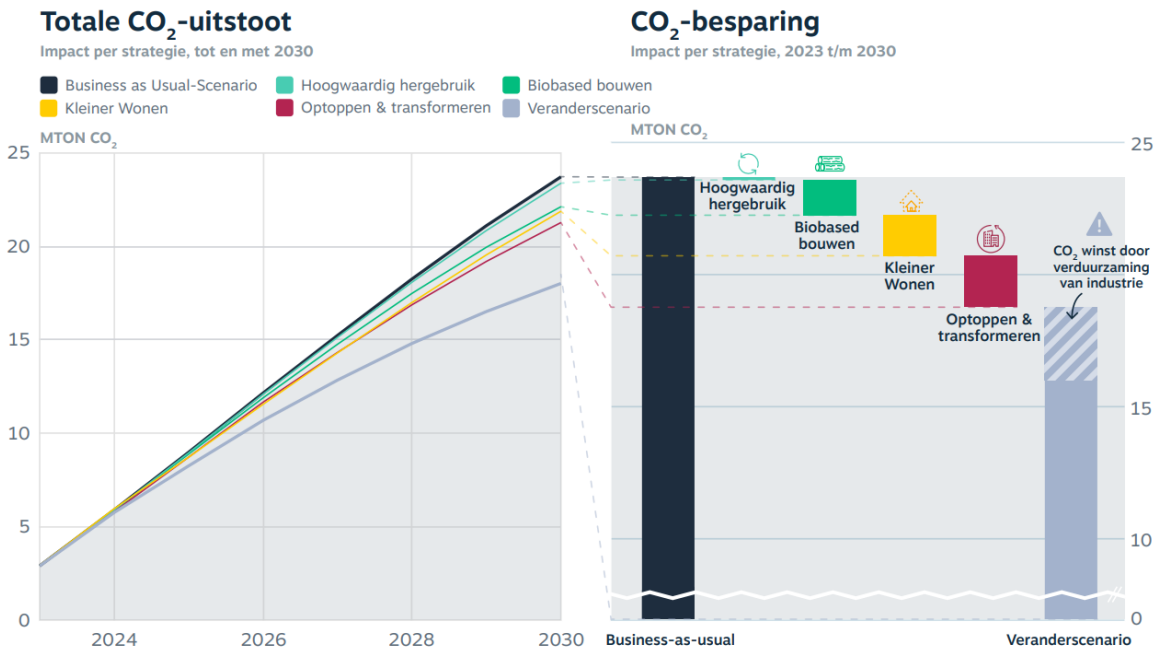

Figure 1.1: Total CO_2 savings of circular strategies in the change scenario (Copper8 & Metabolic-consulting, n.d.)

The main focus of this research is stipulated on enhancing the utilization of the specific change scenario of building with bio-based materials due to the main potential it has from a construction company's perspective leading to their core business, whereas the other three major sustainability shifts in the construction sector are left out of the scope.

1.1.2. Research Problem Statement

The frequent use of timber building structures in the residential construction sector can make a significant impact on mitigating climate change by reducing CO_2 emissions (Keijzer et al., 2020). According to Hafner and Schäfer (2018) this is mainly because the production of timber elements is less carbon intensive than traditional materials such as steel and concrete, additionally timber has the capacity to capture and store carbon, and even more wood elements are ready to be upcycled, reused and recycled.

Despite these potential benefits of timber, which are evident, the use of the material is still underutilized in the Netherlands. Currently, the market share of timber (frame) construction in the Netherlands is modestly approximately 3% (Fraanje, 2023). According to Fraanje (2023) the expectation is set that this market share will grow due to the fact that timber undergoes a major leap in constructing with CLT and due to the increasing market demand. Even though this growth is expected, building with timber currently poses difficulties varying from social, economic, technical, and political issues. One of the main reasons for the reluctance towards timber structures is the (perception) of higher building costs in comparison to traditional construction materials (Jones et al., 2016). It can be stated that the transition towards a sustainable building industry which includes incorporating bio-based materials and timber building concepts is a major shift in the working and building procedures and therefore asks for a socio-technical perspective. This perspective has been overlooked in the changing scenario as stipulated by Copper8 and Metabolic-consulting (n.d.) and is crucial in utilizing timber building practices as implementing innovations is not solely driven by technological advancements or economic incentives but is also influenced by various multifaceted aspects such as social, cultural, institutional and political factors.

This report therefore emphasizes the use of innovation diffusion strategies to improve the adoption of timber from a Technical Innovation System (TIS) perspective, in order to meet the growing need for sustainable construction methods with the utilization of bio-based materials and products (Ortt & Kamp, 2022).

1.2. Concluding Remarks Chapter 1: Introduction

Starting off, the motive of this research has been highlighted by the increasing urgency of environmental concerns and evolving regulations that necessitate innovative and competitive solutions in the construction industry. With 38% of global CO_2 emissions attributed to buildings, and 10% from construction materials alone, **it is critical to reduce these emissions to mitigate climate change**.

In addition, the Dutch government's ambitious goals for incorporating bio-based materials and reducing CO_2 emissions by 2030 highlight the **pressing need for sustainable practices**. However, the current state of art of the residential construction industry using timber, shows that only 3% of the total amount of residential new buildings are constructed with the raw material wood. Therefore the pace of implementation and existing socio-technical barriers pose significant challenges. This research emphasizes **the importance of adopting a socio-technical perspective and innovation enabling strategies** to enhance the utilization of timber in construction, aiming to achieve sustainable development goals and address the residential shortage while at the same time mitigating climate impact affected by the residential construction industry.
In the following, Chapter 2 the research approach of this study will be explained. Herein the main research question, chosen methods, and research scope will be given.

2

Research Approach

2.1. Research Goals

The main goal of this research is to identify the key socio-technical factors and essential actors, that influence the large-scale implementation of new timber-building practices in The Netherlands, by taking a market perspective. Furthermore, this study will focus on gaining insights into the complex interplay of actors, conditions, and dynamics contributing to the emergence of markets for timber building practices that result in moving out of the early adaptors phase as the current status is. By identifying the critical key factors and potential bottlenecks within the different construction phases during the design and implementation of timber building practices, valuable insights will be gained on how to effectively tackle these challenges within a limited timeframe. The outcome of the study will be presented by a self-made socio-technical model that outlines the selection of two types of timber building practices, the related success factors, the involvement of stakeholders, and the scale and timing of the implementation of the innovation in order to successfully enter the market.

2.2. Research Questions

The defined research goal is translated to the following main research question:

How to enable timber transition in the multifaceted and complex residential construction industry from a TIS framework perspective?

In order to answer the main research question adequately, four deepening sub-questions will be examined in this research. In figure 2.1 an overview of the six sub-questions is showcased in a flow diagram, where each proposed research sub-question is linked to the intended methods and outcomes that will be conducted in this study. In the following part, the proposed sub-questions are explained:

Sub-questions:

1. What are the key socio-technical drivers, barriers, conditions, and actors that involve large-scale implementation of timber building practices in The Netherlands?

   The first sub-question of this research analyzes what the current key socio-technical factors are. These factors incorporate aspects such as motivations, drivers, and barriers and in addition investigate which actors within the residential market are crucial in facilitating the transition. Through conducting extended literature research on these factors, a solid base will be created moving

towards the socio-technical framework.

2. What type of socio-technical perspectives influence and determine the shift towards timber building projects in relation to the modified TIS building blocks?

   Thereafter the second sub-question focuses on identifying which socio-technical perspectives which are found in the instances through data gathering can be distinguished. Herein the aim is to find the overarching categories in the set of instances and what characteristics can be identified that facilitate initiatives on the timber projects that undergoes piloting.

3. How do these determining characteristics influence the transition towards timber building practices in The Netherlands?

   Subsequently the third sub-question of this research centers around evaluating and validating which characteristics are the most determining throughout a timber project. Overall crucial insights from practice will be gathered in what are the quick wins, opportunities to focus on, and optimization trajectories leading to additional insights and supplements for crafting the socio-technical model.

4. How to integrate the determining socio-technical characteristics through a strategy framework in order to provide actionable recommendations for the deployment of timber building practices?

   The fourth and last sub-question aims to combine the structured data into a categorization of actionable enabling processes and recommendations. Herein this question aims to draw the relevant relations between the socio-technical factors and enabling processes towards crafting a framework. Whereas the result of this framework should propose specific, inspiring, and triggering recommendations for both scientific and practical relevance.

2.3. Research Methods

For this research overall a qualitative research methodology will be employed, this includes a thorough desk research and literature review, embedded case study research, and in-depth interviews with the relevant stakeholders and actors within the construction industry. An overview of all these methods of research is showcased in 2.1.

2.3.1. Desk research and literature review

As the starting point desk research is performed in order to answer the first sub-question of this research. Herein relevant information and data from practical public research are collected, with a focus on the current status of timber building practices in the residential and construction industry, but also research on the development of innovative timber building concepts and the related success factors. Since desk research, known as secondary research, is essential for understanding the current status quo of innovation and the related observations from practice, performing the research gives insights into the research topic and establishes the specific research context for this thesis. Simultaneously literature review will be employed by reviewing existing scientific literature through structured literature review and backward-forward citation research. Analyzing literature will answer the sub-questions two to 4 including the fourth sub-question. The used resources for the literature research consist of published reports, academic papers, market studies, and industry analyses. Furthermore, the basis on the theoretical and contextual concept will be created by conducting literature research on technical innovation systems frameworks, including the relevant TIS framework of Ortt and Kamp (2022). The findings herein will give insights into evaluating the suitability of the TIS building blocks specifically for the construction industry. Moreover, the extensive literature research will form the crucial basis for finding the knowledge gaps in the existing literature and will play a crucial role in making a comparison with the collected data in the discussion of this research.

2.3.2. Embedded case study

Subsequently, a case study approach on an innovative timber building concept will be carried out. The case study method will be used to answer the second and third sub-questions of the research. Specifically, an embedded case study approach has been chosen, where the focus is on the analysis of multiple factors or objectives while considering different aspects of the case (Bass et al., 2018; Budiyanto et al., 2019). This approach is opted, as it will be particularly useful in exploring the performance of the concept and the complexities that came along with developing and implementing the concept and since confirmability is enhanced by using an embedded case study approach. The evaluated TIS building blocks can be confirmed by analyzing the TIS building blocks on real-life timber projects. This will also yield insights into the hurdles, barriers, and practical experience during different project stages. Other advantages of embedded case studies include in-depth research of real-life complications, analysis of contextual data, and quantitative and qualitative findings. The targeted case study group where simultaneously semi-structured interviews will be conducted are industrial experts, professionals, and practitioners within the construction company. In addition, also the clients' perspectives involved in the timber projects on the chosen cases are interviewed, which will substantiate the view of taking different perspectives into consideration and create a more persuasive argument. Data collection for the embedded case study is intended through document analysis of each project, including tender documents, risk assessments, and semi-structured interviews. However, it is important to note that a researcher must reduce biases and restrictions when using case studies since they use an iterative strategy to explain, validate, or build hypotheses and a long learning curve, issues about rigor, and a lot of documentation should be taken into account (Eisenhardt, 1989; Zainal, 2007).

2.3.3. Semi-structured in-depth interviews

The last method used in this research is conducting semi-structured in-depth interviews. The interviews will also answer the fifth and sixth sub-questions. Semi-structured interviews are a versatile method since they collect qualitative data within a specific context (Knott et al., 2022). Since this type of interview will use a topic guide with prepared questions to gain insights from the interviewees into past events, it offers information about the nature, meaning, and understanding of the development of timber building practices within the construction company. Therefore in this research, the interviews will be used to explain, illustrate, and explore the key factors and market actors that are required for a large-scale diffusion of timber-building practices by also collecting people's ideas, opinions, values, and beliefs seen from different perspectives about the innovation and also allows for more in-depth questions, as there are opportunities to ask for clarification from the respondents about their answers and insights. The conducted semi-structured interviews are aimed at understanding the challenges that occur by introducing new innovations of in this case timber building practices and eventually will contribute to outlining the selection of introduction niches that consists of factors such as the scale and timing of the implementation regarding timber building practices in order to penetrate the market, and the essential actors needed. Some disadvantages are that interviews are deemed to be more time-consuming than other methodologies. This disadvantage can be mitigated by using a semi-structured approach with prepared questions beforehand can save time in selecting questions for different respondents. Additionally, according to Kvale (1994) the drawback of interviews is the subjectivity, reliability, and bias of the research. However, by planning in advance and defining the ambiguity, this drawback can be minimized. In addition, the interviews are conducted with different respondents, whereas a measure of consistency will also minimize the subjectivity as the same questions will be asked to all the interviewees in a structured interview with predetermined questions.

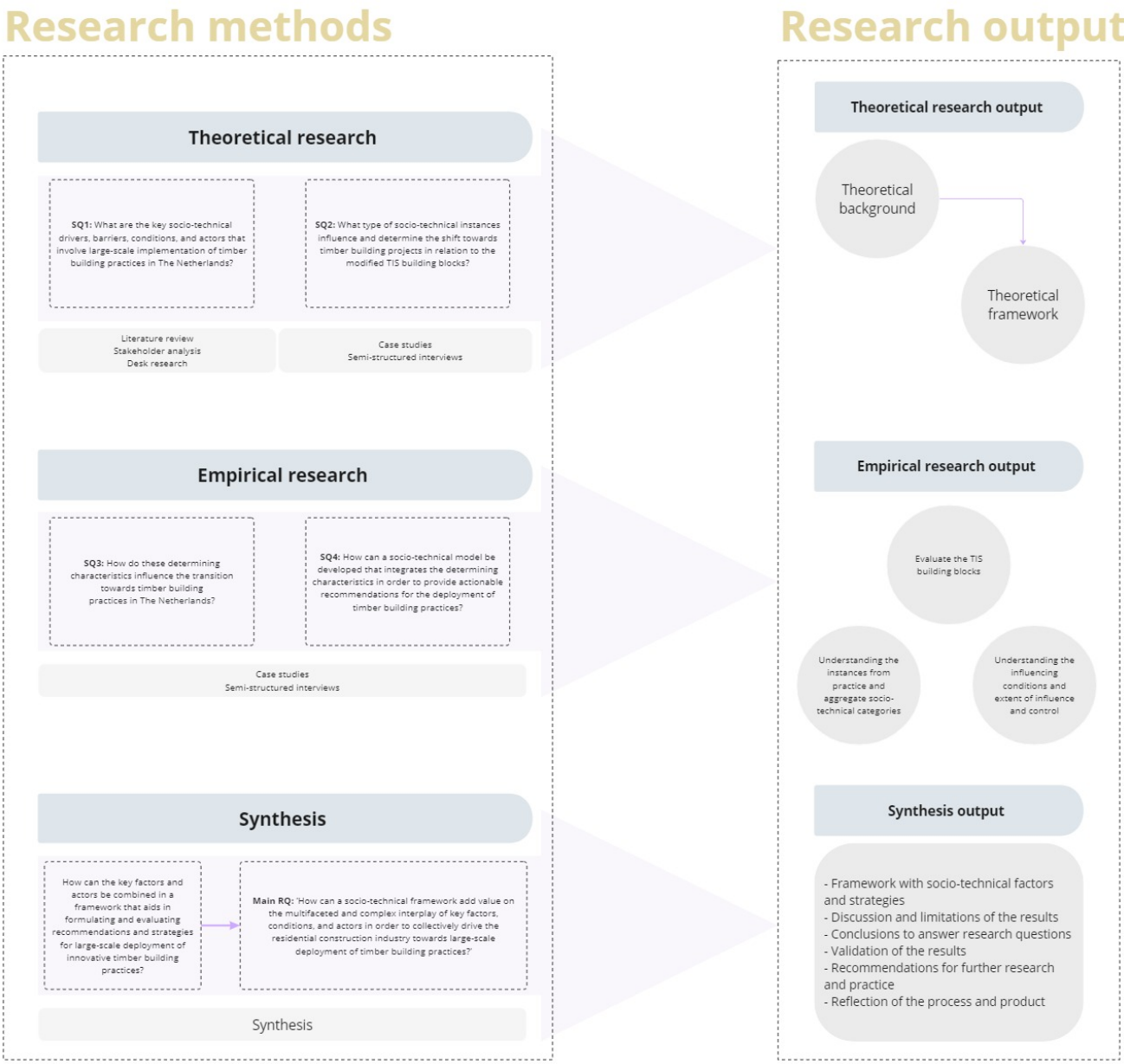

Figure 2.1: Overview structure of research design with related methods and outcomes

2.4. Research Scope

While analyzing the groundwork and conducting the methods certain aspects within the research scope are considered as the main focus. A research scope is therefore defined, in order to maintain the research focus and generate valuable results. In the following part the main principles of the research are outlined:

- **Dutch residential construction industry**
  In this research, the conclusions drawn are valid for the Dutch residential construction industry. The conclusions on the TIS building blocks regarding drivers and barriers to implementing timber building concepts can vary per country. In the Netherlands, for instance, building with concrete is customary and has been done for many years, while other countries can have different customs with regard to related laws and regulations on the use of construction materials. An important note hereupon is that this study incorporates implications for generalization in different contexts

including not only the Dutch context but also international research possibilities.

- **Interplay socio-technical factors**
  The focus of this thesis lies in the interplay between socio-technical factors that play a crucial role in choosing timber as construction material in residential projects. Within the field of various socio-technical factors specifically the ones that are present in the residential sector are considered in the framework. Therefore the indicated factors derived from the TIS building blocks are evaluated and when needed modified towards the sector-specific factors, drivers, and barriers within the residential construction industry.
- **Dual perspective from respectively construction company and clients**
  Thereafter, the focus of the interviews and conclusions are considered from the dual perspective of internal representatives within a construction company as well as the external clients and institutes. The interplay between socio-technical factors evidently lies both in the choices that are made internally during an innovation trajectory and are eventually evaluated by the outer environment which are the clients and the related value chain of partners.
- **Timber building concepts for dwelling and midrise apartments**
  In this research, the focus is on timber building concepts suitable for dwellings including a pinch of viewpoint on midrise apartments in timber. Therefore only buildings with a maximum of six stories and of a housing nature are considered, further investigation in higher multi-story buildings that are either complex or multi-functional is not considered within this research's scope. Subsequently, within the scope of this research, the focus is mainly set on conceptual housing where production on a large scale is a requirement.
- **Designation of distinction between wood and timber**
  In this research, the word timber is used to define wood used as a building material. Herein wood from the trees is transformed into modern engineered wood products (EWP) through several production processes, which will be called timber in terms of use, strength, and structural possibilities.

2.5. Research Outline

The report has been divided into three distinctive sections that make up the structure of this research. In addition, each section is broken down into chapters while each section answers specific research questions as shown in figure 2.1.

The first part of the report starts with the introduction of the research. Herein the motivation of the research is mainly described, including the state of art regarding the problem statement and the relevant research approach where the research questions, methods, and scope are given.

In the second part of the research the definition phase comes into place. This phase describes the findings of the desk research and literature review that has been conducted. Furthermore, it includes the problem context and the relevant theoretical framework that will be used as the basis of this research. The definition phase will end with describing the evolution of theoretical socio-technical frameworks by highlighting the characteristics of the TIS framework of Ortt and Kamp (2022).

Thereafter, the third and last research part is the qualification phase. The qualification phase will describe the results of conducted methods including the embedded case studies and semi-structured in-depth interviews. The embedded case study focuses on analyzing and qualifying the defined building blocks in the definition phase, specifically applied to a timber building concept for dwellings and apartment complexes. Thereafter the findings of a total of seventeen interviews were conducted with various stakeholders who are involved in the decision-making process of timber building concepts. Here the data gathered consisting of valuable insights and perspectives will be synthesized by data structuring. In the final two parts, which are the synthesis and concluding parts, the knowledge and insights that have been collected from the previous sections are combined. These will eventually lead to the discussion, conclusion, and recommendations for this research and the handcrafted framework as the intended final result.

2.6. Concluding Remarks Chapter 2: Research approach

After introducing the research motive and the current state of using timber in The Netherlands Chapter 2 has described the research approach including the main research question with the supporting sub-questions. The main research question of this study is as follows:

'How to enable timber transition in the multifaceted and complex residential construction industry from a TIS framework perspective?'

This research focuses on unlocking the potential of timber building practices within the Dutch residential construction industry by **examining key socio-technical factors, market actors, and enabling strategies**. The scope is specifically tailored to the Netherlands with implications for international study opportunities by addressing the residential construction industry's drivers, barriers, and enablers. Emphasis is placed on the interplay between socio-technical internal company decisions and external client evaluations, particularly for timber building practices and tenders.

The research is **structured** into **four distinctive sections**: **firstly an introduction** outlining the motivation and approach of this study, **secondly a definition phase** establishing the theoretical framework and problem context through a literature review, and**thirdly the synthesis phase** analyzing case studies and interviews. In part four, the **final section** consisting of the **Discussion, conclusion, and recommendations** of this study the findings and insights are combined to provide comprehensive recommendations and a tailored strategy framework for promoting timber construction.

In the following, Chapter 3 gives the literature review conducted on several influencing themes on the transition towards timber such as stakeholder analysis, the drivers, barriers, and enablers during the implementation of timber, the interplay of key-factors and actors in timber building practices, and innovation in the construction industry.

PART II
DEFINITION PHASE
LITERATURE REVIEW

3

Literature Study

3.1. Climate change in the building industry

The building sector which the residential industry is part of, is one of the biggest contributors to climate change and resource depletion. As stated by UNEP (2020) and henceforth as shown in figure 3.1, the built environment sector is responsible for 39% of the annual global CO_2-equivalent emissions. Therefore both the direct and indirect emissions of the residential sector specifically account for 17% of the total carbon emissions. These emissions stem from building processes such as manufacturing, transportation, installation, maintenance, and disposal of building materials.

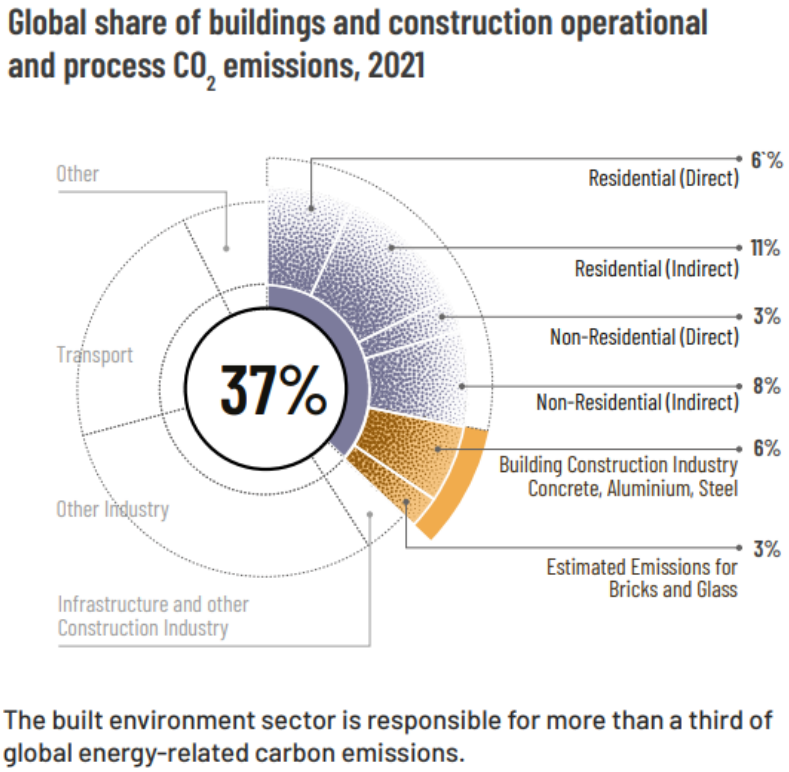

Figure 3.1: Global carbon emissions from the built environment (UNEP, 2020)

Even though certain decarbonizing interventions have been taking place, the expectation still remains that the built environment will surpass the allowable global temperature rise, which has been addressed in the Paris Agreement from 2015 to be within 2 degrees Celsius, and most preferably 1.5 degrees Celsius Cao et al. (2021).

In 2019, the Netherlands established a national climate law that aims to reduce CO_2 emissions by 49% by 2030 and 95% by 2050 compared to 1990 (Klimaatakkoord, n.d.). According to CBS (2023), CO_2 emissions have decreased from 1990 to 2024, as illustrated in figure 3.2. Significant decreases in CO_2 emissions were observed in the built environment sector in 1990, 2004, and 2018, as shown in figure 3.3 (CBS, 2019). In May 2023, the Dutch coalition agreement revised the indicative objective for the built environment to a residual emission of 13.2 Mton CO_2 equivalents in 2030 (Rijksoverheid, n.d.-a). Despite this aim, it is evident from these figures that the required reductions between 2024 and 2030 are more than the reductions achieved between 2004 and 2018 specifically in the built environment. Therefore reducing CO_2 emissions in the construction sector should be prioritized from now on.

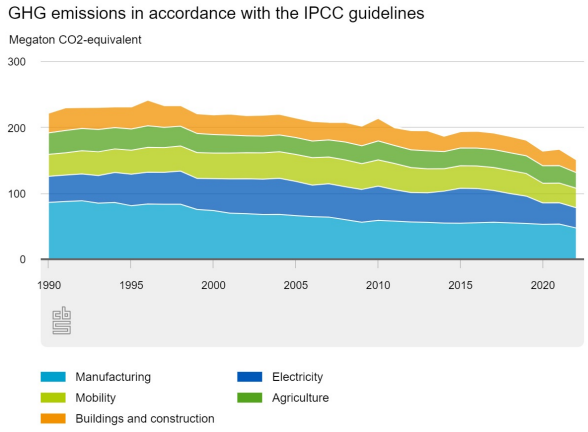

Figure 3.2: Trend-line greenhouse gas emissions of The Netherlands in accordance with the IPCC guidelines (CBS, 2023)

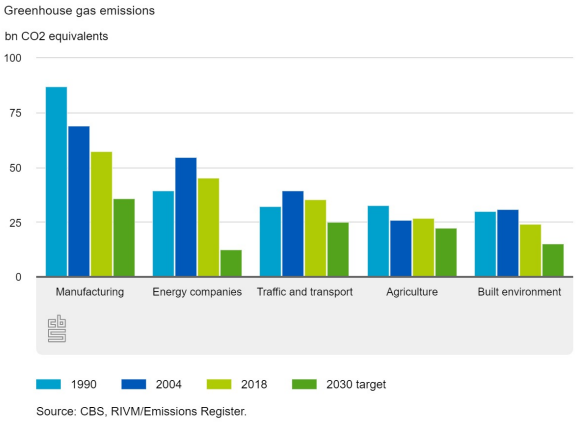

Figure 3.3: Overview greenhouse gas emissions per industry in The Netherlands (CBS, 2019)

3.1.1. Greenhouse gas emissions for buildings

In the theme of greenhouse gas emissions, there are mainly two components of CO_2 emissions present, which are embodied carbon and operational carbon. Embodied carbon is defined as the emissions emitted during the production of the building, which is caused by for instance extraction, transportation, and manufacturing of building elements through renovation and maintenance of building assets (Akan et al., 2017). The term embodied carbon is not widely used, more often it is called 'carbon footprint'. On the other hand, there are operational carbon emissions, which hold the ongoing operation of the building from sources such as power, heating, cooling, and day-to-day running of a building.

Till present the main focus of reducing building-related greenhouse gas emissions has been on the operational carbon emissions. Through applying various initiatives to building projects such as innovative solutions, new building standards, and improved insulation this shift respectively is gradually taking place. These initiatives lead to a reduction in operational carbon emissions, however in order to achieve net-zero buildings the embodied carbon emissions are equally important. Unfortunately, this category of emissions has mostly been neglected in both research and practice. As stated by Moore and Doyon, 2023 rather than focusing on reducing direct emissions of a dwelling's use through the different project's phases, a focus should be to better incorporate considerations of material impact, and specifically embodied energy in the shift towards sustainable building practices. According to Chastas et al. (2018) targeting embodied carbon can contribute to a wide range of reduction between 9% and 80% of a residential building's total lifecycle emissions, as most embodied carbon emissions are cre-

ated before a building is built. The study of Robati et al. (2021) have investigated that eventually from the new global construction projects between 2020 and 2050, 49% of all building GHG emissions will be caused by embodied carbon. With this reasoning there can be concluded that a growing urgency is present to reduce specifically embodied carbon emissions. In order to reach targets set by the Dutch government to reach net-zero embodied carbon emissions by 2050 the use of sustainable materials is inherent.

As stated earlier the study of Gustavsson et al. (2006) found that the reduction of a building's environmental impact especially in terms of embodied carbon can only be achieved by increasing the proportion of wood-based materials in the main building structures which is relative to concrete materials. Herein the design choices on materials should therefore already be made in the very early stages of a building tender or project. Unfortunately, once a dwelling is build and delivered, its performance and environmental impact will be locked in the building itself for many decades. With this given it is inherently important that the housing built today should meet high sustainability standards to minimize its impact through years of use. Subsequently, the focus of incorporating timber in the mainstructure of the building needs to be mainly on the design stage, where the old rule of thumb estimates that around 80% of a dwelling's impacts are locked in during the first 20% of the design process (Moore & Doyon, 2023). Therefore according to Moore and Doyon (2023) failure to ensure new housing performs to a higher standard means that much of the housing not yet built will likely need to undergo expensive retrofits. The findings of the paper by Minunno et al. (2021) support the importance of exploiting timber in building projects, as the use of timber results in substantial savings over concrete structures as it found that in terms of reduction in GHG, the use of timber can reach 43% of embodied energy and 68% of carbon savings when utilized to its full potential.

Greenhouse gas emissions of companies

From a company's perspective three different GHG scopes of CO_2 emissions that are generated, can be distinguished. Scope 1 includes direct emissions from activities generated by the company itself, whereas scope 2 accounts for purchased energy, and lastly, scope 3 which is a broader measure includes all the the direct and indirect emissions originating from purchased raw materials and services as well as the further processing use and disposal of sold products (Wei et al., 2020). The emissions from scope 3 are the largest sources of emission, where in fact the emissions are recorded in much greater detail (Kircher, 2021).

In accordance with scope 3, these CO_2 emissions can be targeted by increasing the use of wood material in the project as well. In addition, the lifecycle of wood poses opportunities for using less energy during manufacturing, storing carbon in the material itself, and the increased availability of biofuels from wood byproducts at the end of the material's lifecycle (Sahoo et al., 2019). The last implies that using biomass for direct substitution of fossil fuels or fossil fuel-intensive materials is an important means of reducing greenhouse gas emissions as it provides a permanent and cumulative reduction in CO_2 emission (Schlamadinger & Marland, 1996). These beneficial aspects of wood as a construction material are shown in figure 3.4 derived from the study of Autelitano et al. (2023). Herein an overview of the various opportunities and aspects of timber are showcased during the materials' end-of-lifecycle can be found.

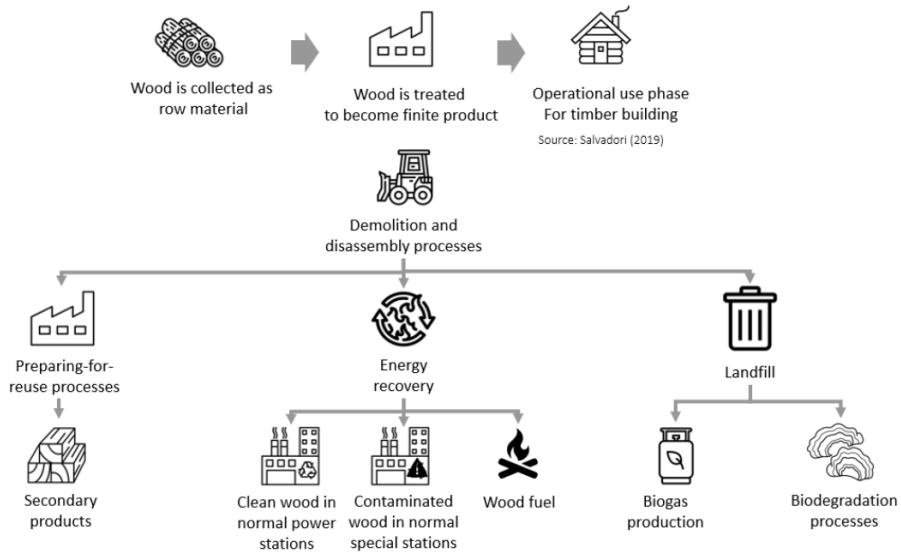

Figure 3.4: Overview of opportunities timber-based materials during the end-of-lifecycle (Autelitano et al., 2023)

Both the academic research and the practical implications stress the importance of using wood-based materials instead of high-emitting fossil and finite resources when transitioning towards the appointed agreements made both internationally and nationally in The Netherlands (Sandanayake et al., 2018). As stated by H. Kaufmann et al. (2018): "The amount of CO_2 in the atmosphere can be reduced in two ways: either by reducing CO_2 emissions or by extracting CO_2 from the atmosphere and storing the carbon, whereas timber has the unique ability to contribute to both possible reduction methods." Therefore, this report focuses on the enhanced utilization of timber as a building material, which stipulates the strategy to mitigate climate change.

3.2. Stakeholder analysis

In order to identify the key actors in the transition towards timber building practices in The Netherlands, a stakeholder analysis (SA) will be performed in this research. The SA will focus on the stakeholders and involved actors that are directly in relation with a contractor that wants to deploy its timber building concept in the market. Therefore a distribution of two layers of stakeholders is distinguished: the inner layers consists of the producers, regulatory government and lead clients & customers. The outer layer of stakeholders have a supporting role in the transition, from a contractor's point of view and consists of partners, knowledge providers and specialist service providers. The onion diagram of these actors that influence the transition towards timber are given in figure 3.5. An important note is that this SA is restricted in a certain scope and aims to offer general knowledge of the most essential parties involved in the timber transition in The Netherlands, so certainly more stakeholders are involved but not considered for the sake of in-depth analysis of the most importan. In the following parts each stakeholder is described with regard to the following aspects:

- Stake or interest
- Resources
- Action channels open to stakeholder
- Probability of participation and manner of doing so
- Influence as a product of resources and participation
- Barriers for implementation
- Action plan elements

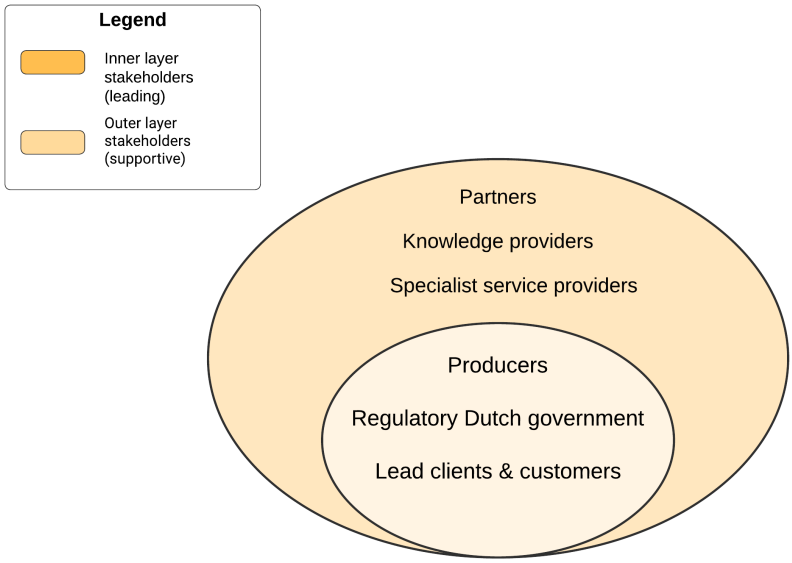

Figure 3.5: Overview onion diagram of stakeholders (inner- en outer layer) infleucing transition towards timber

3.2.1. Inner layer stakeholders

Producers: Timber building contractors and suppliers

The viewpoint of this SA is around the overcoupling term 'producers' that is a crucial stakeholder in the transition towards timber building practices. The stakeholder of producers consists of timber building contractors and directly related suppliers. Contractors and suppliers carry out the actual work on the construction site. From this executive role, they should be able to make the choices feasible in the practice. In addition, according to Copper8 and Metabolic-consulting (n.d.) they have a role to play as a purchaser of materials from suppliers. Their practical experience in the design and development phases positions them well to advance the transition to timber construction. By furthering their still-developing knowledge of timber and its implementation possibilities, they contribute to the sector's growth. Increased demand for timber constructions allows these builders to refine their methods through greater experience. Some have even developed proprietary production techniques that can be influential in the broader adoption of timber construction. Thus, the role of timber builders is crucial in driving this transition forward. As found in the literature the transition towards timber does not only enfold around the use of the new raw material, but also the involvement of industrialization and the innovative way of constructing by using conceptual building techniques. These intertwined transitions will be elaborated more extensively in section 3.6.

Currently, there have been found that many contractors in the residential construction industry are hesitant to select timber as a construction material mainly due to the fact that they lack experience and necessary expertise (Vermeulen, Marco, n.d.). Nevertheless, there are certain contractors in The Netherlands who have shown courage and chose to use timber in their construction projects. Herein a step into the early adaptors phase of the timber transition is made through enhancement of modular and conceptual building with timber, which brings forward the beneficial aspects of constructing with timber. Furthermore, in the residential market, certain covenants have been signed by market parties including several contractors which shows commitment to incorporating timber into their projects. Subsequently, the involvement of all important market actors is required in order to gain a deeper understanding of the evolving and change in supply chain (Bronsvoort et al., n.d.).

The main stake of producers (e.g. timber building contractors and suppliers) is firstly to contribute in lowering their CO_2 emissions by using more bio-based materials as is often stipulated in the organization's strategy, mission and future goals. Secondly, the interest of these parties comes to making a profit by developing innovative timber-building concepts. Subsequently facilitation of development with regard to timber concepts, requires substantial financial resources and enhanced technical knowledge from contractors in house. In addition, their action channels are open to stakeholder' focus on expanding their expertise in timber's technical applications which will be useful in the development of a new concept and starting a new innovative trajectory. As expected producers tend to be highly involved participators, due to the fact that these parties make significant investments in innovative timber building concepts and therefore develop, secure, and share knowledge about timber constructions. The producers' influence as a product of resource of participation in the transition is that they are able to develop timber products that require capital, knowledge, and materials that fit the market demand. When this timber concept is developed, contractors can have influence on the production market of timber.

Regulatory Dutch Government

The Dutch government, where also the local municipalities are included in this analysis, both play an important role in the shift to timber building practices in the Netherlands. The main task of Rijksoverheid, the Netherlands' central government, is to craft and define the outset framework for timber construction and additionally act as a catalyst by initiating the transition towards a sustainable and circular construction sector. Herein the government also currently engages in specific goals, activities, and organizational collaboration needed to rapidly scale up the market for bio-based raw materials as stipulated in the National Approach to Biobased Construction (i.e. Nationale Aanpak Biobased Bouwen) (Rijksoverheid, 2023). Provinces, one layer down in the hierarchy are primarily responsible for addressing the housing crisis through smart spatial planning and decision-making. While they are in charge of choosing suitable locations for future buildings, provinces have a moderate influence on the material demand and environmental impact of house building (Copper8 & Metabolic-consulting, n.d.). Municipalities have been more significant in recent years, notably in the housing industry. They develop frameworks like the Environmental Vision and Plan, oversee housing and building projects, and sell

their own land (Copper8 & Metabolic-consulting, n.d.). Municipalities function within the legal framework parameters of the Building Decree to achieve this goal, which means that their criteria are based on the Dutch government's sustainability standards.

Their key goals are to promote sustainable construction methods, reduce national CO2 emissions, and ensure public safety and adherence to building rules. The government has a great capacity to create and enforce legislation and policies that encourage sustainability. For example, they can enact construction codes that encourage the use of lumber while ensuring that these materials meet safety and environmental standards. They can also provide financial incentives, such as subsidies or tax exemptions, to encourage timber construction projects.

The government can take action by developing and implementing legislation that mandates or encourages the use of sustainable resources such as timber. For example, they can pass legislation requiring a particular percentage of new buildings to employ bio-based materials. Furthermore, the government can fund and support research activities to advance timber construction techniques, ensuring their safety and efficiency. Public awareness campaigns are another important avenue, since they may educate and encourage both industry experts and the public about the benefits of timber buildings, raising acceptance and demand.

The Dutch government has a significant influence due to its regulatory and financial capabilities. They can effectively steer the building industry toward more sustainable practices by enforcing strict standards and providing incentives. Their effect can be seen in the implementation of the "City Deal Circulair en Conceptueel Bouwen," which includes biobased construction as one of its primary initiatives, as well as grant funding for pilot projects that illustrate the viability and benefits of timber construction. The government's actions not only change market behaviors but also ensure that sustainable practices become the norm in the building industry.

Lead clients & customers

The third major stakeholder in the inner layer participating in the transition to timber building methods is the timber producers' principal clients and consumers. This group includes institutional investors, housing firms, private property owners, and residential developers. Housing corporations and individual property owners play an important role in the transition to timber building because they possess a major portion of the current real estate stock. Furthermore, lead clients of construction businesses include institutional investors that provide financial resources to help timber projects get off the ground. Pension fund investors, often known as institutional investors, are among the few who may motivate the building business to generate green value (Copper8 & Metabolic-consulting, n.d.). Subsequently, pension savings are only meaningful after tens of years. In their capacity as financiers, they might demand developers' plans and so organize the necessary financial factors, such as funding. Furthermore, residential developers are an important client of timber producers because they are responsible for both the financing and urban area planning of timber projects. Real estate developers purchase the site, assume the risk, and pick the companies responsible for design and implementation. It is up to them to design the program within the spatial planning frameworks as well as the sustainability aspirations and combine these crucial key aspects into one business plan (Copper8 & Metabolic-consulting, n.d.).

The key stakes of this group's lead clients and customers are to achieve sustainability goals, reduce long-term running costs through energy-efficient buildings, and increase property value and marketability. They have large funding for new construction projects, as well as access to market intelligence and consumer trends, which allows them to considerably influence design and material decisions. Their action channels include using timber as the major material for new constructions, funding research and development for timber construction, and collaborating with sustainable suppliers and builders.

Their chances of participation are moderate to high, particularly among those committed to sustainability, because they can invest in experimental projects and demonstrate successful timber buildings. Their effect is significant due to investment decisions and market demand, allowing them to shape trends and establish standards in the residential construction market. For example, by selecting timber for a new residential development, they can set a precedent that encourages other developers to follow suit, resulting in widespread acceptance and adoption of sustainable building practices.

3.2.2. Outer layer stakeholders

Partners: Architects

Thereafter partners that are inherently relevant in the residential construction industry are architects, who are situated in the outer layer in the transition towards timber. The role architects play is crucial as a partner, because they have the incentive to initiate and encourage timber within the design phase. Their interest is allocated to pushing the boundaries of design and sustainability. At the same time, their stake is situated in meeting the client's needs preferably with assignments to create designs for sustainable buildings. Furthermore, architects are eager to expand their professional reputation and marketability as they are dependent on the amount of assignments they get. Therefore they are in possession of understanding the timber design approaches and have access to networks within the residential construction industry from their professional relationships.

As found in the figure 3.6 the related action channels that are open for partners, respectively architects are they have to develop knowledge and designing methods for using timber as primary construction material, while collaborating with contractors and suppliers. Herein maximization of timber use and initiating opportunities through educating clients on the benefits of using timber within residential construction projects. The willingness to participate is found to be strong, due to the fact that trends are increasing the popularity for sustainable architecture, which allows them to pioneer design advances and promote timber in projects. Furthermore architects have significant influence over design decisions and support suggestions of the client through their own timber experiences in their portfolios and advocating for its use in high-profile projects.

Knowledge providers

The second stakeholder that has been identified to be situated in the outer layer of the transition towards timber is knowledge providers, which includes universities and research institutes. Universities and research institutes have access towards crucial knowledge sources that is inherently needed to be spread in the residential market in order to take the next step out from the early adaptors phase. The incentives for knowledge providers are conducting valuable research in sustainable construction through filling current knowledge gaps in timber construction and at the same contributing to environmental sustainability objectives. Universities and research institutes are valuable resources for the residential market because they are able to provide knowledge in fields such as timber engineering, materials science, and sustainability. Even more they have access to research funds academic alliances, and are able to perform testing that validates the performance and quality of timber. Often there is found that knowledge providers are part of a collaboration with industry partners as seen in timber pilot projects and also in innovative trajectories such as timber product development.

There can be stated that the engagement of knowledge providers is almost always high because their intrinsic motivation comes from possibilities to propose research initiatives and collaborations that provide evidence-based recommendations for industry practices. They encourage innovation and raise industry standards by disseminating research and best practices. For example, by releasing groundbreaking studies on timber's structural qualities, they can give the scientific basis required to enable wider industry use and even more adopt current laws and regulations accordingly to the performance that have been adequately tested with timber leading to diminishing (potential) barriers for adopting timber in projects.

Specialist service providers

The final stakeholder that acts in the transition towards timber and is located in the outer layer of the market as well, are specialist service providers. This stakeholder group includes several actors such as insurers, consultants, and banks, that supports the transition towards timber building practices. This group of stakeholders is responsible for supporting issues such as risk management with new building materials and processes, and are expected to have the expertise in house on relevant services that promotes timber construction. The services that are necessary for deployment of timber buildings are relevant risk assessment tools, as well as financial products, insurances and services that is tuned towards timber projects. Especially the actor insurers are directly involved as a specialty service provider, as they play an important role in insurance for timber buildings for future owners/residents. Such insurances are inherent new in comparison with concrete buidings and insurers therefore need insights into any (new) risks that may be related to the insurability of the object provided by the residential market. When insurers do not have a clear understanding of these often (perceived) risks this can form

an obstacle to gain insurances in constructing with timber respectively but also poses challenges for customers that are in need of a suitable insurance (Copper8 & Metabolic-consulting, n.d.).

The influence of service providers are rather limited within the timber transition as their role and responsibilities are mainly allocated in managing risks and providing financial support where they can encourage the use of timber by offering attractive terms and services. For example, by creating specialist insurance policies for timber buildings, insurers can reduce concerns about expectations of long-term timber performance and mitigating risk factors which eventually enables trust and can lead to potential investments by lead clients in sustainable construction approaches through consultation.

In order to understand the interplay between the key factors for implementing building practices by the so-called 'entrepreneurs' within the residential construction industry and the essential network actors, the use of a market and system failure framework gives crucial insights into the interplay between them as defined by Woolthuis et al. (2010). The final framework with the seven categories that have been analyzed on the specific six crucial stakeholders and parties within the transition towards timber is shown in figure 3.6.

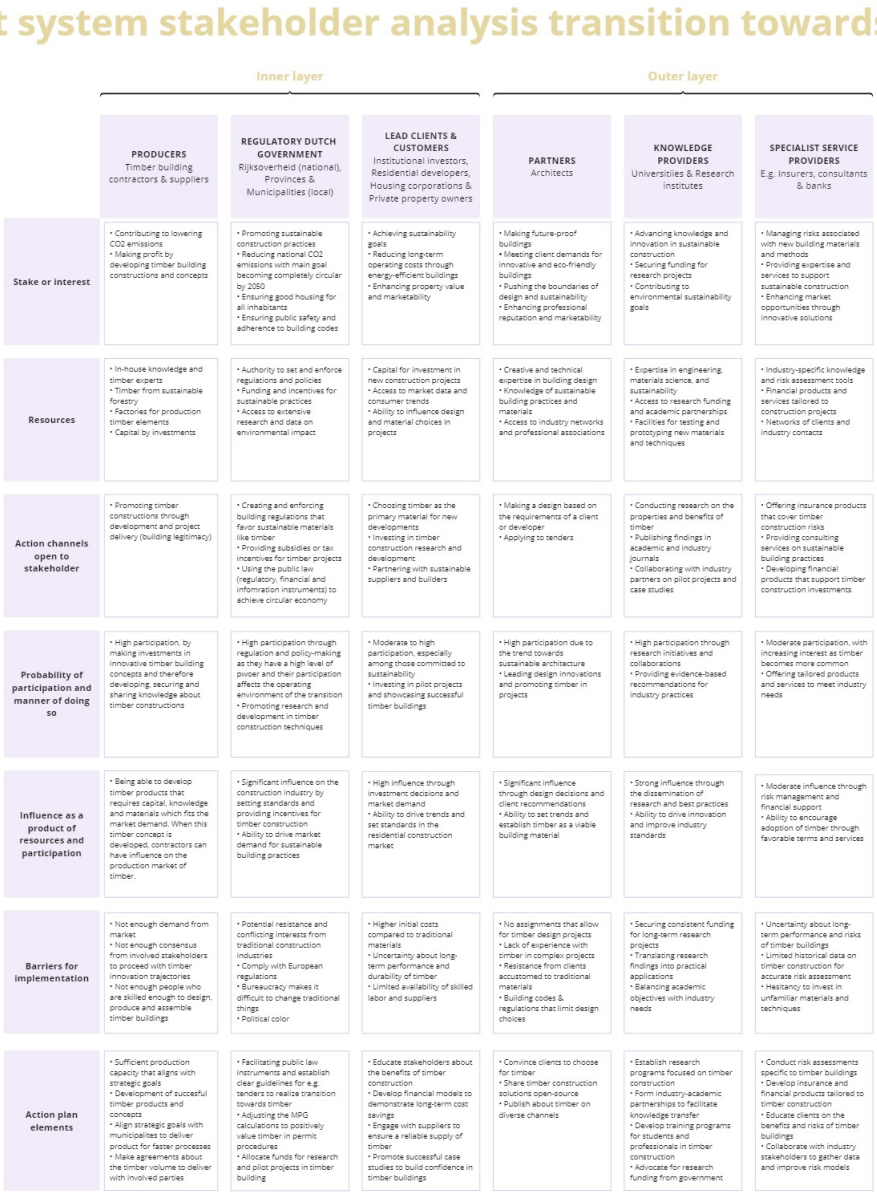

Figure 3.6: Stakeholder analysis market and system failure framework

Furthermore, a distinction between system-following and building entrepreneurs within the residential construction industry can be made. In figure table 3.1 the main characteristics of both following and building entrepreneurs are given, wherein the transition towards building practices needs the building entrepreneurs, who take the initiative to create a new network, are ahead of the game and actively develop technologies for which they have enough capabilities and more importantly these entrepreneurs try to create a new demand by informing and demonstrating the innovation (Woolthuis et al., 2010).

	System following entrepreneurs	**System building entrepreneurs**
Network interactions	They 'jump on the bandwagon' of incumbent firms to use their access to markets. They collaborate with vested interests.	They create a new network of willing players outside of the vested interests. Feel cooperation with vested interests is counterproductive.
Institutions	**Hard** Rules and regulations provide impulse for sustainable innovations as large firms (to which they supply) are pushed towards sustainability **Soft** They adjust to current cultures, norms and values as products 'sell on accepted criteria as price and comfort'. Sustainability is not put forward if it clashes with common beliefs.	**Hard** They are 'ahead of the game': find that most regulations are barriers for innovation and voluntarily set new standards. **Soft** Sustainable norms and values are emphasized to legitimize their sustainable innovation. They persuade others to change their mindsets and behaviours on sustainability.
Capabilities	Enough capabilities in-house and good access to knowledge suppliers. They wait for technologies to prove themselves commercially so they can adopt it.	They actively develop technologies, for which they have enough capabilities, as they see technology as an important driver for innovation. Their relationships with knowledge providers are a stimulus for this.
Market demand	There is enough demand for sustainable products. They try to reach this market through existing channels and with proven technologies.	They try to create new demand by informing, demonstrating *etc*. They miss lead actors, e.g., the government that demands high ***quality*** so that new solutions can prove themselves (also in demonstration projects)
Market structure	There is a small group of actors that dominates construction industry. They 'use' the dominant energy players as clients and distribution channels.	The market is 'locked' by a few very dominant and conservative actors. They try to challenge this existing power coalition by creating networks of new players.

Table 3.1: System influences and strategic reactions of system following and system building entrepreneurs (Woolthuis et al., 2010)

3.3. Innovation diffusion theories

In general, decision-makers such as developers, contractors, builders, and politicians lack knowledge and experience about building with timber. In contrast, there exists a wealth of experience, standards, knowledge, and tradition regarding mineral building materials. Since the common approach is familiar, calculable, and profitable, there is no willingness or readiness to shift toward timber construction, which is seen as too complex and too risky (Moore & Doyon, 2023). Regarding complexity, concerns about humidity were mentioned as a notable aspect of attention, since it influences the conservation of the material and the safety and durability of the construction. Although there is great awareness about the benefits of its use for the decarbonization of the sector, which is seen through European initiatives promoting sustainable construction methods and building materials, as stated by (Moore & Doyon, 2023) a remarkable pressure within users and politics is not yet present, giving construction companies and developers little incentive to rethink their usual processes.

In order to identify the pivotal players within the housing sector and their incentives to actually rethink their usual processes towards transitioning in adopting timber building practices, an evaluation

of the current residential market structure and central stakeholders have to be carried out. In the following part, the status quo of the residential market and two innovation diffusion theories (Rogers & Moore) are analyzed.

3.3.1. Rogers (2012): Diffusion of Innovation through market structure

The market structure mainly determines the openness of the market to new players, new innovative products, and processes, which refers to the market dominance of certain parties in the market (Woolthuis et al., 2010). According to Woolthuis et al. (2010) entry into a field or market is hampered for construction companies by a number of factors, including high initial investment costs with regard to knowledge development, establishment of capital-intensive production or research facilities, or 'sunk costs'. Currently, the under-deployment of timber building practices in The Netherlands can be pointed out by the following market events occurring in the construction industry (Geraedts et al., 2014):

1. Parties (market and government) still look at each other too much to step out of habits and behavioral patterns focused on volume and capacity;

2. Parties do not yet dare to experiment to a large extent with more on services, services and users targeted organization and production processes;

3. There is still insufficient experience in working with quality criteria in tenders instead of at the lowest level price;

4. There is still insufficient business economic perspective for a shift towards a more sustainability-oriented offering;

5. There are still insufficient incentives for drastically reducing avoidable costs (failure costs);

6. The application of innovative knowledge requires a fundamentally different behavior behind the front door of the different parties.

In 1962 the groundbreaking study on the diffusion of innovations, Rogers et al. (2014) examined how individuals and their social systems relate to the adoption of new ideas. An idea, method, or item that is novel to someone can be considered an innovation. After that, the adoption process transforms into the thought process that the person uses to bring this concept or behavior to life. 'Diffusion is the process by which an innovation is communicated through certain channels among the members of a social system over time,' according to Rogers et al. (2014). Furthermore Rogers et al., 2014 defines communication as: 'Participants create and share information with one another in order to reach mutual understanding'. Since risk and uncertainty are inherent to innovation, people try to minimize them by sharing information with one another or by making it up with additional project costs. This is the current process that a structural timber building goes through in its supply chain. Because timber structure construction is still relatively new and lacks standardization, stakeholders exchange information to safeguard themselves and lower risks and uncertainties. As a matter of fact, industry relationships have a significant impact on construction innovations (Dubois & Gadde, 2002; Miozzo & Dewick, 2002). 'Loose couplings' is how Dubois and Gadde (2002) characterize the relationships in construction. This characterizes the transient alliances of businesses and people who band together to finish a project before splitting up. Blayse and Manley (2004) provide an additional explanation of the situation, stating that relationships are important because they can facilitate the flow of knowledge through interactions and transactions between individuals and firms.

Currently the market of the residential construction industry with regard to the innovation of timber construction is still in the early phase when looking at the innovative product diffusion market curve in figure 3.7 developed by Rogers et al. (2014). Herein the market of timber building practices consists mainly of early adaptors and early majority, showing that structural timber buildings are still in the early phase of innovation adoption (Gosselin et al., 2018).

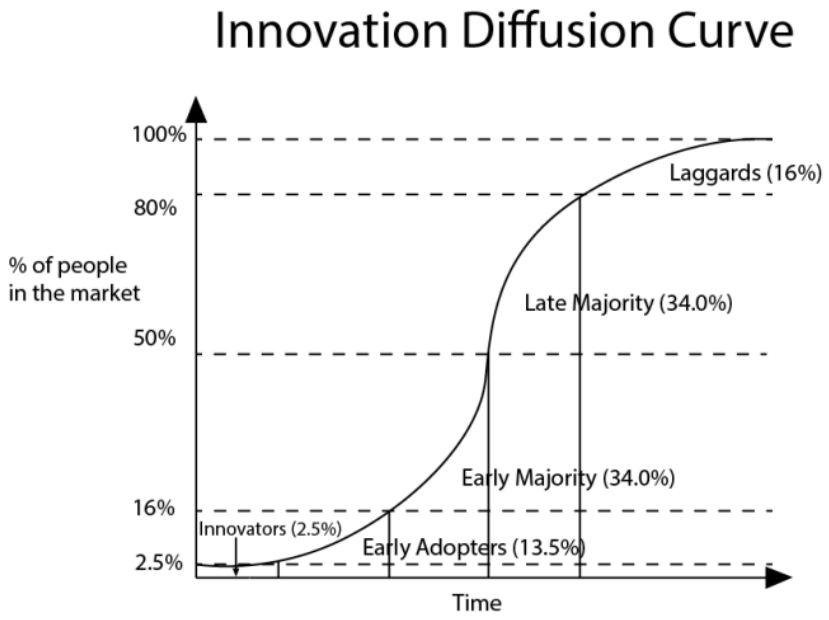

Figure 3.7: Innovative product diffusion market curve, adopted from Rogers et al. (2014)

3.3.2. Moore (2012): Hierarchical levels of innovation

When looking at the literature on innovative transitions within the construction industry, the discussed complex factors and challenges across socio, political & industrial fields, form several opportunities to accelerate the provision of timber in building projects and namely in the new housing buildings (Moore & Doyon, 2023).

Within broader discussions of urban sustainability transitions, housing has long been identified as a niche (Berry et al., 2013; Moore, 2012; Smith, 2007). In part, this has emerged from an understanding that a transition to a low-carbon housing future will require more than just a technical solution, and in fact, will require deep structural changes to the way housing is provided and used (Doyon & Moore, 2019; Moore & Doyon, 2023; Raven et al., 2021). Analysis of housing as a niche, though, has proven difficult. The health and well-being of households, as well as their liveability, costs, financial gain, and access to employment, services, and leisure activities, are significantly impacted by housing design, technology, location, quality, performance, and affordability (Moore & Doyon, 2023).

A transition towards innovative practices, can be outlined in four different phases over time set out against the hierarchal levels of innovation. The landscape of the innovation transition is illustrated in figure 3.8. Herefrom there can be stated that the transition towards timber building practices is currently in the pre-development stage (Moore, 2012). According to Moore (2012) there has been little discernible change at the systemic level, but there has been significant experimentation and development at the niche level, and in certain jurisdictions, pressure to modify the status quo is beginning to mount. It might be argued that in some jurisdictions with more stringent minimum performance requirements, the regime is about to enter the take-off phase, wherein the niche challenger is starting to weaken the existing regime and increase its own confusion.

A proactive push and pull strategy utilizing a range of policy tools and industry innovations will be necessary to significantly enhance housing quality and performance and facilitate significant structural changes within the housing sector. This will necessitate a well-defined plan outlining the modifications that will be required in the upcoming years and decades. Any pathway should be created by working backwards from longer-term objectives and timeframes (such as sustainable housing by 2050) and forwards from where we are at the moment in order to guarantee a well-thought-out approach. As per the evidence of the development of housing regulations and the pressing need for change, it is recommended that all jurisdictions implement sustainable housing requirements by 2030 at the latest, following the guidelines presented in this book. Jurisdictions must develop policy pathway plans to figure out how to go from their current situation to the desired 2030 outcome as quickly as possible if

they are to succeed in this. This will give the housing sector, other stakeholders, and homebuyers confidence and transparency. It will also give the sector time to adjust. The policy pathway can serve as a framework for innovators in the housing sector who wish to surpass minimum requirements. This will work to lower any costs associated with the necessary adjustments, stimulate design and construction innovation, and help create a competitive advantage.

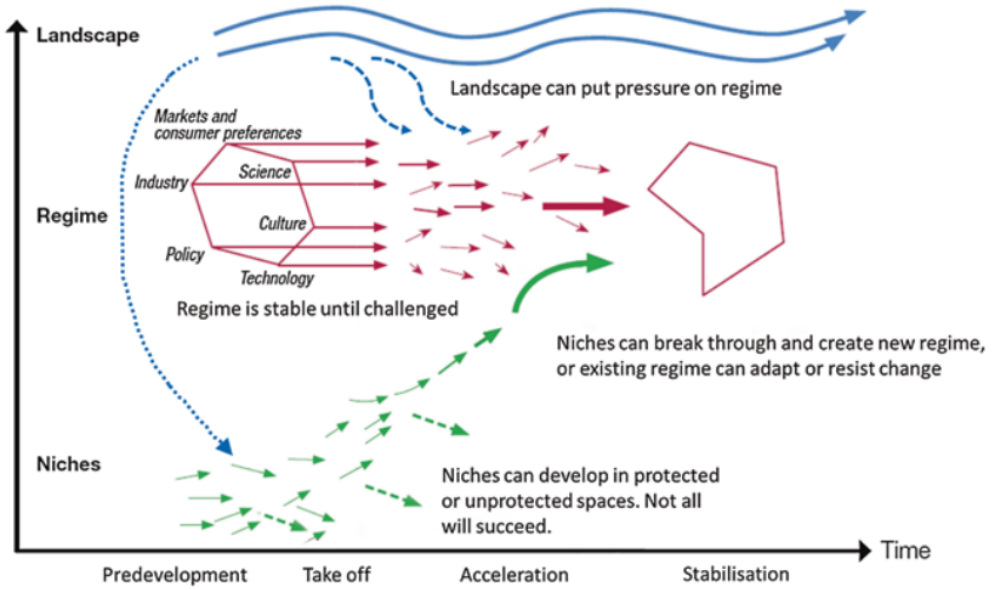

Figure 3.8: Landscape of transition with regard to innovations and interactions between the three nested hierarchical levels (Moore, 2012)

3.3.3. Innovation development

Regarding innovation itself, the policy perspective has recently changed from a product-based emphasis to the view that innovation is a process that is systemic (Edquist, 2004; Galli, Teubal, et al., 1997; A. Kaufmann & Tödtling, 2001; Lundvall et al., 1992). In a similar vein, contemporary business literature promotes a change in thinking from the idea that only products have value to one in which value is created in business systems that are creative in how they combine the resources of the firms and other actors (customers or other firms) for the production and delivery of services (Tykkä et al., 2010).

As discussed by Tykkä et al. (2010) many players in the European Union generally agree with the Organisation of Economic Co-operation and Development's (OECD) definition of innovation. This definition sets forth the various categories of innovations in the residential construction industry:

1. The introduction of a good or service that is novel or greatly enhanced in terms of its attributes or intended applications is known as a product innovation.

2. The application of a novel or greatly enhanced production or delivery technique is referred to as a process innovation.

3. Using a new marketing strategy that involves major adjustments to a product's packaging, design, placement, promotion, or price is known as a marketing innovation.

4. Using a new organizational strategy in the company's business operations, workplace layout, or external relations is known as organizational innovation.

3.3.4. Positioning of entrepreneurial building companies

In the residential construction sector, building companies can be considered innovators or entrepreneurs for their use of cutting-edge technologies, like timber building concepts. The market and environment in which they operate restrict their ability to act as entrepreneurs, necessitating the introduction and spread of certain innovations not only within their own structure and organization but also in more extensive deployments that encompass the entire system context (Moore, 2012). As a result, societal pressures, interactions, policies, and regulations all have an impact on entrepreneurs. These elements are referred to as the ”field” in which the innovation is used. The established sector, with its methods of operation and integrated routines and structures, presents one of the biggest obstacles for entrepreneurs in the construction business. According to Moore (2012) in order to overcome this obstacle, a field entrepreneur must have the intention or capacity to alter the institutions and structures that currently exist. This can be accomplished by implementing strategies that center not only on their enterprise but also on actively altering the environment that fosters the growth of their enterprise (Moore & Doyon, 2023).

In order to embrace innovations and align with the future, the construction industry needs to restructure itself along the following transition paths, as per the Routekaart Innovatieakkoord established by the study of Geraedts et al. (2014):

1. Construction as a service provider: Since residential construction projects are a form of service provision, the end-user should be the starting point both short- and long-term.

2. Construction adds social value; as the residential sectors address social issues in the areas of housing shortage, optimal living experience, and comfortable living, construction projects are evaluated based more on the quality and efficiency of production methods than on price and speed.

3. The innovative nature of the construction industry requires clients to transition from traditional tendering to functional specification. This will eventually coincide with the shift away from conventional designs and solutions and toward creative and sustainable ideas.

4. The outward gaze: The construction industry is evolving from a closed to an open industry that operates with honesty and transparency and fully collaborates with other stakeholders. People have mutual trust. The final consumer is in the center. Promoting chain integration, or cross-project collaboration between businesses that function as a single organization, is crucial to the development of these pathways.

3.4. Drivers and potential opportunities of timber

The current residential construction industry in The Netherlands has been focusing and is steered towards sustainable building practices, which is due to on the one hand regulative pressures from the national government on price fixing and colluding practices and on the other hand the strict tightening of environmental regulations. As quoted by Vos (2007) the industry should be functioning in a way that 'meets the needs of the present without comprising the ability of future generations to meet their own needs'. The approach towards enhancing sustainability within companies encompasses the 'triple bottom line', this concept considers the integration of impacts in economic, environmental, and social terms (Gimenez et al., 2012). According to Kuitert et al. (2019) the definition of transparency should also be included, which is an important condition for well-functioning markets and for ethical innovation businesses within the construction industry.
In the following chapters, the drivers and potential opportunities for the utilization of wood-based materials especially modular buildings with timber are discussed.

3.4.1. Sustainability impact

One of the key characteristics of timber is that the material has the ability to capture and store CO_2 emissions. This process starts when biomass is created, thereafter photosynthesis takes place to remove carbon dioxide from the atmosphere. By following this procedure, a developing forest can function as a carbon sink in the situation where more trees are planted than burnt or decomposed, due to the removing more carbon from the atmosphere than is released (Grace, 2004). The building's lifespan and end-of-life circumstances have a significant impact on the value of carbon storage in timber structures. An important note to make is that the storage of CO_2 is only momentary, in the specific phenomenon of decomposing biomass after the lifespan of timber elements, which releases back the same quantity of carbon into the atmosphere. According to Hawkins (2021), the assumption of decomposing all biomass should be reconsidered, due to the fact that timber leads to delays in carbon emissions, where benefits on creating more time for system adaptation, a reduced chance of reaching a possible climate 'tipping point', and increase in the potential for future permanent CO_2 storage are ultimately the future solution. Therefore building residential residences in timber can result in low-embodied carbon construction systems, wherein the principle of 'design for disassembly' will offer significant opportunities for greenhouse-gas emission reduction and waste avoidance (Lehmann, 2013).

The fact that wood is a renewable resource gives it a significant advantage over other building materials (Blaß & Sandhaas, 2017). According to for Standardization (2011) the definition of a renewable source is a resource that is grown, naturally replenished, or naturally cleansed, on a human time scale. This indicates that, with proper management, we can presume this resource will always be available. This is in contrast with limited resources, like coal, oil, and natural gas, which are produced naturally over a long timeframe of thousands of years, and therefore they will run out before they can replenish themselves.

A crucial precondition in the utilization of wood as a natural resource is maintaining healthy forests. This indicates that the harvesting of timber has the least negative ecological impact possible (Luijkx et al., 2021). Therefore, annually no more trees should be harvested than can be regrown, as is the case with any natural resource. Currently, Europe's forests act as a carbon sink because each year, more trees are planted (720.6 m^3) than are harvested (522.3 m^3) (Luijkx et al., 2021). One fundamental assumption made in this thesis is that all wood originates from forests that are responsibly managed. Fortunately as stated by Luijkx et al. (2021), 98% of the time for timber sheets and 99% of the time for softwood, the wood used in the Netherlands can be verified to have been sourced sustainably.

3.4.2. Economic surplus value

Building with timber has been found to incorporate certain economic surplus value. Herein the transition towards timber building practices is desirable from an economic perspective for two specific reasons. First of all, as the residential construction industry is a big user of energy and materials and is accountable for a large part of the CO_2 emissions generated, and at the same time creates significant waste streams, finding the urgency from an economic perspective is crucial (Nuñez-Cacho et al., 2018). Costs are a very important driver in the residential construction industry, but like most new technology, as demand increases productivity reduces costs in both manufacturing and streamlining the process (P. D. Kremer & Symmons, 2018). Besides that building with timber as a construction material uses less energy compared with traditional construction (typically concrete and steel) methods and approaches,

including carbon sequestration, timber holds the potential of enhancing project timeframes and therefore enlarging the economic surplus at a certain level of upscaling. According to P. D. Kremer and Symmons (2018) the economic surplus value for timber can be exploited by taking cost-effective advantages, and the best features of timber production, since they are structurally efficient, lightweight, easy, and quick to install at the construction site. Taking this advantage can lead to big-scale industrialization with the concept of the circular prefab building principle, which will be explained in further detail in section 3.6. Using wood components that are prefabricated, and manufactured off-site, allows for a higher speed of assembly, resulting in higher revenue and margins with a reduced number of site personnel (Tupenaite et al., 2021; Yates et al., 2008).

Secondly as stated by the research of Woolthuis et al. (2010) the residential construction industry is not 'footloose', which means that the enhancement of sustainable innovations and performance will create benefits in the regions and countries they operate in, but also knowledge and experience can be built up and fostered. This will eventually lead to a pivotal and competitive position in the residential construction industry within the market both nationally and internationally.

3.4.3. Technological advancement

Wood as a construction material for residential buildings has already been used since the Middle Ages. However according to Hough (2019), concrete began to dominate the market about 1920. Wooden buildings were also less popular due to durability concerns and the fact that they were unsafe in the event of a fire. Recently the uptake of wood has started the transition towards building with bio-based materials, where the popularity and application of engineered wood products (EWPs) has been increasing due to recent developments in the range of EWPs for structural applications.

It is found that the use of CLT, which is a construction technique where construction elements are manufactured through cross-laminated layers in wood has been taken its advancement in the residential construction industry. Large-scale CLT (Cross Laminated Timber) projects were initially constructed in the Netherlands five to ten years ago (Luijkx et al., 2021). The potential of wood for high-rise structures has also expanded with the recent technological advancements in engineered and prefabrication of wood. This was primarily due to the fact that, with proper design and application, engineered timber products can have a higher fire resistance (Green & Eric, 2012). Furthermore, the advancement of timber by prefabricating its elements, ensures that the quality of the products can be controlled inside the factories, which makes the overall use of timber more appealing (Luijkx et al., 2021). The research by Green and Eric (2012) on top states that the technological acceleration of timber as a construction element will lead to the competitive position for specifically midrise buildings and eventually surge more interest in the use of timber elements in various applications.

3.4.4. Social benefits

The adoption of timber also creates social added value regarding merits for the users. It has been concluded that humans feel happier, healthier, and more productive when they are connected to the natural environment. Numerous scientific studies confirm that active and passive encounters with nature are positive for human health (Nyrud & Bringslimark, 2010). Utilizing natural materials in construction, like wood, lowers stress and enhances well-being in general. Wood interiors are ranked significantly higher than laminate interiors, according to a study by Jiménez et al. (2015) that looked at the psychological effects of wood and laminate products in the indoor environment. This is primarily because wood interiors were much more physically and mentally stimulating and made study participants feel warmer and cozier. Another study conducted by Fell (2010) verified a strong link between wood and human health. A variety of office settings were constructed, using white, non-wood interiors as the control and wooden interiors as a treatment, in order to examine the effects of natural products on the 'autonomic nervous system' in the built environment. According to the study's findings, having wood in the office lowered 'sympathetic nervous system' (SNS) activation, which controls people's physiological stress reactions (Fell, 2010). It was confirmed by additional research that people feel safer and more connected to nature when they touch wooden surfaces (Syed, 2020). These findings can confirm that wood is a construction material in plain sight and therefore the opportunity to have direct and indirect contact stimulates physiological relaxation and has merits for people's well-being.

3.5. Current barriers for constructing in timber

The current state of under-deployment of timber building practices in The Netherlands is evident, even though the benefits of using timber have been widely known, highlighting the current residential market failures. As stated by Moore and Doyon (2023) the market should steer towards a 'perfect' neo-classical market, which indicates that if housing consumers or the housing construction industry sees value in improving the design, quality, and performances of using timber, consumers or building stakeholders will drive such improvements.

The current barriers for construction in timber can be divided into four categories, namely the 'acquisition phase', including respectively phase 1 as shown in figure 3.9. Thereafter the 'design phase' comes in, which is allocated to phase 2 which includes designing the timber concept and procurement of both materials as partners. The third and last phase is considered to be the operational phase, where production and assembly in figure 3.9 correspond with phases 3 and 4. These identified phases are illustrated in figure 3.9 and cover almost the entire project cycle, wherein the winding-up phase has not been segregated. The last phase, which is phase 5, is the handover phase, whereas maintenance is not part of a timber project's life cycle, from the viewpoint of a construction company, due to the fact that construction companies in the residential industry are most often not responsible for the maintenance after delivery. The most discussed categories are the production and assembly stage of utilizing timber, which shows that the residential construction industry has great concerns about actually realizing timber buildings (Santana-Sosa & Kovacic, 2022). The next most discussed stage is the design stage, which has huge impacts both in the production and assembly stages, especially when prefabrication is present. Herein the design stage entails a more detailed definition and also relates the the acquisition stage due to the higher complexity and lack of expertise. It can be concluded that the design stage heavily influences correlated stages and is pivotal considering the barriers coming from this stage. Finally, the acquisition stage is discussed the least, where the limitations to opportunities are evident. According to Santana-Sosa and Kovacic (2022) the barriers during the acquisition phase create enormous repercussions on the whole process and therefore affect the entire construction industry. It is crucial to create and demand awareness towards this stage.

In the following part, the certain barriers that are currently present and that lead to the locking in concerning the potential of utilizing timber are divided in the four categorical phases and will be further explained.

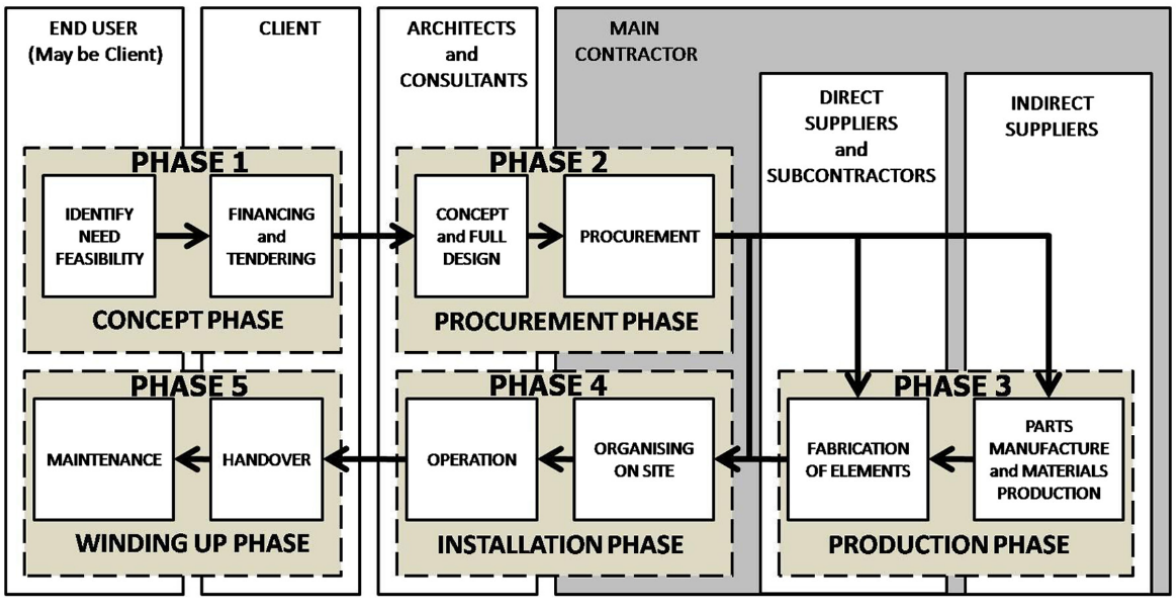

Figure 3.9: Phases with involved actors in a typical construction project lifecycle (Behera et al., 2015)

Acquisition phase

The study of Santana-Sosa and Kovacic (2022) found that among the research group, the nominations of the perceived barriers in the three major project stages, which are the acquisition, design, and production and assembly phases are mostly in the production and assembly phases. This can be found in figure 3.10. However, herein the importance of the acquisition phase during the implementation of innovative concepts, such as timber building practices and moreover the interplay between the three different stages in relation to the acquisition phase is undermined. Therefore investigating the socio-technical factors that occur during the transition and implementation of timber in the residential construction industry poses valuable insights for the strategic movements of construction companies.

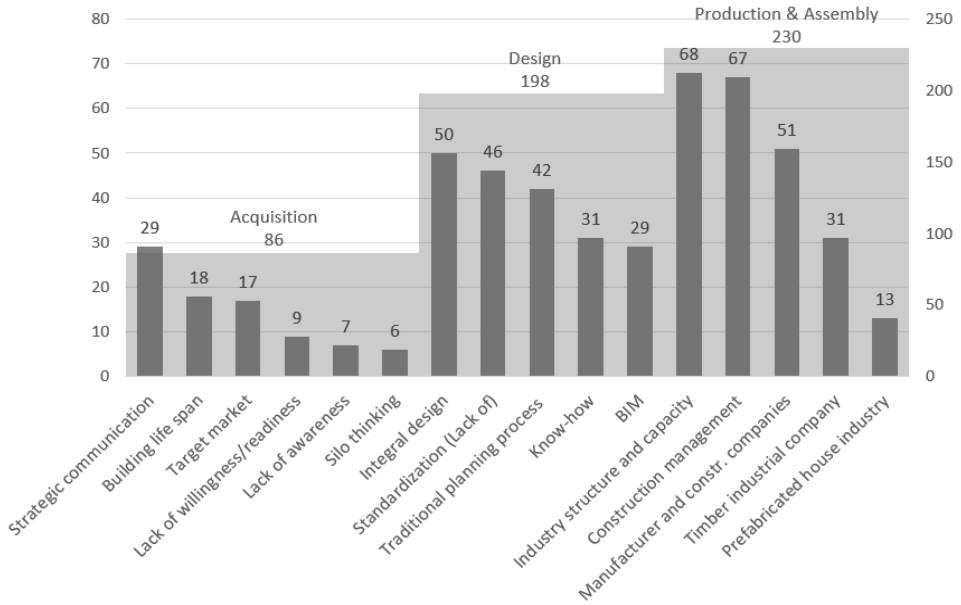

Figure 3.10: Frequency of nominations of three project stages regarding acquisition, design, and production and assembly phases (Santana-Sosa & Kovacic, 2022)

3.5.1. Traditional construction industry

Research of Henderson and Ruikar (2010) has indicated that implementation of new technologies and practices in the construction industry commonly faces barriers. It can be said that these barriers are often not technical but institutional, economic, and social (Borges & Radgen, 1997). Especially the construction industry is often regarded as a mature, slow-to-change sector, due to the traditional way of processes, work culture, and traditions (Gann, 1995). In The Netherlands, the construction industry has been building for over 70 years with concrete, and in the residential construction industry specifically with the method of tunnel casting. Therefore the transition towards an emission-free system of building by implementing new wood concepts within the residential sector is expected to encounter several constraints.

In the study of Sarkar (1998) research has been conducted on the innovation characteristics of the technical options and the barriers that appear, and lead to obstruction of successful implementation of the innovation.

Firstly the construction industry involves many groups with different specializations, varying from the design and construction phase to materials supply that have to work together in order to create a building product. As noted by Sarkar (1998) technical change occurs rather slowly, where the diffusion of innovations has been set to take two to three decades to diffuse to a significant extent. Moreover in the building sector technological change occurs even slower ranging from several decades up to a century (Grübler, 2003).

Secondly, the construction industry has the common characteristic that the rate of adoption of introducing new products and processes can be slow-paced in the beginning. As stated by Klein Woolthuis (2010) the demand quantity problem is the reason for the slow-paced start and therefore at the very early stage of developing an innovative concept, and from the moment of deploying the

new concept. Herein the market is a crucial linchpin for construction companies in order to become sufficiently large by deploying innovative concepts. This will get the construction company to the stage where the products can be 'produced' in larger quantities, and the 'child diseases' have to be discovered and restored to make a large 'role out' possible (Klein Woolthuis, 2010). The demand for high quality needs to be stimulated by lead users or lead markets, which activates parties to innovate and seek cutting-edge new technologies. The leading role for this hike at the start of the innovation can be taken by the government through public procurement or setting standards to increase the requirements for products and processes (Goverse et al., 2001).

3.5.2. Perception of clients and consumers

One of the key factors for implementing timber in construction projects is the perception and concerns of clients and consumers on timber buildings. According to Zainul Abidin and Pasquire (2005), clients are in a position to continuously improve new construction (output) from a life cycle perspective and are also a major force behind the adoption of sustainable construction. Additionally, from a client's perspective there is an anticipation that construction companies will innovate, seek out fresh concepts, and enhance construction outputs (Kulatunga et al., 2009). Preferably the innovations form into 'improved outputs', which refers to aspects like higher quality, lower costs, faster delivery, and, more recently, better life cycle performance. Therefore according to Levander (2010) it is crucial that the perspective and drivers of clients and consumers are taken into account while developing and adopting new innovations, but also are encouraged to request advancements in the building industry. However, as building with timber is a novel innovative way of building in The Netherlands, timber framed houses and properties go beyond clients' frame of reference in four different dimensions (Levander, 2010):

1. New production process;
2. Non-local new actors;
3. Different frame material which in turn entails new technical solutions;
4. Uncertainties regarding operations and maintenance in the owner phase.

The uncertainty of building with timber from clients' and consumers' perspectives is imposed by the unknown. As mentioned earlier the timber construction material and technique results in new production processes, way of thinking, and involvement of new actors, which have not been widely adopted and therefore ask for coping with ambiguous risks and probably extra costs (Levander, 2010). According to Moore and Doyon (2023) people do not have enough understanding or knowledge about mass timber construction, and even though you get the developer, architect, engineer, and contractor to support it, there is the quantity surveyor who says that 'I am not so sure about this' and places some contingency funding into the project - extra costs, and then that blows the costs of the project right out.

As studied by Dubois and Gadde (2002), complexity in construction projects results from uncertainty and interdependence between tasks and actors. G. Winch (1998) asserts that the building is a complex product system, thereby supporting the notion that constructed products are complex. The complexity and variety lead to fragmentation, which forces the clients to communicate with a number of different parties throughout the building process (G. M. Winch, 2001). Therefore, the construction process and even more from the clients' point of view, the building acquisition process may contribute to uncertainty, as the industrialized process' novelty of constructing in timber likely makes the already intricate, traditional, project-oriented process more uncertain (Levander, 2010).

With regard to the maintenance of timber buildings, these aspects from a client's perspective are described as a 'complex technical production factor', due to the durability (long economic life cycle) and costliness (immobility along with the high capital costs (Levander, 2010). From the study of Levander (2010) this is due to the ambiguity and lack of performance regarding the new construction system and installations, where uncertainty in potential savings or a question as to whether the savings are sufficient to warrant the use of a new system of construction can be met. Performance management is therefore a crucial key factor for clients and currently, it can be concluded that market participants

have taken insufficient responsibility for the actual performance after completion and project delivery (Cokins, 2009).

From a consumer's view their perception of wood is that it is a natural, warm, and versatile material, however regarding strength timber does not equate with traditional materials such as bricks, steel, and concrete (Parry-Husbands & Parker, 2014). Additionally, customers believe that wood is prone to rot and mold development as well as termite attack (Lehmann, 2012; Parry-Husbands & Parker, 2014). Anecdotally, it seems that a lot of our opinions about wood originate from what behavioral scientists refer to as "instincts." Human behavior patterns that are innate and exist without instruction or training are called instincts (Spink et al., 2010). As stated by the study of Spink et al. (2010), instincts can be thought of as "evolved cognitive mechanisms" or as the genetic adaptation of particular traits that predispose humans to act in a particular way in particular situations. Customers' answers to questions about wood and its relationship to fire, water, and termites may be the result of innate. The structural integrity of wood members is ensured in structural applications by accounting for the "char rate," or the quantity of wood material that is sacrificed by fire (P. Kremer & Symmons, 2015). In reality, timber components are concealed and shielded from the weather and termite infiltration by cladding and lining the building in a manner akin to conventional construction, unless exposed for aesthetic purposes (P. Kremer & Simmons, n.d.). When built properly, mass timber components are shielded from the elements and less susceptible to events that could compromise the structural integrity of the building.

Concerns concerning termite attacks, fire, and decay were also voiced by customers regarding the risks connected to using wood (Parry-Husbands & Parker, 2014). The public does not consider these issues when considering steel and concrete as building materials. Builders who are responsible for marketing projects to buyers are inevitably going to be reluctant as a result of these unfavorable opinions (Moore & Doyon, 2023).

3.5.3. Financial constraints

At present, as stated by Copper8 and Metabolic-consulting (n.d.) full timber construction is still more expensive than traditional construction, however, it is expected that bio-based construction will become more interesting in terms of price in the coming years, partly due to economies of scale. As of right now, bio-based construction carries a surcharge of approximately 3.4%, wherein it is anticipated that this will fall until 2030.

The given that building with timber is more costly than traditional building methods, can be perceived as a barrier by clients. Herein financial constraints are also present when implementing timber building practices, laying on one side at the client's and consumer's hand. Most of the uncertainties mentioned above relate directly to costs, where costs are the decisive factor in design decisions (Haroglu et al., 2009). The group of important stakeholders of the timber innovation has other motivations distinct from self-interest and profit maximization, which are part of the choice process, but evidently, constraints are budget and availability (Moore & Doyon, 2023).

Two types of operational costs can be distinguished, costs on short-term (initial construction cost) and long-term (operations and maintenance). The financing of sustainability investments can be difficult to obtain because of certainty with regard to return on investment, and therefore attractive banking financing opportunities are lacking (Bouwteam, 2012). This applies both in the residential construction sector (private owners and corporations) as well as in non-residential construction. Herein a shift from focusing on short-term costs towards the long-term costs is essential. From this context, a distinction between private and public clients can be made, where public clients have a longer owner perspective (Frödell et al., 2008). For these clients, the long-term uncertainties regarding financial costs found by Levander (2010) are energy consumption, durability, and long-term performance, motion-causing problems, and consequences of water leakage. Also, according to Moore and Doyon (2023) the difficulty of securing insurance for timber building projects and the cost premiums, coupled with hesitancy around perceived consumer opinions, make financing for innovative timber projects challenging. From a consumer's view, certain elemental factors and basics have priority even before other factors like improved sustainability, resulting in housing consumers facing a constrained choice. Herein the budget and financial incentives are pivotal (Moore & Doyon, 2023).

Design phase

3.5.4. Laws and regulations

Since 1945 the Dutch housing policy has been developed which enholds the laws and regulations that address subjects such as social housing, spatial planning, housing quality, and sustainability. But this policy has been creating a constant tension between government intervention and market influences (Boelhouwer, 2002). The government formulates regulations regarding building with timber in the NEN building codes, but that is sometimes in conflict with emerging innovations from the market. As stated by Boelhouwer (2002) this is because the innovation is compared and applied to the current industry-specific reference standards, and therefore not suitable for the use of new material such as wood. The evaluation of the residential building's performance is measured by the 'Environmental Performance of Buildings, the so-called MPG (MilieuPrestatie Gebouwen). The MPG is a norm that is used to assess the environmental impact of new-build residential buildings and office buildings (larger than 100 m²), by specifically looking into their energy consumption and carbon emissions over their lifecycle (RVO, 2017). Currently, the MPG in The Netherlands consists of eleven indicators, varying from energy performance, material use, flexibility and adaptability, circularity, and innovation and technical advancement. These indicators are planned to be strengthened and expanded in the upcoming years, due to the feasibility of environmental targets set by the Dutch government and align its building sustainability standards with international frameworks and standards, such as those developed by the European Union or international organizations like the International Organization for Standardization (ISO) (Rijksoverheid, n.d.-b). Unfortunately, at the moment sustainable materials including timber score in many respects even worse than traditional materials such as concrete and steel, as evidenced by the CO_2 emissions of the entire life cycle of wood (Boelhouwer, 2002). This is due to the assumption all timber materials used, will be burned at the end of their life cycle resulting in high CO_2 emissions, Overall, the negative indicators for timber in the Dutch residential sector within the context of the MPG would primarily relate to issues surrounding material production, treatment, and construction practices rather than inherent properties of timber itself (Boelhouwer, 2002).

3.5.5. Technical implications of timber

Researches have been conducted on the technical aspects of utilizing timber in residential buildings, wherefrom the critical technical factors of wood can be divided into three technical limitations: humidity protection, fire safety and resilience, and acoustic performance.

Firstly, a technical limitation of using timber in building practices are that the material shrinks, swells, twists, cracks, and bends over time during different climatic conditions. Therefore in mass timber buildings, if moisture management measures are not considered, designed for, and monitored, condensation and moisture build-up can cause internal stresses and moisture gain that can lead to decay, crack development, and structural issues (Shirmohammadi et al., 2021). However an important note can be made that most interior structures are designed in such a way that moisture entering the structure is prevented. This indicates that for timber structures, no extra precautions are required. Therefore, there could be serious repercussions, so when designing with wood, more thought should go into the material's durability. Properly designed structural timber elements have the potential to last just as long as equivalent concrete or steel components (Hough, 2019).

Secondly, in construction projects, safety is a very important indicator. According to Shirmohammadi et al. (2021) the potential biological and thermal degradation of wood as a material can therefore be seen as a challenge and limitation (e.g. in the case of fire hazard) towards designing with timber and safety regulations. Solid timber has a relatively high tensile strength, however the compressive strength is lower than for concrete (Blaß & Sandhaas, 2017). While engineered timber has improved structural qualities, it is still not as strong as a concrete structure of the same size to support the same loads. If by any chance a fire breaks out, a timber-framed house will not be able to withstand the heat and flames in the same way a brick or steel structure would. Although a timber-framed house can be treated with fire retardants, this tends to slow down the surface spread of flames as well as reduce the production of smoke (Buchanan & Abu, 2017).

Thirdly, for the user experience a limitation of using timber, is that timber frames are not able to resist sound transmission as well as a block-built home purely because the block home has more density to it. In the studies of Nilsson et al. (2023), it is found that especially in high-rise buildings of cross-laminated timber (CLT), the increasing building height directly influences the elasticity of junctions

and thus affects the sound transmission between apartments on different stories. In addition, the low weight of timber introduces difficulties when it comes to vibrations. This requires additional calculations and often additional design measures. The vibrations can be reduced by adding mass to the structural timber floors or by increasing the strength of the timber (Gustavsson et al., 2006).

Production and assembly phase

3.5.6. Limited experience supply and value chain

In the production and assembly phase of innovating and building a timber structure, a multitude of strong partnerships and relationships with various stakeholders are required. The study of Gosselin et al. (2018) clearly illustrates providing long-term stability between the various parties within the chain.

As described by Behera et al. (2015) the supply chain of a typical timber building can be mapped from a linear perspective that includes many stakeholders and encapsulates various relationships. In chapter section 3.2 the incentives and motives of these different stakeholders will be further discussed. Behera et al. (2015) stated that: 'The typical supply chain for any given construction project could include architects and engineers, main contractors, specialty subcontractors, and timber elements suppliers that come together one time to build a project for a specific owner.' From this, a representation of a typical structural timber building supply chain can be derived, which is illustrated in figure 3.11. Depending on the mode of construction, a typical structural timber building supply chain can include six or five stakeholders. figure 3.11 shows the representation of these two options. Typically, a real estate developer needs an architect to design the building and an engineer to draw and calculate the structure. Another contract is given to the main contractor who will hire a variety of sub-contractors integrating a builder (Gosselin et al., 2018). Finally, a supplier of structural timber elements is awarded a contract to manufacture the timber elements required for the structure.

In addition, in the study of Schraven et al. (2019) it was found that supply chain actors tend to have a bilateral dependency on other parties at specific changes and therefore also transitions. Bilateral dependency in the value chain refers to a situation where two or more entities within the value chain are mutually dependent on each other for the successful operation of their respective activities (Schraven et al., 2019). Actors tend to mainly focus on their own business model when faced with impactful changes in the supply chain (Gaustad et al., 2018).

According to Schraven et al. (2019) understanding the bilateral dependency between actors within the value chain will lead to gaining valuable insights from the defensive and reactive attitude of these actors. Therefore when an actor is acting on its responsibility at first, this can trigger a chain reaction of parties following this by making changes that can benefit and further trigger their bilateral dependent counterparts to follow. It can be said that, when a bilateral dependency is known for a supply chain actor, then an obligatory party could change the actors' calculus with suitable incentives (Schraven et al., 2019). These incentives can lead to the development of new technologies by for instance improving the product quality of secondary materials, which creates more supply, from demolishers and demand from concrete producers, contractors, and designers.

Close integration between all actors in the supply chain and therefore the fact that supply chain management, strategic partnerships, and collaborative agreements have to be adopted by the construction industry. This is needed in order to start and even scale up the production and supply of timber elements. As timber supply chains need to adopt the transition towards the new innovation of timber buildings, this leads to a new way of producing and supplying. In The Netherlands, the traditional construction methods have led to limited experience in the seamless coordination and organization of the production and assembly phase. Herein several key criteria that influence the supply chain are identified by Gosselin et al. (2018), where the type of contract in procurements or projects is noted as a key criterion. Kantola and Saari (2016) argued that the 'most traditional and commonly used project delivery system worldwide is the design-bid-build system.' This mode is mainly characterized by the linearity of the scheduling process and the separation of the design and the building steps. From a construction company's perspective, the adoption of this project delivery system results in the first timber projects that are being built consisting of challenges in the supply and assembly phases, from which important lessons learned and the 'child diseases' emerge from the projects (Gosselin et al., 2018).

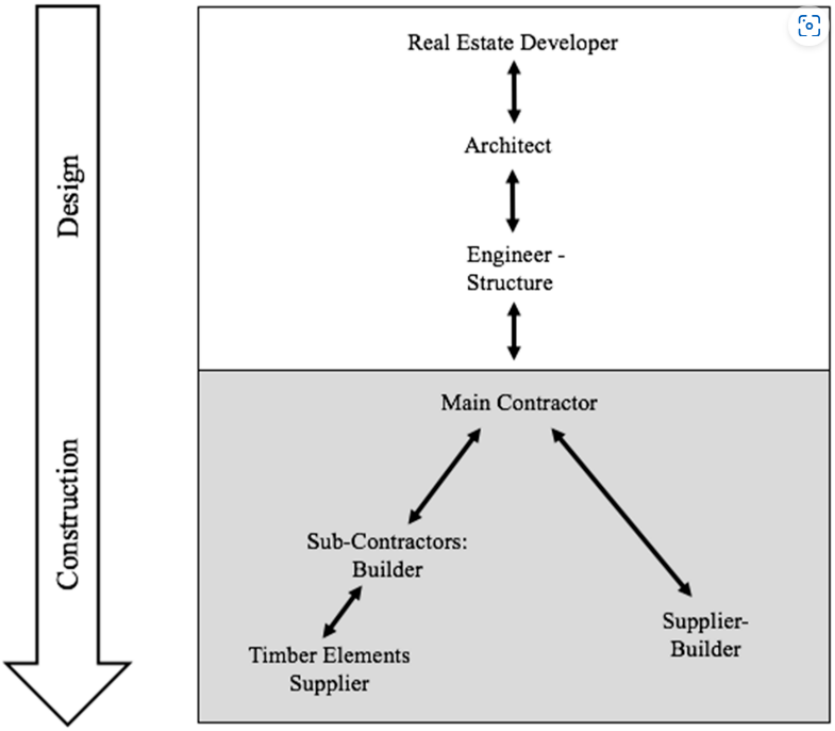

Figure 3.11: Timber supply chain and involved actors (Gosselin et al., 2018)

3.5.7. Carbon reduction not monetised

Another barrier to choosing timber as the main construction material in tenders and projects is that the positive effects of timber with regard to lowering CO_2 emissions are not sufficiently considered when choosing the structural material. The current laws and regulations set in The Netherlands of the standard carbon estimation turn out to be undervaluing the potential biogenic carbon storage of timber (Keijzer et al., 2020). The monetization of timber in sustainable construction is hindered by the dominance of the concrete and steel industries in European standard committees. Recent updates to the NEN-EN 15804 standard explicitly state that temporary CO_2 storage cannot be included in calculations for the lifecycle sustainability of a building (Van Belzen, 2020). Therefore this approach disregards the carbon storage potential of timber, as the material is often burned at the end of its life, leading critics to argue that it offers no net positive environmental impact. The steel and concrete sectors, which hold significant influence in shaping regulations, resist changes that would recognize the benefits of timber. However, experts like Van Belzen (2020) highlight that new mass timber products, such as CLT and glulam, particularly with dry connections, are well-suited for high-quality reuse, extending CO_2 storage beyond current assumptions.

According to Lippke and Perez-Garcia (2008) clearly the incentives for managing forests, choosing building designs, and choosing certain manufacturing processes, including fuel sources, would shift significantly if the markets were to incorporate these higher values of carbon emissions into market decisions. Remarkably, however, the largest volume of goods delivered to markets in the shortest amount of time results in the most carbon benefit. This is in contrast to the fact that forest carbon may be boosted by longer rotations, both on its own and in certain cases even incorporating the carbon storage of wood products (Lippke & Perez-Garcia, 2008). The construction industry is therefore not incentivized to consider and use timber more frequently due to the lack of monetization for potential carbon reduction. (Assaad, 2024).

3.6. Industrialization & Conceptual building

Prefabricated housing industry

Currently in the residential construction industry timber building practices are developed by the phenomena of (standardized) conceptual building and industrialization (Lessing et al., 2015). These two ways of building facilitate the leap to the market of utilizing timber buildings in the residential sector.
The philosophy behind conceptual construction as described by Lessing et al. (2015) is to standardize the design of the building as much as possible leading to a reference design, where the fastened large-scale, and efficient construction of these reference buildings on projects are made feasible. Building with concepts often results in industrializing the reference buildings, where the production of namely timber elements is executed in the manufacturing facility. Here from the prefabricated construction elements are assembled on-site in a fast and less intensive way, resulting in a faster, safer, and eventually more affordable way of constructing (Santana-Sosa & Kovacic, 2022).

Currently, prefabricated timber buildings in the residential construction industry are quite challenging to set up, because they lack the required infrastructure. To ensure that their market moves at a steady pace and to continue delivering housing, entirely new production lines would be required. According to Santana-Sosa and Kovacic (2022) these production lines operate with highly standardized building elements with predictable time and cost structures, allowing for the adjustment of elements and components within a raster while maintaining the same joints and details. Since submission and execution plans are not required, this results in a notable reduction of effort in design and production planning (Lessing et al., 2015). The interface between design and production is important for industrializing a product, wherein digitalization enhances the implementation of BIM and integrated design. Currently, as stated by Santana-Sosa and Kovacic (2022), it can be said that production processes in the construction industry are not yet industrial, and experts predict that in The Netherlands there is found that due to the higher labor costs for humans compared to robots and better infrastructure will form a tipping point. In addition, a common characteristic of conceptual building is upscaling the manufacturing by purchasing in large units, which allows for significant cost savings in the procurement of materials and components (Lessing et al., 2015). When combined with reduced work in design and production planning, this boosts industry efficiency and profitability, while investments in sales reduce overall cost reduction (Santana-Sosa & Kovacic, 2022).

3.6.1. Shift product-based construction process

According to Ribeirinho et al. (2020) the construction industry reportedly needs to move away from a project-based approach, where specially designed structures are worked out on site, and toward a product-based construction process. It is found that standardized sub-elements and building blocks are designed like functions, manufactured separately, and combined with branding characters and customization options. Manufacturing and implementing lightweight building materials within large prefabricated elements and modules requires developers, manufacturers, and contractors to specialize in end-user segments by utilizing repetition for efficient production flows (Ribeirinho et al., 2020). As digital technologies are expected to foster collaboration and improve supply chain control and integration, this will eventually lead to the emergence of new business models and cooperative contracting. Furthermore, the system will be in line with other industries such as automotive or shipbuilding through automated production processes and automated parametric design using object libraries. Significant investments in facilities, machinery, equipment, and human resources are required to offset this disruption (Ribeirinho et al., 2020).

Timber as a less-carbon-intensive renewable raw material aligns with the trend of conceptual building and industrialization while attending to the impact of their extraction, production, use, and deposit, and to its lightness. This results in the reduction of the overall construction weight, meaning less foundation and less embodied carbon emissions, which allows great workability in factories and on-site easing high levels of prefabrication within large elements with integrated functions. Additionally, the branding of contemporary buildings based on ecological, healthy, natural, and regional materials within optimized production processes aligns with a society that tends to promote more sustainable lifestyles (Ribeirinho et al., 2020). Herein a small number of construction companies in The Netherlands have already adopted their own timber concept and align with their strategy, by providing transferable and customizable branded systems.

3.6.2. Integrated design phase

While upscaling the implementation of timber buildings by industrializing the timber concept, an integrated design approach is required. Due to timber's material neutrality and linearity negative circumstances can be provoked at the interface between design and production, which can lead to mistakes, redesign, and eventually time and cost overruns. Furthermore, prefabrication requires earlier decisions and higher definitions where a design freeze must be established, with no execution-related planning and no on-site alterations that could cause significant delays or damages (Ribeirinho et al., 2020). Redesign processes result in unrewarded time and cost overruns when crucial parameters and data for the most efficient use of resources are ignored or improperly applied. Two different re-design stages are covered by Ribeirinho et al. (2020), on the one hand, design parameters pertaining to material properties and prefabrication requirements are typically lacking when it comes to timber construction. The same thing happens when projects with a concrete focus are converted to timber constructions. In an ideal world, the choice to construct with wood is made early on in order to envision an ideal layout. Tender procedures, on the other hand, are materially neutral and meant to facilitate a fair market in which timber is at a disadvantage. The execution plans at the interface between planners and timber contractors or experts are typically incomplete or inaccurate due to this lack of knowledge about prefabricated timber construction processes, and they need to be revised, adjusted, and exchanged on a regular basis. However, there is a re-design phase at the interface between design and production, based on the various "in-house" developed solutions of the companies, where all details need to be adjusted to the specific systems, platforms, and supply chain of the involved companies (Ribeirinho et al., 2020). This is a complex and multidisciplinary process when not monitored properly this can lead to significant delays and overruns in terms of time and money, as well as a great deal of frustration and dissatisfaction between value chain actors.

To improve efficiency and avoid damages and unforeseen issues, a number of timber-specific parameters pertaining to structure, fire, acoustics, humidity, energy, and prefabrication must be coordinated in the early stages of design. Important decisions, such as those pertaining to technical building equipment and their interfaces, must be made more quickly than in traditional mineral constructions. This is because there is often a lack of mutual understanding among the various parties involved and their unique requirements, which results in poor coordination, misunderstandings, and disruptions. According to Ribeirinho et al. (2020) it is highly necessary to provide a detailed account of the design process, team roles and coordination, work packages, internal and external communication, interfaces, interdependencies, responsibilities, input, output, and resources within a timeframe specific to each project and team. Common inefficient problems brought on by this lack of coordination include not working on updated documents, information loss, parallel and overlapping processes, or an unnecessary level of detail. Several digitalized tools such as BIM or interfaces where planner models and timber construction companies collaborate to optimize solutions is highly suggested (Ribeirinho et al., 2020).

In addition, Ribeirinho et al. (2020) points out that the integration of the client is necessary when industrializing a conceptual building product in order to state goals, requirements, and estimated budget, supporting a design to fixed costs. Because multi-story timber buildings are inherently complex, designing them requires a significant amount of time and effort, as well as high-quality resources that are underutilized. Greater effort should be put into fathoming the needs and wishes of the client and incorporating these into the reference building in an early stage to avoid undesirable changes or late decisions in a later stage. This could therefore result in making great adjustments and reschedules with large negative consequences impacting overall logistics, costs, and time through the supply chain with their delivery times and suppliers (Ribeirinho et al., 2020).

As noted by Ribeirinho et al. (2020) conventional tendering procedures act as a barrier to industrially produced constructions, limiting the way that design and construction interact—two categories of construction were identified. While a thorough and itemized list of execution specifications promotes fairness in the market, it also limits the ability of the participating construction companies in the tender to create optimal solutions. Although it is only advised for simpler constructions, a functional list of specifications with performance programs and no in-depth description of individual parts allows timber contractors to be involved early and optimize solutions. This type of specification is thought to be superior for prefabricated buildings. Within this framework, the research of Ribeirinho et al. (2020) emphasizes the necessity of reforming the procedures for industrially manufactured construction tendering, evaluating the extent of autonomy and accountability for planners and contractors, and offering concrete designs without specifying every detail in order to prevent excessive forward planning and

backward adjustments.

The study of Ribeirinho et al. (2020) proposes a solution for an earlier integration of timber expertise in the design stage that can be based on three strategies: hiring an independent timber specialist who guides the team through the processes, having an experienced design team which is uncommon in the industry, and expecting the timber construction company to be involved, either contractually or as an advisor.

3.6.3. Industry structure and capacity

One of the main benefits of timber construction is the off-site construction, and particularly in urban areas where neighborhood disturbances from noise, dust, traffic, and space are more common. The primary objective of the residential construction industry is to convert traditional, resource-intensive construction sites into assembly fields, which will increase quality and efficiency while reducing the likelihood of errors and accidents (Ribeirinho et al., 2020).

Even though timber building practices are taking their advance, in the residential construction market only a small number of companies are able to implement these sustainable innovations due to the fragmentation of the market. Because of this, even with the desire to increase the number of timber building practices, the industry will not be able to meet the anticipated demand pressure due to its small-scale structure, capacity, and current infrastructure and procedures (Ribeirinho et al., 2020). To expand their capacity, (Ribeirinho et al., 2020) states that manufacturers would need to build more infrastructure, which would require significant financial outlays and a guarantee of sufficient requests for their amortization—something that isn't currently achievable because there aren't enough consistent, recurring requests.

In order to scale up industrialized residential building products, it is recommended to establish a bidding community or network of suppliers to guarantee deliveries and a smooth workflow (Ribeirinho et al., 2020). This would involve a number of small, adaptable businesses producing various building components and allocating one of them to handle the work on-site in accordance with industrial companies, similar to those in the prefabricated home or automotive industries. In order to establish a productive production network, the industry must get past the barriers and challenges, which include a lack of standardization, a lack of willingness and inclination to collaborate, a lack of sharing of proprietary knowledge and systems, and variations in the organizational structures and platforms used for production (Ribeirinho et al., 2020).

3.7. Concluding Remarks Chapter 3: Literature review

After the research approach and main research question has been defined. This chapter dives into the literature review and therefore is intended to answer the first research sub-question of this study. Which is defined as follows:

'What are the key socio-technical drivers, barriers, conditions, and actors that involve large-scale implementation of timber building practices in The Netherlands?'

The main findings from the literature study are firstly the urgency and priority of the construction industry of reducing both embodied and operational carbon emissions in order to reach the set targets, both national and internationally. The main focus in the past decades has been on reducing operational carbon emissions, however **in order to achieve net-zero buildings the embodied carbon emissions are equally important**, which unfortunately have been neglected in both research and practice. It is found that the **reduction of buildings' environmental impact** especially in terms of embodied carbon can **only be achieved by increasing the proportion of wood-based materials** in the main building structures relative to concrete materials, where the **design choices on materials should already be made in the very early stages** of a building tender or project.

Currently, **the market** including developers, contractors, builders, and politicians **does not have the full incentive and willingness to shift from the familiar common traditional building approach towards the innovative building structures of timber construction**, which is seen as too complex and too risky.

On the one hand the the implementation of timber comes with **benefits on the triple bottom line aspects with regard to social, economic, and technical factors**. The main beneficial characteristics of timber are that the material has the potential to minimize its environmental impact throughout the materials whole lifecycle, also timber is renewable and due to the technical advancement of producing wood into timber-engineered products, the economic surplus value and therefore the important trade-off between cost and quality is becoming increasingly tangible and promising.

On the other hand the **main barriers** with regard to the **perception of clients and consumers on timber can be concluded to be the newness of the technology** in the whole value chain from laws and regulations, towards limited experience in the design, supply, and value chain, which **poses immense uncertainties and risks** with regard to operational costs, but moreover the ambiguous maintenance and failure costs during the timber's project lifecycle.

Recommendations from the literature highlights that the c**onstruction industry must transition from a project-based approach**, where structures are designed and built on-site, to a product-based process that uses standardized building blocks and sub-elements. These components can be prefabricated, customized, and combined with branding options, enabling timber construction to scale in the residential sector. An **integrated design approach is critical**, focusing on industrializing, standardizing, and digitizing the entire timber construction value chain while meeting client needs and preferences.

In the following, Chapter 4 outlines the theoretical framework this study will be extended on by analyzing relevant socio-technical systems and transition theories. Eventually, the TIS framework of Ortt and Kamp (2022) will be explained and the resulting five TIS building blocks will be given. Upon these building blocks the analysis will be conducted in the further process of this research.

4

Theoretical Framework

4.1. Defining outset of innovation theories

4.1.1. Innovation trajectories and systems

Before diving into the theories of socio-technical transitions and specifically the TIS framework, certain definitions of innovation trajectories and systems should be explained.

According to Galindo-Rueda (2019) the definition of innovation is a new or improved product or process or a combination that differs significantly from the unit's previous products or processes and that has been made available to potential users (product) or brought into use by the unit (process). As researched by Johne (1999), there are three different kinds of innovations: market, process, and product innovation. In addition, six types of innovation are distinguished by the study of Johannessen et al. (2001): new goods, new services, new manufacturing techniques, opening up new markets, new suppliers, and new organizational structures. Wheelwright and Clark (1992) establish a connection between three primary trends and the importance of product innovation: fierce global rivalry, fragmented and demanding markets, and diversified and rapidly evolving technologies. According to Langley et al. (2005), big product innovations feature a fully new set of qualities, establish a new product category, and cause changes in consumer behavior, in contrast to minor innovations, which consist of small-scale modifications to existing goods. Additionally, the development and promotion of new product categories frequently necessitates the addition of new market participants, which creates novel avenues for market interaction. Product innovation requires two main conditions: novelty and usage (Oostindië & van Broekhuizen, 2008). According to Hardaker (1998), companies have looked into the idea of fast product innovation, which calls for a close alignment and simultaneous movement of markets, products, and technology with the goal of increasing aggregate value. This approach helps them overcome the various obstacles that come with developing new products and innovating existing ones. It has been identified that innovation is a linear process that involves development, marketing, manufacturing, and research. Though it ignores innovation's complexity and does not include feedback loops—which are fundamental to development processes—this approach does deviate from the reality of innovation in a number of ways (Kline & Rosenberg, 1986). Innovation is not smooth and linear, it is rather the product of several intricate and sometimes chaotic processes (Kline & Rosenberg, 1986). Herein feedback loops are created both inside and between the development stages since it is not an isolated occurrence but rather the result of contact and collaboration between players in the public and private sectors (Kline & Rosenberg, 1986; Van de Ven et al., 1999).

Although product and process innovation has proven to be a means of competitiveness, innovative products do not assure success unless the importance of marketing is taken into consideration (Johne, 1999). Market innovation focuses on finding better (new) target market opportunities as well as better (new) methods of market service. Tidd and Bessant (2020) emphasize that companies need to have a thorough understanding of the markets' and technology' levels of maturity before using conventional marketing strategies. They also suggest using a two-by-two matrix approach to examine the relationship between market and technological maturity. Herein four quadrants are distinguished:

- **Differentiated** The markets and technology are both well-established, and the majority of innovations involve enhancing the usage of current technologies to better serve a known client base through support, pricing, and packaging.
- **Architectural** New products, services, or applications are created by applying or combining existing technologies. In this context, competition is centered on meeting niche markets and fostering strong customer relationships. Henderson and Clark (1990) noted that these innovations are frequently able to be integrated into preexisting frameworks.
- **Technological** New technologies are created to meet established client demands. Here, developers essentially drive innovation, and performance—rather than cost or quality—determines the level of competition.
- **Complex** Markets and technologies are new and constantly changing.

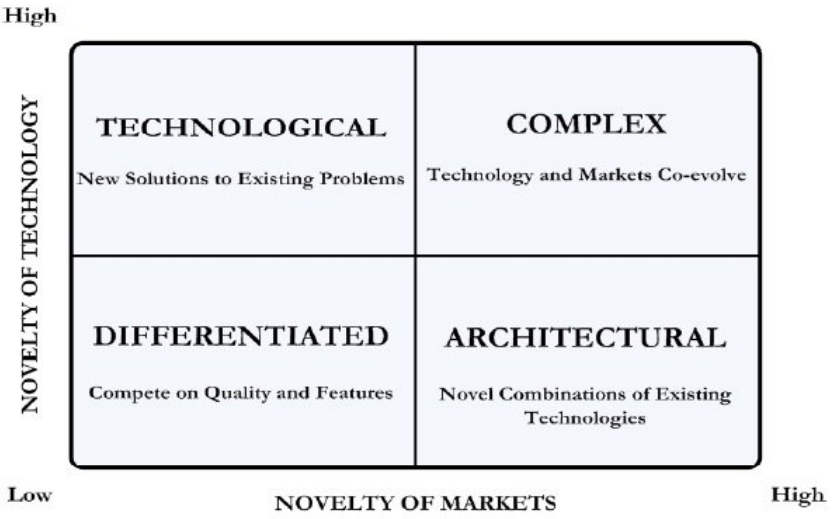

Figure 4.1: Matrix with the correlation of technology maturity and market maturity (Tidd & Bessant, 2020)

There are two ways to describe the innovative aspects of transitioning towards timber, the first is product innovation, and the second is process innovation. Product innovation is the process that includes the technical design, R&D, manufacturing, management, and commercial activities involved in the marketing of a new or improved product (Soete & Freeman, 2012). Besides that process innovation lies in the systematic change from a project-based approach of building towards product-based building. This asks for both a new way of internal processes within the organization and processes in manufacturing industrialized timber buildings.

4.1.2. Systems view

Analyzing buildings and the actors involved as socio-technical systems by examining functional dependencies and requirements along with interests, perspectives, and actor interactions, can help to better understand and eventually overcome barriers to sustainable building practices. This approach therefore goes beyond the conventional functionalist system view. According to Carlsson et al. (2002), an innovation system is a collection of interconnected parts that work together to produce, disseminate, and use technology. In the sense that they might not exist in reality but are used conceptually to deepen our understanding of innovation, innovation systems are analytical constructions (Bergek et al., 2008). When examining constructing timber constructions at the "'roject level,' they can be viewed as distinct socio-technical systems with requirements that vary depending on the project. On the other hand, it is possible to see the 'project level' examination of building construction as a distinct socio-technical system with distinct requirements. In technical terms, traditional buildings differ from artifacts like vehicles in that there is less of a tight coupling at the technological level, which reduces the need for close actor interaction or 'system building' by a single main actor (Hardin et al., 2015). Here, building systems are somewhat loosely connected since they depend on the interactions of multiple professions, such

as planners, architects, and building services, among others. Particularly with regard to sustainability criteria, building codes, which regulate the technical requirements placed on structures, provide a rather wide framework that establishes minimum standards. Unlike ordinary structures, there can be stated that timber buildings require a significantly tighter contact between suppliers, specialists, and users due to the increasing complexity and strength of the functional interdependence among various components.

Transitions towards timber building practices, or the fundamental organizational, technological, and institutional changes in production and consumption that will result in more sustainable growth, are the focus of the newly growing area of ”transition studies.” Actors, networks, and institutions make up structural components (Bergek et al., 2008). The fundamental procedures that are crucial to the development of an innovation system are known as ’functions of innovation systems.’ They are the dynamic interactions that take place between the system’s players, networks, and institutions. Building a supportive ’ecosystem’ around the new sustainability technology is facilitated by each important procedure. More significantly, an innovation system’s emergence and growth are accelerated in positive cycles by the interaction of system functions, raising the likelihood of a successful product on the market (Jacobsson & Bergek, 2004).

4.2. Socio-technical transitions

Various studies are present that explore the methods to enhance sustainability in the housing sector. These studies suggest several potential future options, including the use of bio-based materials in residential construction projects. It is widely anticipated that the largest improvement in sustainability in the construction sector will stem from a diverse array of technological advancements (Kibert, 2016).

In the past 15 years the research of studies on the social part of technology have been neglected, it has been identified it was only focusing on the ‘content’ of technology and not the ‘impact’ of technology on society. According to Murtagh et al. (2020) many of the early researches and approaches concerning sustainable innovations’ potential are examined in an isolated manner rather than considering a holistic approach by taking a collective market perspective on integrating sustainable technologies across the construction industry with regard to the residential sector. The divergence between scientific research and practical research highlights a crucial knowledge gap in implementing sustainable construction-building practices effectively to fasten the pace at which real-world applications for sustainable transitions are developed. The idea at the heart of these notions is that technological systems and artifacts are created with prospective choices, wherein choices that aren’t always obvious and conscious in mind. Technical progress lacks an innate and persuasive logic, whereas decisions are based on organizational, political, economic, and technological reasons as well as actor-strategies. On these phenomena socio-technical approaches therefore begins by dissecting technological change from the viewpoint of individual (or organizational) actors from a micro-sociological point of view. In socio-technical systems, or actor-networks, social and technological components are inherently interdependent.

The idea of separate approaches to the social and technical systems of an organization could no longer suffice for the complex, challenging, and newness of deploying an innovation. Socio-technical transitions do not solely focus on the technological development itself but involve broader changes within socio-technical systems, including shifts in cultural norms, institutional frameworks, industrial networks, and procedures (Geels, 2004). Therefore, the transition towards timber can be seen as a socio-technical system, by changes in dominant practices (routines, behavior, action), structures (institutions, economy, infrastructure), and cultures (shared values, paradigms, worldviews) from one state, stage, topic, or location to another are caused by structural non-linear systems (Moore & Doyon, 2023). The interplay between technology and human interaction can result in complex, unanticipated, and uncontrollably developing relationships, which is the case. Due to its open nature and susceptibility to outside inputs, the complex operating environment will have a significant impact on the transition towards timber (Walker et al., 2008). According to the Merriam-Webster definition, a ”complex” thing is ”a whole made up of complicated or interrelated parts” that are increasingly interdependent and intricately entangled (Janlert & Stolterman, 2008). Non-linear interactions between complex system elements, such as feedback loops with delays, can occasionally result in non-deterministic, emergent, unpredictable, and unexpected behavior. Also, rather simple systems can have complexity because of context-dependent feedback loops and dynamic interactions. Therefore the social, cognitive, and

dynamic complexity of the system must be taken into consideration when analyzing and designing STS for effective operation in a complex environment (Janlert & Stolterman, 2008).

According to Rohracher (2001) there are two main reasons to use the insights of studies performed on social-technical factors. The first reason is to find the inter-relations between factors which adds value to the current system. This can lead to management of processes during the transition towards timber constructions, for instance the improvement of the political quality within the social-technical system. In this field the processes and factors during the implementation of a transition evolves in the 'micro-level'. Herein the tasks as socio-technical mapping of the transition and perspective of actors involved, type of present collaboration and decision-making structures, that will prompt ideas to attain improvements on better integration of actors and technical system requirements, to strengthen the links between designers and users or to support socio-technical system building (Rohracher, 2001). The second reason is taken from an analytical viewpoint of socio-technical research which concentrates on the strategies and viewpoints of various stakeholder groups, such as the individual attempts to enforce or resist towards certain definitions of sustainability for timber bulidings. As stated by Rohracher (2001) deconstructing those actor strategies and the rhetoric involved could contribute to the quality of the public dialogue about ways to achieve more sustainability in this sector by making discussions more transparent and reflexive. Identifying actor groups that are impacted by technology change but not active in its formation, and concentrating on a wide variety of players, may contribute to democratizing the technological change process. Therefore, understanding the multidimensional nature of socio-technical transitions is essential for identifying key elements that facilitate the innovation and deployment of sustainable timber-building practices.

The use of socio-technical systems (STSs) complies with the need to integrate two types of structures and processes: technical systems and social systems. Herein the unique challenge and interplay that combines two types of fundamentally different systems is addressed. The two systems are explained by Fischer and Herrmann (2011) as follows:

- **Technical systems.** This system focuses on the engineering side of the innovation in order to provide anticipatable and reliable interactions between user input and the system's output. Therefore it enholds all the tools, techniques, devices, procedures, and knowledge used by system users in order to convert system inputs into system outputs (Pasmore, 1988). It can be seen as a melting pot of technologies, policies, and practices which describe the modes of production and users' actions when performing tasks (Bélanger et al., 2013). This relationship is engineered to serve the needs of users and is at least incrementally preplanned.

- **Social systems**. On the other side, the social systems are contingent on the interactions of actors in the market and the result of continuous evolution including emergent changes and behavior, that occur during the implementation of innovations. Herein the work system is comprised of the individuals and organizations present in the system, which includes their unique social attributes (Paja et al., 2013). It compromises the collective attributes and environment in which the organizational work system operates, whereas the components of organizational structures and people are present. The organizational structures are related to the rules, roles and responsibilities guiding the system actors during tasks. The people aspect lies in all the stakeholders involved in the innovation system and highlights the importance of support and acceptance of the involved actors. Herein the organizational structure, which includes reward and authority structures as well as knowledge, skills, attitudes, values, and needs, makes up the social subsystem.

The strength of STS lies in that it integrates these different systems in a way that the performance and effectiveness of an innovation mutually is enhanced. Even more important, the integration of technical and social systems helps them to develop and to constitute each other, where for instance technical innovations support interaction among community members, and the members themselves can contribute to the development of the innovation, which is commonly seen in open-source communities (Fischer & Herrmann, 2011).

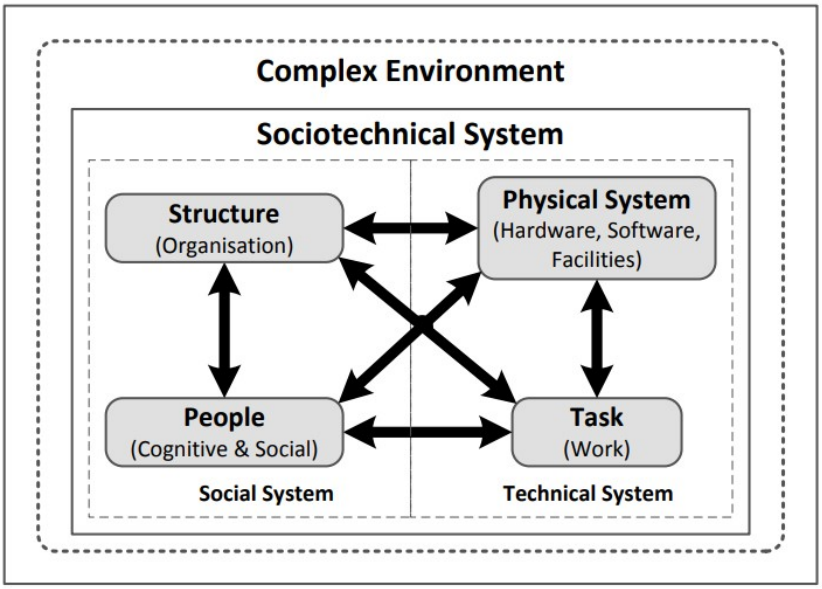

Figure 4.2: Socio-technical system in complex environment (Bostrom & Heinen, 1977)

4.3. Sustainable house transitions

A large body of research on sustainable housing transitions can be traced back to Smith's initial studies (Smith, 2007). Smith (2007) used a socio-technical (or sustainability) transitions framework to define the current regime and investigate the emergence of sustainable housing niches. This research has significantly advanced our understanding of the differing socio-technical aspects of niche actors and the regime, as well as the ongoing pressures between them. Since Smith (2007) work, a lot has changed in the sustainable housing industry, both in terms of technological innovation and better knowledge of the social implications of housing. Furthermore, research on sustainability transitions has developed, with a number of new areas of emphasis proposed to enhance comprehension and application of transitions. It is found that certain reconsideration has to be made on how housing is conceptualized within sustainability transitions and consider alternative approaches to housing transition research. In order to achieve this, more attention has to be taken towards socio-technical factors than to the dynamics of the housing niche regime. Socio-technical systems are multi-factor processes made up of several components, including technologies, policies, and practices.

It is evident that there have been some significant changes in the sustainable housing sector when we assess it using these socio-technical dimensions. Regarding industrial structure and organizations, for instance, the delivery of sustainable housing has moved from custom-built single buildings at a premium to delivering several buildings and even entire precincts at minimal or no cost premiums. Furthermore, emerging lines of inquiry emphasize the necessity of taking ethical considerations into account when governing the transition to sustainable housing. A focus on socio-technical aspects shows that the delivery of sustainable housing is not limited to the traditional housing sector, but is also involving input from other industries, such as energy networks (e.g., battery storage and renewable energy generation) and transportation (e.g., public transportation and electric vehicles). There's also a "messiness" that arises at varying rates of development (new vs. existing housing, for example). As a result, from a traditional transitions perspective, housing is not well suited to be viewed as a niche. The shift to sustainable housing cannot effectively confront these more profound structural changes in the current housing regime without a rethinking of housing.

4.4. TIS Framework Ortt & Kamp

The first studies conducted on TIS, stems from Eric Trist and other social scientists at the Tavistock Institute of Human Relations in London, shortly after World War II (Mumford, 1995). In this research, specifically the TIS framework of Ortt and Kamp (2022) will form the base framework and will be applied

on the transition towards timber buildings.
The TIS framework of Ortt and Kamp (2022) is a classification of STSs and analyzes technological change, which is valuable for examining promising technical innovations, as it captures the diverse functional dynamics of innovation systems while adopting a company perspective. Currently, the perspective from construction companies within the building industry is overall neglected in socio-technical transitions. This approach is lacking as construction companies are in charge of considerable economic influence in society due to their ownership of significant assets and their capacity for substantial investments in pioneering innovative technologies. Therefore, they possess the economic resources necessary to expedite the progression toward sustainable transitions as timber building practices. Eventually the framework of Ortt and Kamp (2022) highlights the importance of adopting a company perspective, and proposes a TIS analysis framework that focuses on strategies in order to understand the complex interplay between socio-technical factors and enhance the chances of successful innovation implementation.

As shown earlier in figure 4.2 a socio-technical system consists of both the social- and technical subsystem. The systems can be divided into four distinct elements at the structural level of TIS: actors, networks, institutions, and technology (Bergek et al., 2013). First of all the system's physical parts are made up of actors. These companies span the whole technology value chain, handling everything from raw material production to product distribution and complementary service offering (Bergek et al., 2008). Secondly, the formal and informal ties that exist between TIS players are known as networks, and they can be structured to carry out particular tasks or develop in an unorganized way (Bergek et al., 2008). Thirdly, institutions consist of culture, norms and routines, which are embedded in the minds of people and actors, as well as laws, regulations and routines, set by the state (Bergek et al., 2008). According to North (1990), the 'rules of the game' have changed in tandem with established technology. Lastly, by accessing the TIS through actors, technology is introduced and develops within it, becoming both an input and an output of the system (Hellsmark & Jacobsson, 2009). The core of technology is knowledge, which is embedded in physical artifacts, drawings, patents, etc., and also in the experience of the human resources handling it (Bergek et al., 2013).

4.4.1. Research Gap

The framework developed by Ortt and Kamp (2022) consists of a research gap concerning the application of the TIS building blocks and their influencing conditions with regard to product & project nature, risks & uncertainty, innovation specific flexibility and multi-stakeholder that can be applied to various technical industries. The TIS framework has not yet been applied to the residential construction industry and therefore this study aims to fill this specific research gap by adapting the framework and conditions to specific construction industry challenges. This eventually would provide relevant insights and directions in order to enhance the implementation of timber building practices and thus facilitating the industry's transition towards sustainability.

Additionally, the research conducted by Ortt and Kamp (2022) is limited due to its static analysis at one moment in time and therefore does not include the evolvement of the innovation over time. Understanding how the TIS framework evolves over time within companies, while considering key factors such as technological advancements, regulatory changes, and market dynamics. Therefore applying longitudinal studies, where insights of the fundamental TIS building blocks will be collected over an extended period of time, is essential to identify possible hindrances and take proactive measures to resolve them during the deployment of the innovation. This will eventually also provide valuable insights into the adaptability of the TIS framework.

Lastly, the TIS framework and the proposed niche strategies focus only on the implementation of a singular innovation and a small group of consumers with their specific wants and demands. But in the residential construction industry, a wide range of sustainable building practices are present even within the same product category. Hence, conducting research on the advancement and readiness of several types of timber building practices is essential for informing companies' investment strategies taking the dynamic and market needs into account. The objective of this research is to build upon the framework proposed by Ortt and Kamp (2022) in order to address the existing knowledge gap.

4.4.2. TIS building blocks

The TIS analysis framework consists of seven building blocks, that together represent all important dimensions within the socio-technical system. The initial set of TIS building blocks showcased by Ortt

and Kamp (2022) are:

1. Product performance and quality
2. Product price
3. Production system
4. Complementary products and services
5. Network formation and coordination
6. Clients and customers
7. Innovation-specific institutions

In Figure figure 4.4 an overview is shown, which can be seen as a summary of the socio-technical framework including relevant influencing conditions, TIS building blocks, and strategies.

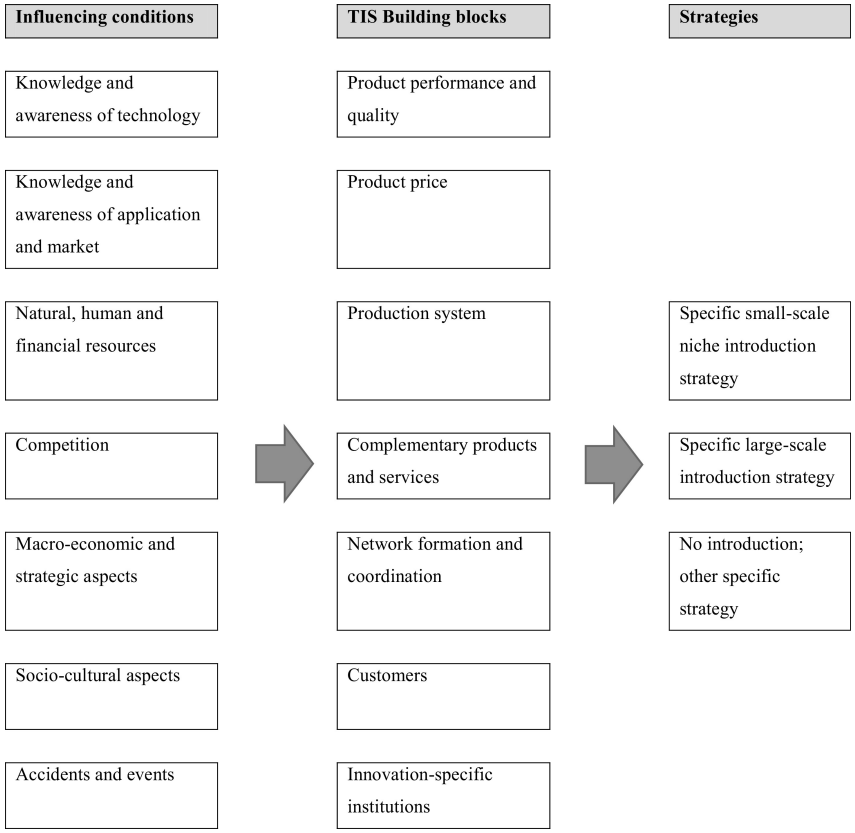

Figure 4.3: Technological Innovation System (TIS) framework (Ortt & Kamp, 2022)

In the construction industry and specifically the residential sector, the complexity of these dimensions is evident in the diverse array of sustainable building innovations, whereas each innovation follows its own unique technological trajectory, ranging from incremental improvements to more radical changes, and necessitating specific supply chains and supporting infrastructures (Häkkinen & Belloni, 2011). This leads to a high level of uncertainty in how socio-technological transitions will evolve over time given the large number of technological alternatives present. Also, it remains uncertain which technological trajectory might be most promising for large-scale implementation.
As the researcher, I adjusted the TIS building blocks before conducting interviews and case studies for the following reasons:

1. Enhanced context-specific analysis.
   The original TIS building blocks by Ortt and Kamp (2022) are designed for general applicability

across various sectors. However, the timber construction industry presents unique challenges and considerations, particularly concerning construction techniques, timber performance, and sustainability. As stipulated by the authors Ortt and Kamp (2022), the initial set of TIS building blocks are crafted from energy-related cases high altitude wind energy systems, reverse osmosis water desalination technology, offshore wind turbines, direct drive generators, and electric vehicles. Therefore the recommendation of the authors themselves is to refine the TIS building blocks to the specific challenges around the innovation and specific requirements whether certain TIS building blocks are evident in the industry after performing a literature review. Therefore in this study, the TIS building blocks are modified towards the innovation transitioning towards timber (product & process innovation) where the timber technique, performance, economic aspect, business processes, and managerial levers are identified as the main challenges. By modifying the building blocks to include elements such as ”Timber performance and quality” and ”Construction techniques and technology,” I ensured a more targeted analysis that reflects the specific dynamics of timber construction. This adjustment enhances the limited timeframe and specific scope of my study in addressing the particular needs and opportunities within the residential construction industry.

2. Comprehensive risk and economic evaluation.
   The adjusted building blocks, including ”Economic viability” and ”Risk assessment and management,” provide a more thorough examination of the financial and risk-related aspects of timber construction. While the original TIS framework focuses on aspects like product price, it does not fully address the broader economic and risk factors critical to timber adoption. By incorporating these elements, I aimed to capture the full spectrum of market risks, cost uncertainties, and stakeholder concerns, which are essential for understanding the diffusion and implementation of timber building practices. This refinement allows for a more nuanced exploration of the economic and risk dimensions that influence the adoption of innovative timber solutions.

Therefore, the seven TIS building blocks are modified towards the specific characteristics of the construction industry and the shift the sector is making from project-based approach to product-based designs which follows the path towards a new way of modular industrialized building procedures. Herein the researched innovation trajectories over time that have been found in the literature research are taken into consideration. The modified set of building blocks is listed in the following:

1. Construction techniques and technology
2. Timber performance and quality - sustainability and environmental impact
3. Economic viability
4. Risk assessment and management
5. Network formation and coordination - stakeholder management

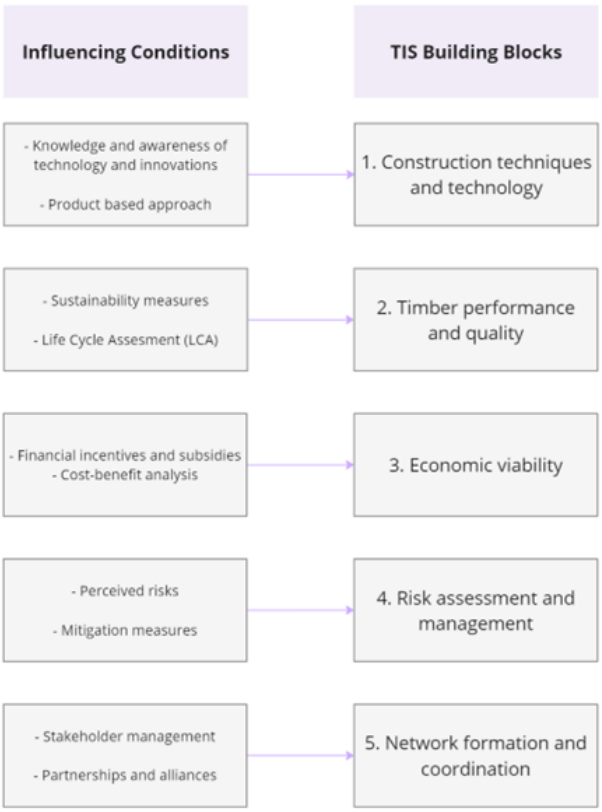

Figure 4.4: Overview modified TIS building blocks to residential construction industry

4.4.3. Description of refined TIS building blocks: technological, social & economic factors

The refined building blocks are further described below. These building blocks include technological factors (construction techniques & technology and timber performance and quality), social, economic and institutional factors (economic viability, risk assessment and management, and network formation and coordination). All of these factors are elaborated below.

Construction techniques and technology

First of all the building block *construction techniques and technology* enholds the methods and technologies used in constructing buildings with timber. This building block will cover the whole process from the design phase towards the construction phase, while taking into account the new way of design approaches such as design-product thinking for prefabrication and modular construction. The relevance of this building block is to understand the process and choices that are made during the implementation of advances techniques and technologies that are pivotal for timber building practices that require specific construction methods that differ from traditional materials like steel and concrete. For this building block the influencing conditions that are determined beforehand are:

1. Knowledge and awareness of technology and innovations. This condition refers to the extent to which the engaged stakeholders of the project are informed about the latest technologies and innovations in timber construction. This includes understanding the benefits and applications of new methods, tools and materials.
2. Product based approach (prefabrication and modular construction). As earlier stated in the literature review the shift towards timber construction techniques naturally leads to designing and constructing building components off-site in a controlled environment (prefabrication) and then assembling them on-site (modular construction). This approach focuses on creating standardized building modules that can be easily assembled, ensuring efficiency, reducing construction time, and minimizing waste.

Timber performance and quality - sustainability and environmental impact

The second building block of *Timber performance and quality* focuses on the performance and quality of timber as a building material by incorporating and assessing its sustainability benefits and environmental impact throughout the projects' lifecycle. Herein the design performance and the quality of the project in timber can be compared to the design with traditional materials. For this building block the influencing conditions that are determined beforehand are:

1. Sustainability measures on the project. During a project the insights on which sustainability measures are taken is a critical influencing condition on the performance and quality of the timber building and is aimed to reduce the environmental impact of timber construction projects.
2. Life Cycle Assesment (LCA). The assesment of (a part of) the life cycle of timber building projects give insights in the the use of certified sustainable timber, energy-efficient construction processes, waste reduction techniques and strategies to minimize the carbon footprint throughout the lifecycle of the building. This can thereafter be compared to a traditional way of building with concrete.

Economic viability

As third building block the *economic viability* of using timber in projects will be investigated. This block analyzes the cost-effectiveness of timber building practices compared to traditional materials, considering both short-term and long-term economic factors, which is fundamental in determining the feasibility and attractiveness in building with timber. The economic aspect also gives insights on the comparison of economic viability with traditional materials. For this building block the influencing conditions that are determined beforehand are:

1. Financial incentives and subsidies. In timber projects the financial incentives and subsidies form a part of the projects' price. In order to assess the economic viability financial incentives and subsidies will be considered, because these have been shared publicly and do not reveal the sensitivity of the information.
2. Cost-benefit analysis. As part of assessing the economic viability of building in timber, certain cost factors in the design will be assessed by using the cost-benefit analysis on the level of differences in costs (lower, similar or higher) compared to the design with traditional materials.

Risk assessment and management

The fourth block will focus on *risk assessment and management* and therefore identifies potential risks associated with timber construction and what have been detected as unforeseen risks during the timber project lifecycle. These perceived risks can vary from technical considerations and design such as fire safety and moisture susceptibility, to risks related to the feasibility and affordability of the project. Understanding and managing risks associated with timber construction projects are essential for gaining stakeholder support and assurance but also ensures the success of the project. The following influencing conditions are present for this building block:

1. Perceived risks. At the start of the timber projects certain risks have been identified by the project team. This follows along with the risk assessment trajectory as stated for every construction project and is relevant to assess in order to gain insights on which risks have been perceived as crucial and have a high impact with regard to the newness of the project.
2. Mitigation measures. In line with the perceived risks, the taken mitigation measures will be investigated and how effective they have worked on the projects' success.

Network formation and coordination

Furthermore, the fifth building block will investigate the initiatives that have been taken with regard to *network formation and coordination* including the involved stakeholders in the timber projects. This includes the construction company, the client, architects and specialized institutes or experts involved. It is crucial to take the network formation and coordination into account for the transition towards timber, because fostering a supportive network will form the drive to the adoption of timber construction projects. Herein the two influencing conditions are:

1. Stakeholder management. Stakeholder management involves identifying, engaging, and collaborating with all parties who have an interest or stake in a timber construction project. The extent to which the involved project network and teams have aligned their goals and have led to joint efforts is pivotal in ensuring the needs, expectations and concerns considered and addressed throughout the project lifecycle.
2. Partnerships and alliances. This influencing condition refers to the formal and informal collaborations between different organizations and entities involved in the timber construction project. Herein partnerships and collaborations with research institutions for innovation, alliances with timber suppliers in order to create a stable supply chain, and effective involvement of regulatory bodies for compliance will be investigated.

The set of building blocks as mentioned above form the TIS framework and have been adjusted for the transition towards timber building practices and specifically for the residential construction industry. An important remark is that the incompleteness or incompatibility of one or more of these TIS building blocks potentially hampers the large-scale adoption of the innovation. Assessing the completeness of these components and identifying conditions that may impede large-scale innovation diffusion allows for the formulation of niche introduction strategies for sustainable innovations.

4.5. Concluding remarks Chapter 4: Theoretical framework

In this chapter, the base theoretical framework which this study will be extended on, is explained in detail.
Starting off with the insights of the transition literature with regard to socio-technical systems. The transition towards timber building practices can be described by **two distinctive factors: product innovation and process innovation**. Inherently with using timber both innovation trajectories have to be sharpened in order to successfully deploy timber in the construction industry. Innovation trajectories inherently start with a focus on technical development aspects, however, in the past 15 years scientific research has neglected the social part of technology. **The idea of separate approaches to the social and technical systems of an organization could no longer suffice for the complex, challenging, and newness of deploying an innovation**. Therefore socio-technical transitions do not solely focus on the technological development itself but involve broader changes within socio-technical systems, including shifts in cultural norms, institutional frameworks, industrial networks, and procedures.

In order to analyze the relations between socio-technical factors a modified set of **five TIS building blocks suited for the residential construction industry has been defined**. The TIS building blocks are modified due to the study's limited timeframe of conducting the research and the specific scope resulting in combining the initial TIS building blocks as defined by Ortt and Kamp (2022) in eventually 5 overarching TIS building blocks. The final set of five socio-technical TIS building blocks analyzed in this study are as follows:

1. Construction techniques and technology
2. Timber performance and quality - sustainability and environmental impact
3. Economic viability
4. Risk assessment and management
5. Network formation and coordination - stakeholder management

As follows, in Chapters 5 and 6 the findings of the three timber projects, that have been chosen as case studies will be dived into. Herein the results consisting of a total of 50 instances from practice derived from the case study documents in combination with the 17 semi-structured interviews will be explained in detail.

PART IV
SYNTHESIS

5

Case Study Approach

In this chapter the approach and criteria for conducting the case studies will be given. As stated in Chapter 2.3, an embedded case study on three different timber projects in The Netherlands will be carried out. The case study performed in this research is to increase the reliability and generalizability of what is found in the literature research and also in the conducted interviews. Herein the analysis of the case studies will be conducted by using the set of building blocks in the adjusted TIS framework for the construction industry. Therefore the case study will be a descriptive analysis based on project and tender documents and the interviews with members of the project teams. Per case study the sources such as documents and project information that have been used for the analysis will be disclosed.

5.1. Sample size case study

Starting with the case study, as described in section 2.3.2 it is determined that a multiple-embedded case study is suitable for this research. As the next step, the sample size, which indicates the number of cases that will be analyzed, needs to be determined. As stated by Gustafsson (2017) the minimum for conducting a multiple case study analysis is two cases, as the data and conclusions that arise from both cases will result in more credibility when conducting only one single case. Moreover conducting an embedded case analysis for this research can only be done by analyzing multiple cases. Therefore in this research, the choice has been made to analyze three different cases in timber building practices for the case study. As the criteria within a socio-technical regime of a project involves great variations it can be stated that analyzing more cases will be for the better. However, the limited amount of time available for this research should be considered when performing the case study. Forasmuch as the goal of performing the case study is to expand the understanding of the transition towards timber building practices in the Dutch residential construction industry and the alignment thereof in tenders and practice, it can be stated that conducting the research in depth is more preferred than in breadth. The sample size of the case study is ultimately chosen to include 3 different timber cases conducted by a Dutch contractor.

5.2. Selection criteria case study

For the in-depth embedded case study, there is carefully looked at the selection of the projects and the involved criteria and relevant characteristics that will form the groundwork of the case study analysis. The projects need to meet criteria and relevant characteristics in order to be chosen for the case study. In the list below the preferred characteristics of the cases are summed up, whereas these criteria serve as a supportive mechanism in order to outline the suitability of the chosen projects. Thereafter a detailed explanation of the relevance and importance of this specific criterion.

- **General criteria**

1. The project incorporates innovative timber construction methods or materials, which results in timber as the main building material or (partly) wooden facades;

2. The project is conducted for a public client or authority;
3. The project has been submitted as tender and preferably awarded and executed by BAM Wonen;

- **Tender/project criteria**

4. The project matches the characteristics of the predetermined TIS building blocks;

5. The tender criteria are known and involves outstanding sustainable criteria which results not in a tender only based on price-quality;
6. The tender involves a risk- and management assessment and has been documented by the projects' team;

- **Criteria with regard to data availability**

7. The timber project needs to be at least in the design phase and preferably in the execution phase or already completed;
8. Post-occupancy performance data, such as sustainability scores and energy criteria should be accessible for evaluation.

The first two criteria form the general criteria that focus on the general principles of this research. As the focus of this research is on the socio-technical key factors of a transition towards timber buildings and incorporates the innovative nature of the new practices. This involves the direct relation with clients and therefore has been taken as the first and second criterion. The third criterion specifies that the projects are awarded towards BAM Wonen and will therefore also be executed by the contractor. Since the master thesis research is in collaboration with BAM Wonen, the data and insights will be more readily available when choosing projects within the portfolio of BAM Wonen.

The second category of criteria is on the tender and project, the research is demarcated to projects where the principles match with the predetermined set of TIS building blocks as set up in this research, which involves construction techniques and technology, timber performance and quality, sustain- ability and environmental impact, economic viability, risk assessment and management, network formation and coordination - stakeholder management, and regulatory compliance and standards. Therefore the fifth involves the importance of sustainability in the tendering process, as it is known that tenders only based on price-quality ratio will not be awarded to innovative timber building designs during selection in the tender. The second criterion of risk assessment and management is chosen to provide detailed insights into the challenges and mitigation strategies used for incorporating timber building practices in the projects and can be compared across case studies to identify best practices.

The last set of case study criteria involves the data availability. Since the case study is heavily reliable in data collection of the projects, the availability of data by interviewing the projects' team members, reviewing tender documents, or making observations in the 'field' is essential. Specifically, the actuality of documents and results of the projects is taken into account, as it forms an advantage during the analysis. The criterion of the projects' current construction phase is therefore leading, which results in the cases chosen need to be at least in the design phase and preferably in the execution phase or already completed.

5.3. Final selection cases

As the last step before performing the case study, a selection of timber building projects of BAM Wonen has been made in order to find the most suitable projects that fit the defined criteria. Only the cases that match the case study criteria will have the potential to add to the generalizability of the case study research (Yin, 2013). One of the main concerns when choosing the cases is the data availability, whereas the documents and processes of all the timber projects are new and not yet well established. As highlighted by Yin (2013) therefore timber projects in which distinctiveness on a qualitative level and therefore richest in information are relevant for this research.

In table 5.1 the set of projects and tenders that comply with the case study selection criteria 1

till 6 are given. Herein all the projects consist of newly built dwellings or apartments that have been designed with timber as the main construction material and involve a certain amount of sustainability criteria that match the predetermined TIS building blocks accordingly as stated in the table.

Project Name	Start of project	Client type (PMC)	Tender or one-on-one	Type of buildings	Project phase	Conceptual building
Ambachtslaan Veldhoven	07-05-2019	Housing corporation – new build	One-on-one	Apartments	Delivered	No
Bloemwijk Alkmaar	30-06-2020	Housing corporation – new build	Tender	Dwellings and apartments	Not granted	No
Parck de Beeck Bergen	11-04-2024	Own project development – Combi BAM – new build	Tender	Dwellings	Not granted	Yes
BeHagen Leeuwarden	07-03-2024	Housing corporation – new build	Tender	Dwellings	Design phase	Yes
Molièrebuurt Rotterdam	26-09-2022	Housing Housing corporation – new build	Tender	Dwellings	Design phase	Yes
Leeuwepoort Utrecht	19-01-2023	Municipality and real estate developer	Tender	Dwellings and apartments	Design phase	Yes, combination of conceptual building and custom build
Weert Keent Moesel	01-09-2024	Housing Housing corporation – new build	One-on-one (Bouwstroom 1.0)	Apartments	Design phase	No, custom build
WeideWald Doetinchem	16-06-2023	Municipality & housing corporation - new build & own project development – Combi BAM	Tender	Dwellings	Start construction phase	Yes, combination of conceptual building and custom build
Zeeheldenbuurt Barendrecht	26-02-2023	Housing corporation	Tender	Dwellings and apartments	Design phase	Yes
De Tippe Zwolle	31-05-2023	Real estate developer	Tender	Dwellings	Not granted	Yes

Table 5.1: Set of projects and tenders after demarcation by criteria 1 - 6

The final selection of three case studies is subject to the objective to choose a diverse set of projects that each have their own characteristics that suit the TIS building blocks and therefore this research as whole. When looking at the set of criteria, the projects that have not been granted towards BAM Wonen, will not be chosen since as stated earlier the projects need to be in a further project phase. When a tender is not awarded, the project phase of design phase will not be reached. As further selection projects that are in a further stage of construction are preferred, this enholds for the projects Ambachtslaan Veldhoven and WeideWald Doetinchem, therefore these two projects are selected to be investigated in the in-depth embedded case study. However, in order to meet the sample size of 3 projects performed in the case study, the third choice is on the project Leeuwepoort Utrecht, as this project involves a different client type and therefore product-markt-combination (so called PMC) that adds to the diversity of cases investigated. Since the first two selected projects involves housing corporations as client type, the viewpoint of real estate developers and the municipality on timber building practices will be considered in the last phase. In addition, as this research is not only about qualitative success as a whole on a project, but rather examines specific elements of the TIS building blocks, the third case is relevant to analyze in the embedded case study.

Ultimately the final set of cases that will be analyzed in the embedded case study is shown in table 5.2.

Project Name	Start of project	Client type (PMC)	Tender or one-on-one	Type of buildings	Project phase	Conceptual building
Ambachtslaan Veldhoven	07-05-2019	Housing corporation – new build	One-on-one	Apartments	Delivered	No
WeideWald Doetinchem	16-06-2023	Municipality & housing corporation - new build & own project development – Combi BAM	Tender	Dwellings	Start construction phase	Yes, combination of conceptual building and custom build
Leeuwepoort Utrecht	19-01-2023	Municipality and real estate developer	Tender	Dwellings and apartments	Design phase	Yes, combination of conceptual building and custom build

Table 5.2: Final selection of projects as demarcated by criteria 1 - 8

6

Case Study results

In the following chapter the results of the embedded in-depth case study on the three chosen timber projects will be presented, including the case descriptions. The case studies are conducted in order to gain more insights in the performance of timber concepts and the complexities that came along with developing and implementing the concept and since confirmability is enhanced by using an embedded case study approach. The evaluated TIS building blocks can be confirmed by analyzing the TIS building blocks on real-life timber projects. This will also yield insights into the hurdles, barriers, and practical experience during different project stages. Other advantages of embedded case studies include in-depth research of real-life complications, analysis of contextual data, and quantitative and qualitative findings.

The structure of the chapter is as follows, as first section the case description of each of the three cases will be given. Thereafter the second section for each case the TIS building blocks will be analyzed and evaluated. This will answer the third sub-question of this research: 'What (type of measures) are determining in distinctive timber building projects in relation to the modified TIS building blocks?'. The third and last section gives insights on how the measures and determining aspects turn out in practice and evolve over time and therefore answers the fourth sub-question: 'How do the defined TIS building blocks evolve over time in timber building projects'.

6.1. Case 1: Small-scale timber dwellings merged with the orchard

6.1.1. Project description and scope

The first case is about a small-scale new-build project for dwellings. The municipality is selling two plots of land with distinct purposes. It includes a combination of self-owned plots for housing development and rental homes, whereas both plots are assigned by a public tender procedure open to all developers, where the best quality-price ratio will be rewarded. The tender procedure consists of two phases, the selection phase where interested parties must submit their applications, which are reviewed based on exclusion and suitability criteria. In the next phase, a maximum of three candidates per plot will be selected to proceed to the award phase, wherein they will be invited to submit their bids. The submission in the award phase contains a ground offer, a project plan, and a presentation. The bids will eventually be evaluated based on predefined criteria and the best-scoring bid on price-quality ratio will be rewarded.

Figure 6.1: Impression case study small-scale timber dwellings merged with the orchard

6.1.2. Case study documents

The first case is analyzed by using the following project and tender documents:

- The information of the tender provided by the client;
- Bid and selection documents submitted by the municipality and awarded tender design;
- The written assessment of the tender bid provided by the client.

In addition also interviews have been conducted with related project stakeholders that were responsible for the selection criteria and the tender content as well as the tender design and its elaboration

- The experiences and practical instances provided by the commercial manager, that was responsible for the tender design that has been submitted and safeguards the communication with the client;
- The experiences and practical instances provided by the project manager, that was responsible for the further working out the tender design into executable construction designs towards production and assembly of the project;
- The experiences and practical instances provided by both clients, who were represented by the sustainability manager of the housing corporation and project leader of the municipality.

Stakeholder	Organization	Function description	Phases involved
Contractor	BAM Wonen	Commercial Manager	Tender – Bid design
Contractor	BAM Wonen	Project Manager	Design – Execution
Client	Municipality of Doetinchem	Project Leader	Tender – Selection criteria & Assesment
Client	Housing corporation Sité Woondiensten	Sustainability Manager	Tender Selection – Execution

Table 6.1: Conducted interviews for Case 1: WeideWald Doetinchem

As stated by the conducted interviews with the main stakeholders of this project, the two-sided view

of the selection criteria, taken measures and design is viewed. This implies that for this case the perspective of the contractor as the clients have been taken into account.

6.1.3. Project selection criteria

For the new build project of WeideWald, the municipality of Doetinchem emphasized the importance of sustainability and social aspects in the tender. Herein the new guideline and criteria of the so-called 'Het Nieuwe Normaal' was used, in order to assess the sustainability aspects that are in line with the Paris climate goals. In this guideline aspects such as circularity, environmentally friendly, and suitability of the designs in the surroundings are mainly important and will be assessed on for the specific tender design.

Furthermore in this guideline the tender contractor candidates must meet certain competencies in the contractors' way of working and experience, which includes the development of green projects, with experience in developing at least a certain amount of dwellings emphasizing nature inclusively and experience in constructing buildings with high circularity ambitions and bio-based materials. But also criteria for maintenance of public green spaces, and environmental- and stakeholder management, including engagement with local residents and stakeholders were pivotal. Specifically, one part of the project was supposed to be built for social housing, therefore the consideration of affordability, maintenance costs, and longevity were equally important criteria for being rewarded with the tender.

The overall ambition of the tender can be divided into two specific visions:

1. **Vision 1: Development vision.** Herein the candidates were sparked to demonstrate how their experience and role in previous projects relate to maintaining or enhancing the sustainable, landscape character of the project. This vision should include explanations of achieved ambitions, the area's intended programming, and public space and parking solutions.
2. **Vision 2: Participation vision.** In addition the importance and method of involving future users, stakeholders, and local residents early and throughout the process to ensure optimal project outcomes were considered as an important aspect. This vision should highlight the candidate's approach to stakeholder engagement and its impact on project success.

6.1.4. Evaluation Case 1: Small-scale timber dwellings merged with the orchard

In the following section for each of the six TIS building block the related measures and insights from the interviews- of both the contractor's perspective as the client's perspective will be described in detail.

1. Construction techniques and technology

INST1.1 Shift construction techniques from project-based approach to conceptual design approach

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From a contractor's perspective represented by the commercial manager, the strategic decision to participate in the tender for a timber project, which served as a catalyst for further opportunities to scale up the current newly built residential sector has been pointed out. The traditional construction techniques of building with concrete and customizing the design for each project will form a bottleneck in order to reach the desirable speed and scaling for the targets on newly built homes in The Netherlands. Herein the commercial manager identifies this shift as stated in the following quote:

'It is very exciting to undertake unique projects with multiple functions. While this is indeed very appealing, I believe the current era demands both speed and scale, which can be achieved through modular construction methods. Therefore, I firmly believe that to meet the housing needs of those currently searching for homes, we must adopt a conceptual design approach. Additionally, the boundary conditions should be structured as sustainably as possible to meet the targets set by both the organization and government policies.'

INST1.2 Early shift construction techniques incorporating sustainable building practices with timber

At the same time, the commercial manager highlights that the shift towards sustainable building practices is slowly taking its pace and is becoming more noticeable in construction building methods. Therefore for this specific tender, the use of timber as a primary material aligns with current trends within the construction industry towards sustainable building practices. The emphasis of this tender on sustainability has resulted in a tender criterium of using timber as the main construction material in the tender design. The case project of timber dwellings merged with the orchard, has utilized an innovative timber building concept as one of the first timber projects of the timber contractor. Therefore the main challenge for this project mainly was allocated to applying a new timber construction concept and a new way of developing and designing the dwellings.

INST1.3 Adoption rate of new construction methods in a conventional construction sector

From a contractor's perspective, the industrialization lead responsible for the constructive aspects of the timber concept that has been used as a reference for the timber project highlights the innovative trajectory and character that they went through the past few years. The innovative timber concept developed by the company has been applied as a construction technique and incorporates technologies suitable to this timber case project. Firstly, the timber concept started from the already existing traditional concrete concept and the design choices for this concrete concept have been revised towards the construction criteria of timber. Consequently, the main criterion of the new timber concept is to incorporate conceptual building elements in the construction structure. Herein the main approach was to find smart repetitive design choices in certain construction design elements that can be standardized. Herein the industrialization lead pointed out that the advancements with regard to design optimization in timber construction technologies have made accelerations in the past few years. This overall asked for the involvement of specialized expertise with regard to construction principles that comply with the building code, building physics, installations, and which parts of the dwelling it was efficient to use prefabricated elements.

The innovation trajectory of the timber building concept was formed on the basis of certain drivers, principles, and a certain program of requirements when engineering and designing the reference design. Diving deeper into the innovation assignment of a timber concept, the main starting point was looking at the future and how the company wants to conceptualize the way the building considers the changing wishes and needs of clients and consumers. Construction from the idea of a building concept was not new, as the contractor already has built with concrete tunnel casting construction for over 25 years and still remains successful. Throughout this period, the concept has been continuously refined to adapt to the evolving market, changing regulations, and the needs of clients and residents. Therefore the main reason for developing a new concept besides the existing traditional concrete concept of the company was to respond to predicted trends and market demands in the construction industry, where building with timber was one of the conceptual construction techniques that made an emerging trend. The basis of the conceptual thinking was founded on the following five pillars:

1. Starting from a reference house and managing deviations;
2. A standardized process;
3. Working in construction flows;
4. Collaborating with fixed partners (co-makers);
5. Focusing on the wishes of the resident.

However, the current conceptual building with concrete have a high environmental impact, is therefore not future-proof, and will not meet the upcoming environment performance buildings (MPG). Herein the need for reevaluation is crucial and is taken back to the start where the choice of the structural frame needs to be reconsidered. Since the choice of the frame is deeply embedded in the entire concept, a comprehensive review is necessary to develop a new, future-proof integrated solution that ensures the concept remains viable for at least the next ten years.

The new concept needed to incorporate advanced digitization and industrialization, by leveraging the 'file to factory' principle. It has been developed into a parametric model, which is similar to the current concrete concept. Most of the work will take place off-site, and the new concept would offer at least the same level of flexibility in appearance as the current one. Moreover, an additional criterion is that the new concept would provide a high degree of customization for residents, allowing them to make relatively simple modifications during the design phase. Several solutions direct and an initial set of a program of requirements that have been formed are listed as follows:

1. Alternative structural frames using wood, CLT, or steel frame construction combined with complete roof and facade elements.
2. Acquiring or establishing a factory to produce process-determining equipment, ensuring independence from the market, scalability, and collaboration with other parties for a viable business case.
3. Enhancing the integration of key pillars within BAM Residential, such as linking Homestudios, parametric modeling, platform technology, and production facilities for enriched information and direct connections.
4. Combining 2D prefabricated elements with 3D units for wet and technical spaces.
5. Using lighter (prefab) constructions for logistical advantages and reduced need for heavy equipment.
6. Separating the structural and interior elements, offering flexibility during both construction and occupancy phases, aligning with criteria of industrialization and circularity.
7. Exploring alternative financing models to keep housing affordable or shifting towards usage rather than ownership.
8. Seeking smart architectural solutions to minimize the number of installations in houses and simple plug-and-play solutions for installations.

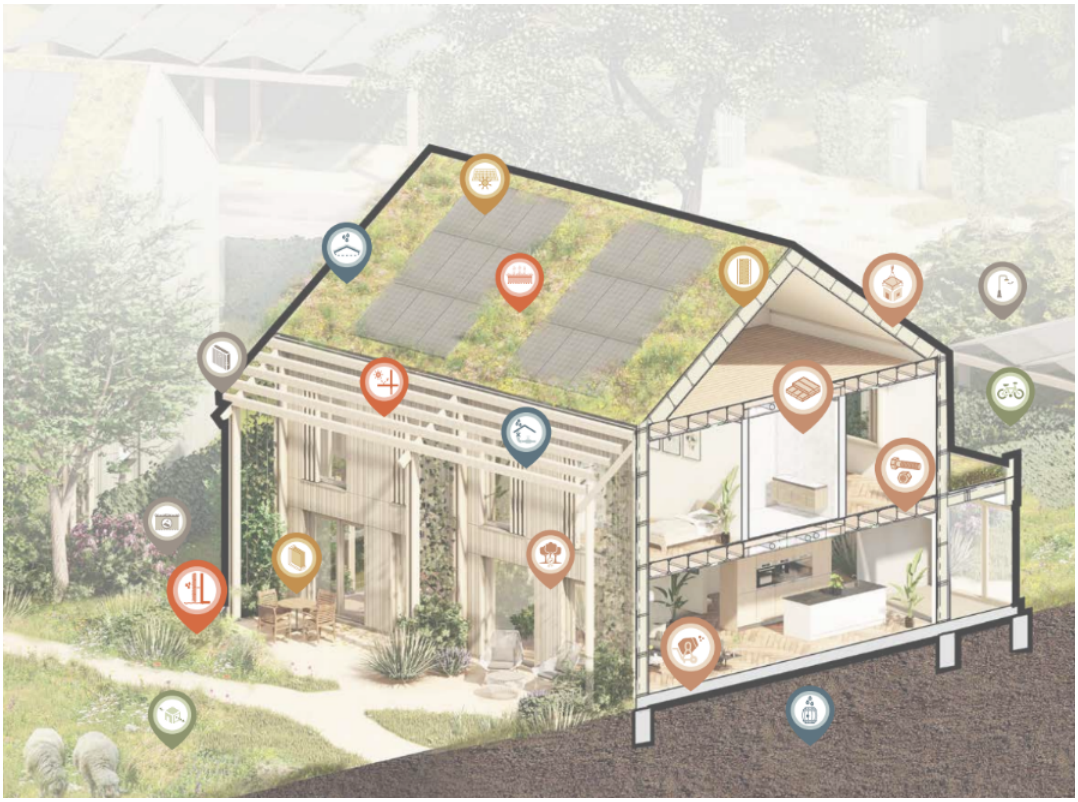

Figure 6.2: Timber building concept flexibility and aspects on the shell

The technical design and construction techniques in this case study project therefore have led to the incorporation of timber extensively in the building structures. The use of timber has not been explicitly requested in the tender, but due to the advice to use the principles of 'Het Nieuwe Normaal' and in order to meet the MPG requirements and circularity ambitions the only solution was building with as much as possible with timber. The design of dwellings utilizes an innovative timber approach, that comes from an industrialized timber product. This timber concept integrates mostly timber frame construction (HSB) and certain parts of Cross Laminated Timber (CLT) in the supporting structure. Specific techniques of using these timber techniques in the concept allow for standardization while accommodating local variations in design and function, showcasing innovation in timber construction methods. Furthermore, certain design flexibility and ease of construction can be achieved by this design, leveraging dry connections for efficient assembly.

The manufacturing of the timber elements will be carried out mostly through factory production and on-site assembly of the wooden elements. In addition, several prefabricated elements, such as the bathroom and technical installations will be installed, to achieve both labor and speed in off-site engineering of these elements. In the project also certain innovative types of wood have been incorporated, whereas for example the use of thermally modified local timber such as poplar wood and European Douglas has been applied, in order to enhance the durability of the dwellings and at the same time to reduce maintenance needs. The modular construction approach of this timber concept not only ensures precision in manufacturing but also supports future adaptability and removability of building components, promoting circularity in the innovative timber construction technique.

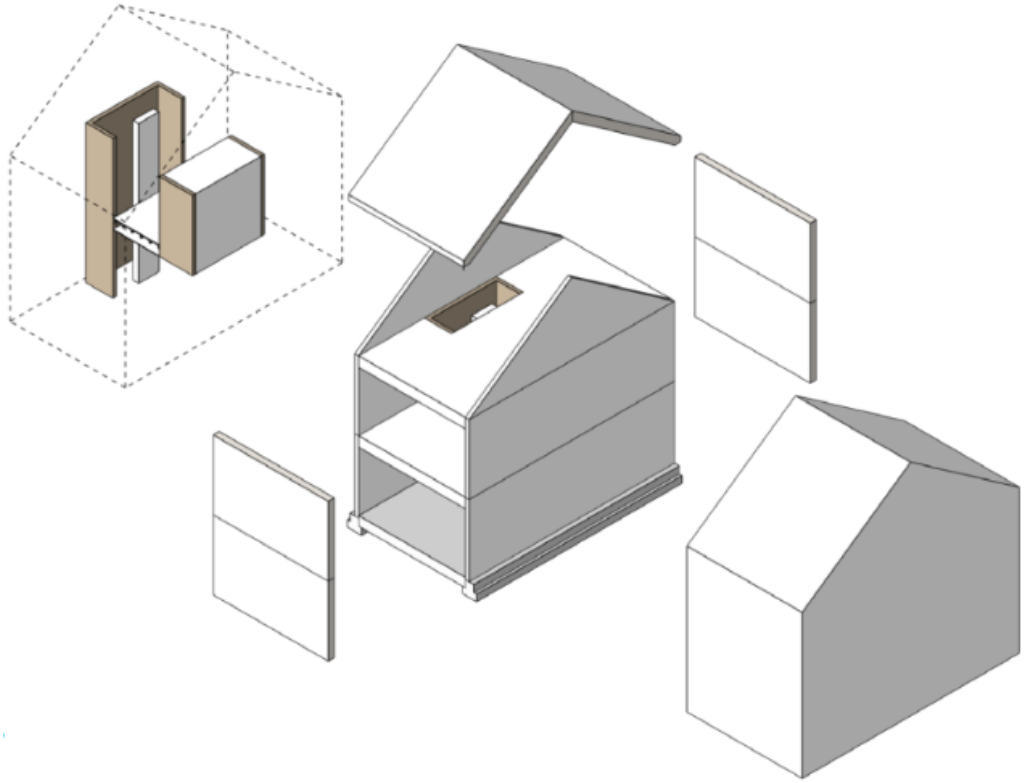

Figure 6.3: Modular elements frame timber construction concept and assembly

2. Timber performance and quality - sustainability and environmental impact

INST1.4 Lack of robust frameworks for timber project assessment

The award criteria of this specific timber project during the tender were centered around sustainability and spatial quality of enhancing bio-based materials. From a client's perspective, using new principles for the tender was a try-out in order to challenge and inspire construction companies and timber of sustainable producers to come up with innovative designs and incorporate sustainability as far-reaching as possible. As stated earlier 'Het Nieuwe Normaal' was used as a baseline for the tender award criteria and according to the project lead of the municipality, the tender team of the municipality has searched for suitable baselines which was quite difficult to find since such sustainable frameworks and regulatory guidelines have not been established by the government yet. As quoted by the project lead, represented by the client:

'Our principle for this tender was to push the contractors to think of building with straw and with recycled bricks or other similar sustainable materials or production of materials. At a certain point, however, we needed something to be able to assess and evaluate the performance and quality of the design methods. Then, 'Het Nieuwe Normaal' came into play. Jan Willem van de Groep is one of the major proponents of this approach, and I already knew him from another project when he was still with the housing association, we came in contact.'

So through a thorough search into sustainable frameworks for tenders, the project lead of the tim-

ber project came in reach with the founder of 'Het Nieuwe Normaal', where through collaboration the founder has also been asked to join the review team for the tender bids and therefore holds an advisory role towards the tender team of the municipality.
The award criteria for sustainability and environmental impact were the following two criteria:

Award criteria 2: Sustainability
Sustainability has been the most important criterion in this tender, where a new evaluation framework have been used respectively 'Het Nieuwe Normaal'. The evaluation matrix for sustainability has been crafted by expert judges and a maximum score of 30 points could be granted for the design bids. Both the zoning plan and the quality plan in the tender were tailored to the project's location, which previously originated from a tree orchard. Herein the proposers were challenged to think out of the box to come up with appropriate sustainability measures and surprise the municipality with their design bids. This openness and transparency within the tender criteria therefore created a lot of design space for the proposers and the design. The assessment has been evaluated by comparing selected designs against those of other bidders. Herein also the competitive approach ensures that only the most sustainable and innovative proposals are selected, aligning with the municipality's environmental goals in the short term.

As stated by the client of this timber project it was at first difficult to find a suitable framework with the incentive to stimulate timber building practices, but they wanted to uphold the tender by maximizing the sustainable aspects. Eventually, the client tender team found a way to assess it according to their mission and goals through 'Het Nieuwe Normaal'. An instance of the evaluation has been pointed out in the following quote of the project lead:

'In order to uphold our standards within the municipality, we established a quality tender team consisting of the district architect, myself, my assistant, an urban planner, an ecologist, and a circular economy expert. We agreed that all designs would first be reviewed by this team and these designs should receive a positive recommendation before a building permit will be granted. Subsequently, this evaluation team representing the client side of the tender, also advises on materials and nature-inclusive measures, such as integrating birdhouses into both the homes and gardens. During the tender process, we emphasized quality over price, with bids accounting for only 10% of the evaluation while sustainability, while the vision of the urban plan, and construction measures made up the majority of the criteria. This approach has ensured us as the client that certain standards were not just preferences but strict requirements, with certain knock-out criteria that could lead to disqualification.'

3. Economic viability

INST1.5 Feasibility vs. affordability - viable business case

From all the stakeholders involved and interviews conducted, the economic viability of the project was mentioned as one of the main challenges and barriers to granting the tender for the final design for production.

As stated by the commercial manager of this timber case the economically viable business case emerged as a critical theme in the interview, particularly concerning the financial implications of using timber in construction. This timber project initially was calculated as a positive business case, meaning that a certain profit margin would be achieved by the construction company. As the project developed from the tender phase towards the production and assembly phase, the timber designs showed certain unforeseen costs where no financial buffer has been incorporated. This made it very challenging for the project team to get a firm grasp on the financial business case. An instance of the financial implications was given by the commercial manager in the following quote:

'Overall, we encountered few obstacles, except for the costs, which remained challenging in this business case. When we started with this tender, the costs for the timber concept were not yet clear. As

a metaphor, we essentially had a toolkit with a wrench and a small hammer, and we had to provide a price. This was the main discomfort and challenge for this timber project, as no one really had a firm grasp on the financial aspects of the project. This was the primary issue.'

INST1.6 Assumptions and uncertainties financial matrix in concrete converted to wood

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In addition, for all residential concrete projects of the organization, a financial matrix is used in order to get a grasp of the project's costs in detail. Therefore for this timber case, the matrix in concrete had to be converted to wood at that time, which was a challenge in itself. For this timber case, many assumptions and uncertain factors have been made in the matrix as the components that were conditioned under changes could not be determined before actually establishing the operational designs and related costs of the project. An instance of an adjustment in the financial matrix was the application of sloping roofs in new construction concepts, which eventually was unprecedented. This raised questions during the project about the construction's implementation and outcomes. Additionally, there were several provisional sums within the basic framework of the new timber concept, which the project team had no control over. Due to the new concept and its related design choices the team was unaware of the exact design specifics. This was hugely critical in the tender, in which initially an added surcharge was taken into consideration. This was done as a matter of fact that building with a new innovative concept, financial risks, and uncertainties inevitably are present and ask either for risk assessment and management or for financial buffers. Consequently, for this timber case, a margin of approximately 9% surcharge compared to concrete was factored in. The project manager of this timber case stated as follows:

'Indicative calculations were made with a surcharge for wood to at least approximate the price difference. It is worth mentioning that we will start sales next week in Doetinchem, where a proper flow matrix has been established, and everything has been refined over the past year. However, due to the fact that during this tender there was no timber matrix present, many assumptions were made.'

INST1.7 Increase unforeseen failure costs due to undertaking an overly complex timber construction project for an initial pilot

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For this project, two challenges combined have led to an unprofitable business case, which was external unforeseen failure cost factors and the complexity of the timber project.
Firstly, the project manager pointed out that while the project had a relatively low land acquisition cost, the higher material costs for timber created financial constraints, especially for projects involving affordable housing. As the timeline from developing a tender design and cost overview toward actual realization took a couple of years. Due to external factors such as price increases due to scarcity of materials, resources such as gas for transportation, and other constraints in supply, the initial tender costs have significantly risen towards unfavorable and unbearable high construction costs. With the external financial factors the commercial manager states the following:

'We decided to invest because we saw the potential for this project to serve as a catalyst for future opportunities. Indeed, we quickly realized that the business case was primarily reliant on the rental sector, which immediately came under pressure, resulting in a loss-making scenario. We initially aimed to offset this with the sales segment, but construction costs have since risen by 13% compared to last year. This increase cannot be compensated for by adjusting the prices. As a result, it is clear that the project is no longer yielding any significant return on investment.'

Secondly, this timber project can be stated as a complex first project while deploying a newly developed building concept. During the tender and while designing the actual timber buildings, the project included many so-called add-ons on the reference design of the basis timber concept. These add-ons were required to be added during the tender, as they contributed to the success factor of winning the bid, but later on, have led to difficulties in managing the trade-off between feasibility and affordability. An instance mentioned by the project manager was as follows:

'Indeed, the financial basis of Flow was somewhat elusive and required further optimization. For instance, over the past year, there has been a shift in insulation materials from rock wool to cellulose. Such changes, as experienced in Doetinchem, added significant costs, around €5,000 to €6,000 per house, which were unforeseen. Therefore, Flow has been optimized, but construction costs have increased. Additionally, there have been project-specific adjustments, such as fully integrating wood in the main facade, a green roof, and pergolas for the houses. Certainly, this was not our original idea. It was stipulated in the municipality's visual quality plan and therefore was a strict requirement: if we did not implement wooden facades and green roofs, we would be immediately disqualified. Thus, if we had not made these choices, we would never have won this tender. Consequently, the unprofitable business case was a combination of multiple factors.'

INST1.8 Spin-off strategic decision undertaking timber project serving as a catalyst for future opportunities and building legitimacy

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During the tender and especially upon proceeding with the design phase certain financial challenges occurred in this timber project. During the interview the commercial manager highlighted several reasons on why the case still has been proceeded with, whereas one of them was the that the company believed in that a spin-off through this sustainable project would be initiated. Specifically, the manager pointed out that the participating in the tender for a timber project was mainly due to strategic reasons and basis, where it was expected by the directors to serve as a catalyst for future opportunities. This statement has been stated by the commercial manager in the following quote:

'For the timber project Doetinchem, we secured a win, and that truly acted as a catalyst for further opportunities. As a result, I noticed that our involvement in inquiries increased significantly. Suddenly, instead of being placed on a longlist in Doetinchem, we were directly shortlisted for other inquiries. This progression enabled us, for example, to submit a proposal for Biobased Leeuwarden in collaboration with Flow, which pertains to the redevelopment of the old Cambuur site and has led to being awarded this subsequent tender.'

This spin-off of winning one of the first timber projects and therefore gaining the attention and opportunities for consecutive timber projects that are suitable for the developed timber building concept leads to a certain favorable switch in acquiring timber projects. The economic viability is stated as being dependent on the number of timber construction projects completed by getting out of the early adaptors phase and therefore scaling up towards significant numbers in the construction pipeline to reach break-even in the investments made with regard to development and operational costs.

4. Risk assessment and management

INST1.9 Conducting a detailed risk analysis and assessment with corresponding mitigating measures prior to starting the innovative timber design

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During the tender, a risk assessment was carried out by the project team consisting of the commercial manager and project manager in order to map out the potential risks, but also chances that could be

identified. This step within the project has been highlighted as crucial due to the fact that building with a new concept and timber as a new material, inherently poses unknown risks and related uncertainties within both the design phase and operational activities. Therefore the main goals of conducting the risk assessment and management were to create awareness of crucial risk factors such as environmental impact, supply chain reliability for timber, and compliance with regulatory standards as well as to ensure project success throughout the design and operational phases. Project success within this residential project was explained as reaching the desirable quality and design result while staying within the predetermined project's budget and therefore delivering a successful business case for the company. A list of the identified risks and chances that are correlated with the TIS building blocks are shown in table 6.2.

Identified project indicators	Risk or chance	Risk ranking	Mitigating measure
Assumptions construction elements such as pergolas and green roofs	Risk	High	Acceptance
Chance of higher failure costs	Risk	Medium	Acceptance
Higher engineering costs due to new timber building concept	Risk	Low	Acceptance
No environmental permit rewarded	Risk	Low	Reduction
Uniform Administrative Conditions for Integrated Contract Forms mentioned in tender documents not included	Risk	High	Acceptance/Transference
Use of MIA subsidy for the business case	Chance	Extreme	-
Increase free-on-name price due to increased quality and due to living in an unique orchard location	Chance	High	-

Table 6.2: Identified risks and chances for Case 1

INST1.10 Mitigating novel high-impact risks through acceptance

The first identified project risk on the list is the assumptions that have been made for the design quality and price of the timber construction elements by the project manager. These elements include the project-specific adjustments from the reference design of the timber building concept such as pergolas and green roofs. As stated by the project manager this has been identified as a high risk and the taken mitigating measure was through accepting the risk. The measure of acceptance means that the project team has acknowledged and accepted the risk without taking specific actions to mitigate it. This measure is typically used for risks with low impact or likelihood or when the cost of mitigation outweighs the potential consequences. Even though in this case this risk has been ranked as high at the start of the project have been chosen to not take further mitigation measures. This can be explained in the following quote by the project manager:

'The described risks were jointly identified, particularly with the input of the commercial manager, highlighting that certain risks pertain to construction costs and risks, while others relate to development costs and risks. These types of risks are inherent, particularly those associated with the construction planning and in accordance with the agreed terms, such as the chance of higher failure costs, no environmental permit rewarded, and alignment with the Uniform Administrative Conditions for Integrated Contract Forms. I must admit that we somewhat underestimated the risks involved in the development of the Flow project, as I assumed things would proceed smoothly. However, in practice, the process has taken significantly longer than expected, and the current model will require further refinement based on the latest adjusted project specifications. This is typical for initial projects, where optimizations continue

to be implemented at the project level.'

Following up the mentioned risks in this quote, the third project risk that was identified as higher engineering costs due to new timber building concept, aligns with the occurrence of project delay due to the elongated end-to-end engineering within the project. This have posed higher engineering costs that was preliminary identified as a low risk in the ranking and accepted without taking additional mitigating measures. The instance given by the project manager was as follows:

'We didn't have an exact timeline, but elements like pergolas and green roofs were initially estimated as risks, indicating a potential for higher failure costs, particularly in relation to the Flow concept. Adjustments made to the base housing design inherently carry the risk of increased costs. This contrasts with our older concrete concept, where risks were minimal due to 25 years of experience. At this stage, we are more aware of how to construct these homes, and risks are now more associated with peripheral aspects of the construction site rather than the homes themselves.'

Two risks that relate to the construction planning and contract forming which have been identified are no environmental permit rewarded and misalignment with the Uniform Administrative Conditions for Integrated Contract Forms. The risk of no environmental permit reward has been ranked as low and due to the standard procedure of reserving a financial buffer. Therefore this risk was tried to be reduced at the start of the project by minimizing the financial impact of any possible delay of not being granted the environmental permit and sticking to the projects' planning in the start of construction. The risk on contract forming and allocating the responsibilities for the projects' design and execution has been identified in the so-called Uniform Administrative Conditions for Integrated Contract Forms (UAV-GC). In this project, a design & contract agreement has been made and therefore the contractor was responsible for not only the implementation of a project but also had control of developing a design solution for the tender. form an important framework for integrated contracts. In practice, this means that the contractor has more design freedom and more opportunities to provide advice. The risk of not including the project-specific conditions in the contract and therefore being held responsible for the delivery without being aware of the specifics has been identified. Due to the legal nature of this contract, the risk has been ranked as high, and through several dialogues, the contractor and client have come to a mutually agreed upon contract. During these dialogues, certain risks have been openly allocated to either the client or contractor and therefore transferred towards the client when agreed upon. These aspects came from the instance given by the project manager of the first case study:

'Regarding the municipality and the environmental permit, the construction site has been somewhat challenging, especially with adjacent lots also being developed during our construction. Specifically, for the rental housing, this was noted in their initial contract, which we thoroughly reviewed and eventually revised in light of quality assurance legislation. They agreed that duplication was unnecessary, leading us to fill in the requirements practically, which has now been resolved, indicating it was a risk we initially anticipated. The client had a concept contract attached to the tender documents, which we did not formally respond to during the tender phase. It was treated as a set of conditions that needed further definition. However, through good communication, we discussed and addressed mutual risks effectively, resulting in a successful outcome. Despite this, I noticed that the client wasn't fully aware of the project's experimental nature. After visiting our prototype house of Flow, they appeared reassured and did not feel like they were part of a pilot project, which aligns with how we presented the project, focusing on our extensive project portfolio.'

5. Network formation and coordination - stakeholder management

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INST1.11 Coordination new processes of internal network formation and task transfers

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In this timber project the the significance of network formation and stakeholder management has been underscored and has been highlighted as of vital importance in order to reach successful execution

of the timber project. The commercial manager described that the network formation was inherent for both internal processes as external collaborations. Starting off with the internal processes and procedures of coordinating the different involved teams has been discussed through several instances, as described in the following quote:

'Yes, network forming and alignments are very important, but I also find it quite challenging for this specific timber project. Because you often encounter conflicting interests, on one hand, we as the responsible project team aim to create something beautiful with regard to the wishes of the client and design things in a certain way, but then industrialisation team might approach things from a more practical perspective, perhaps not wanting to implement certain project specific adjustments in their production processes. Therefore you end up in a bit of a tension between different entities within the company, and it can be difficult to determine who ultimately has the final say or who holds the authority.'

Herein there have been pointed out that from the start the alignment of feasibility in the design and where the frames for project adjustments are ultimately decided was unclear. In combination with external factors such as the allocated teams having other priorities at crucial times and certain project delays of awaiting approvals was mainly challenging in the internal processes.

INST1.12 Network formation with knowledgable external partners and building strong relationships

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Throughout this timber project networks with external stakeholders were searched by the project team that includes collaboration with partners such as architects, local authorities and also engaging the client. One partnership that resulted in the winning design and bid was that the project team has strategically partnered up with local architects. This architect had already experience with designing with timber as main constrcution material and therefore encompassed the needed knowledge and expertise for this tender. The design has been strengthened through the aligned visions of both the contractor as architect and resulted in an enhanced project's credibility in the eyes of the client. The commercial manager's points out that it is inherently important to build strong relationships and coordinate effectively with all parties involved to achieve project objectives. These tasks has been allocated as one of the main responsibilities of the commercial manager involved. From a clients' perspective network formation and collaboration also took place with regard to implementing 'Het Nieuwe Normaal' as scoring framework for the tender bids. The client of this project, respectively the municipality, described it in the following:

'On one hand, you can recruit suitable people for the welfare committee on this specific timber project, but often they will also volunteer themselves when they recognize the project's significance and the desired contribution to a higher goal. For instance, Jan Willem expressed interest in the project by suggesting that we adopt 'Het Nieuwe Normaal' approach. I eventually told him to draft a proposal and join the evaluation process for the tender, thereby integrating his expertise into the team. By involving someone with specialized knowledge in the evaluation committee, we ensure that the submissions receive an impartial and expert assessment. However, it is important to note that when strict criteria are set, participants often aim to meet the minimum requirements rather than excel, resulting in average outcomes rather than top-quality submissions. For example, while we mandated the use of biobased materials, there was a tendency for participants to push the boundaries of what was acceptable. To address this, we organized an informational fair coinciding with the sale of our plots, which featured professionals in timber construction, sustainable landscaping, straw construction, and green mortgages. Additionally, we presented the project and involved a Tiny House Community to help shape perceptions about the uniqueness of the neighborhood. This event was aimed at ensuring potential residents understood that living in this neighborhood would require a different mindset—although it would be accessible to everyone, not everyone might find it suitable.'

INST1.13 Increased focus in tender (request) on engaging both direct stakeholders and additional interested parties

In this tender for the timber project a certain focus has been allocated on engaging both direct stakeholders as additional interested parties such as customers and citizens living in the neighborhood has been incorporated. Herefore one specific award criteria have been formulated that incorporates involvement of stakeholders. This award criteria can be described as follows:

Award criteria 1: Tender submission program
As stipulated in the tender documents the evaluation of the designs and program that have been submitted by the contractors was partly on how the type of buildings considers the livability of the environment and the housing need that is inherent to the mission of the municipality. Therefore the proposals and tender design of the contractors must demonstrate how they would contribute to the specific housing quality and requirement that enhances the living conditions within the community. The fulfillment of this criteria therefore needed to include a clear vision for potential facilities as a well-thought-out plan for implementation and management of the environment with the involved neighbors. Additionally, the proposal was required to address how construction-related disruptions would be minimized. This was the case because the environment was technically sensitive and directly schools were located. Using timber in the buildings herein has the benefit to minimize the environmental impact through short construction times and less transport movement. Timber also enhances the livability and quality as bio-based materials are directly in the sight of the neighborhood. In addition, the adaptation and enhanced quality of the dwellings itself have been incorporated in the bid, which ensures that the standards for both the municipality as the housing corporation will be met. Subsequently this resulted in engaging both directly related stakeholders as well as customers as interested parties that should be kept informed.

6.2. Concluding remarks Timber Case 1: De Kwekerij

After the TIS building blocks were modified for the residential construction industry, the analysis of the TIS building blocks on the three timber cases are carried out. For each of the three case studies and the remaining interviews a concluding chapter will be given in order to share the key-findings and insights in chronological order. The second research sub-question that will be answered in the analysis of the findings is as follows:

'What type of socio-technical perspectives influence and determine the shift towards timber building projects in relation to the modified TIS building blocks?'

In the previous section, the instances from practice with regard to the project De Kwekerij Doetinchem have been described. In the following part for each of the instances, the impact on project success as control of the project team over the measure is placed into a so-called quadrant matrix. **This quadrant matrix shows easily the impact of the instruments and measures given from practice impact the success of a timber project and how the project team can act upon it.** In the following part, the quadrant matrix is explained in detail.

The axes of the quadrant have been defined based on two key dimensions: impact and control. This matrix approach leads to categorizing the found instances in practice, the key drivers, and barriers and eventually helps in making strategic decisions, prioritizing actions, and managing risks effectively in timber construction projects.

The first quadrant, the 'Monitor' quadrant is located at the bottom left corner. This quadrant consists of low-priority factors and instances, that have little impact on the project's success and involve low influence from the project team. These instances allocated at the Monitor section need to be monitored to ensure they do not unexpectedly influence the project.

The second quadrant, the 'Manage' quadrant is situated at the left top corner, which highlights instances that have a high impact on the overall project success of timber cases, but are low in control by the project team. This quadrant steers towards development strategies to mitigate high-impact barriers that are difficult to control through for instance lobbying, partnerships or risk management.

The third quadrant, named as 'Optimize' quadrant can be found at the bottom right corner categorizing low-impact and high-control instances. Herein instances are placed that are easily controlled but have a lower overall impact on the project.

The fourth and last **quadrant** called the **'Focus'** quadrant holds the top right corner and also considered the most important quadrant with instances as it consists of high-impact controllable drivers where efforts should be concentrated.

The defined instances of the first case have been inserted through the analysis in the previous section. The result of this analysis is plotted in the matrix table 6.3 consisting of the earlier defined four quadrants.

Herefrom it can be concluded that the focus of instruments and measures on the timber project De Kwekerij as seen in Quadrant 4: 'Focus', the right upper quadrant have been on the overarching categories: **managerial levers and business processes**.

Classification of Impact	Low control	High control
High impact	• INST1.3 - Adoption rate of new timber construction methods in a conventional construction sector • INST1.8 - Spin-off strategic decision undertaking timber project serving as a catalyst for future opportunities and building legitimacy • INST1.10 - Mitigating novel high-impact risks through acceptance • INST1.13 - Increased focus in timber tender (request) on engaging both direct stakeholders and additional interested parties	• INST1.1 - Shift construction techniques from project-based approach to conceptual (timber) design approach • INST1.2 - Early shift construction techniques incorporating sustainable building practices with timber • INST1.5 - Feasibility vs. affordability – viable business case • INST1.6 - Assumptions and uncertainties in financial matrix converted from concrete in wood • INST1.7 - Increase failure costs due to undertaking an overly complex timber construction project for an initial pilot • INST1.11 - Coordination new processes of internal network formation and task transfers • INST1.12 - Network formation with knowledgeable external partners and building strong relationships
Low impact		• INST1.9 - Conducting a detailed risk analysis and assessment with corresponding mitigating measures prior to starting the innovative timber design
	Control/Ease of Implementation	

Table 6.3: Overview instances of Case 1: De Kwekerij Doetinchem from practice in four quadrants

6.3. Case 2: Mid-rise timber construction apartment complex

6.3.1. Project description and scope

The second case is a mid-rise timber construction apartment complex where high sustainable ambitions have been set by the client. This project is a one-on-one request, where no tender was discussed. Therefore the party and the collaboration had already been made clear in advance.

6.3.2. Case study documents

The second case is analyzed by using the following project and tender documents:

- The information of the principles of the new timber project provided by the client
- Ambition alignment documents submitted by the client and the contractor
- Written meeting notes on the client-contractor sessions and discussions

In addition, also interviews have been conducted with related project stakeholders that were responsible for the selection criteria and the tender content as well as the tender design and its elaboration

- The experiences and practical instances provided by the commercial manager, that was responsible for the project design till the production phase and involved with conversations and meetings with the client.
- The incentives, experiences, and instances provided by the director of the region south of the contractor for selecting the first timber projects.
- The experiences and practical instances provided by the client in this case the housing corporation, which was represented by the project manager of the timber project.

Stakeholder	Organization	Function	Phases involved
Contractor	BAM Wonen	Commercial Manager	Tender – Bid design
Contractor	BAM Wonen	Director Region South	Strategic Selection Tender
Client	Housing corporation woonstichting 'Thuis	Project Manager	Tender Selection – Execution

Table 6.4: Conducted interviews for Case 2: Veldhoven Ambachtslaan

As stated by the conducted interviews with the main stakeholders of this project, the two-sided view of the selection criteria, taken measures and design is viewed. This implies that for this case the perspective of the contractor as the clients have been taken into account.

6.3.3. Project principles and criteria

The client of this project, which was a housing corporation is committed to fostering a sustainable society, driven by the belief that a healthy and green environment enhances human happiness. Their approach emphasizes the use of materials and products that respect both human and environmental well-being. In addition, the client aims to minimize living costs for tenants by promoting energy conservation.
In the following part, the principles and ambitions are described as stated by the project description and the Q-wiser as defined by the triangular relationship: client, architect, and contractor.

Ambitions of the housing corporation

The housing corporation seeks to lead by example, inspiring others with successful initiatives and welcoming innovative ideas from tenants and partners. By 2050, the client aims for all its housing to be completely CO2-neutral. This objective encompasses several key components: energy-neutral construction for new buildings, the use of sustainable materials, and a strong focus on energy conservation to benefit both the climate and tenant expenses.

In this timber project at the start a highly ambitious vision of the housing corporation on sustainability goals and taken measures for the project must be included. These goals were formulated through adherence to the Natural Step (TNS) principles. Herein prioritation and attention to human needs, natural urban spaces, sustainable energy, and the use of materials within closed-loop systems were incorporated. This principle in addition includes the use of sustainable building materials, such as wood and bio-based materials. In addition a focus has been allocated on construction techniques that minimize environmental impact and enhance the recyclability and reusability of the used construction materials.

Implementation of project design and principles
Another crucial point within the design phase of this timber project was the ambition the client had to implement opportunities to actively involve residents in the decision-making processes. This would eventually encourage them to participate in shaping their living environment and therefore future residents would become aware of why this project has incorporated such high sustainability standards. By engaging the future residents a sense of ownership and collective responsibility will be formed.

Figure 6.4: Impression case study mid-rise timber construction apartment complex

6.3.4. Evaluation Case 2: Mid-rise timber construction apartment complex

In the following section for each of the six TIS building block the related measures and insights from the interviews- of both the contractor's perspective as the client's perspective will be described in detail.

1. Construction techniques and technology

The insights and instances given on the construction techniques and technology for the case Ambachtslaan can be divided in subcategories of: newness of construction material and technology, standardization and industrialization, and lessons learned during design and construction phases.

INST2.1 Ensuring compliance with Dutch Building Codes

INST2.2 Allocation of responsibilities research and piloting on construction technique between contractor and client

As stated by the director of Bouwen Op Maat (BOM) from BAM Wonen, constructing in timber is relatively new in The Netherlands and also new for the construction company, although it is more common abroad. The newness of construction material and technology poses two events to occur, the occurrence of proving and complying with the building codes in The Netherlands, and allocation of responsibilities with regard to research and piloting between the contractor and client. As stated by the director in the following quote these two events occurred simultaneously:

'Since we lacked in-depth knowledge ourselves, we sought out partners with expertise in timber construction. This led us to collaborate with Hering in Switzerland, a company with experience in this field. During this process, we discovered that Dutch regulations, particularly concerning fire safety and noise, are stricter than those in other countries. At the same time, timber construction is also new for many clients. This requires us to invest significant effort in educating clients about this different method of building and all that it entails with coming to an agreement on which design choices to make with timber.'

One particular instance that occurred in the project Ambachtslaan is that the design of the project initially was in concrete, the traditional way of building apartment complexes. After winning the Cobouw awards as the most sustainable project in collaboration with the same client, the project team including the director recognized that the future of construction is evolving, and as result, they wanted to go beyond our previous achievements, such as winning the most sustainable project in the Netherlands. Thus, the contractor decided to use Ambachtslaan which was in collaboration with the same progressive client to establish a basis for a new approach in circular and biobased construction, resulting in the development of a timber building. The project manager stated the following about the choices made on the construction of the building:

'Although the project was initially designed in concrete, and the frameworks were set with the municipality and zoning plans, the client gave us considerable freedom to propose solutions and scenarios. This allowed us to develop a design process where we could innovate within the constraints.'

INST2.3 Converting design from concrete into wood while adhering to traditional design choices

The project team consisting of the commercial manager, project manager, and architect including several specialists started the design of this timber midrise project through evaluating several construction techniques and what would be suitable technologies to consider. The design at fist was accustomed to be designed with concrete, because the project already was started before the housing corporation changed the ambitions for this project towards incorporation of bio-based materials. Therefore the approach resulted in switching fully to using timber as main construction material led to reconciling which existing systems would be most suitable for the timber construction of the apartments. The conclusion therefrom was adopting a column-and-beam structure. The team believed this solution would offer a certain amount of flexibility, and in addition allowed the building to be repurposed in the future such as converting it into office space or merging residential units. The use of steel braces or concrete are found to reduce the flexibility, therefore with the projects' requirements and additionally. Subsequently from a sustainability perspective, timber beams seemed more favorable as they are less carbon-intensive, also important financially, the use of the timber structure appeared more advantageous upfront. The process of thinking through designing in wood and leading to insights of using new sort of construction technique has been explained by the project manager as follows:

'We started the design by integrating column-and-beam system directly into our floor plans, indicating where columns and beams would be located. Initially, this seemed feasible, but as we progressed, we encountered increasing difficulties, particularly in terms of acoustics and the routing of utilities, such as kitchen plumbing that needed to traverse different units to reach the main drainage pipes. We continuously sought to resolve these issues until it became evident that our initial approach was flawed,

prompting us to restart the design process.'

Herein the iterative design process, discovering the technique and coming back to the fact that wood requires a completely different approach can be summarized that shaped the design process of Ambachtslaan.

INST2.4 Shift towards timber inherently leads to incorporating both standardization and industrialization

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At the start of redesigning the apartment complex in timber the project team quite soon highlighted that the core value of the construction technique for Ambachtslaan was to minimize on-site work, and therefore aiming to complete as much as possible in the factory. One of the outputs was delivering large elements to the construction site that require minimal assembly. The project team of Ambachtslaan switched to a new manufacturer that supplied CLT (Cross-Laminated-Timber) solid walls for the project. These walls were as much prefabricated as they come fully prepared with plasterboard on both sides and installed electrical outlets, requiring almost no additional work on-site. Herein the commercial manager stated the following with regard to standardization and industrialization:

'The use of prefabricated elements, especially in timber construction, involves two parallel processes from my opinion, the design process of understanding how timber as material works while standardizing recurring patterns, and at the same time the operational process of prefabricating and industrializing the timber elements and assembly on site. While this approach might initially seem complex, it actually becomes more manageable once you break free from conventional methods and adopt a completely new mindset—particularly when it comes to assembly. Eventually these two shifts also allowed for the project Ambachtslaan to integrate sustainability by firstly using timber as main construction material but also additional sustainable measures such as greenery more easily by extending the already set ambitions.'

The project manager concluded that the shift towards timber inherently lead to incorporating both standardization and industrialization as the current construction industry is facing with labour shortages and heavy work on the construction site, which are both unfavorable to reach the desired construction speed.

INST2.5 Design optimization and adoption upon conducting research with designing in timber

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The first lesson learned for Ambachtslaan within the design phase is to avoid layering different type of apartments on top of each other that requires many difficult connections and detailing. The final design of this project involved layering gallery and corridor timber apartments, which made the execution and assembly immensely more difficult for a pilot project. Therefore the project manager stated that it is crucial to ensure that similar types of apartments are stacked to achieve project success.
Another lesson learned with regard to the construction is that the use of timber column-and-beam structures, which involve numerous individual elements that need to be installed separately, is inefficient. Herein coordinating the construction work with the transport and logistics of all the elements was very complicated. In comparison to the traditional way of building with concrete, the number of movements and deliveries has tripled for Ambachtslaan. The project team pointed out that in the following project they are switching towards producing larger elements in the factory, thereby reducing the number of components that need to be assembled on-site.

One of the main technical lessons learned involves the lower thermal mass of timber compared to concrete, which requires a different type of installation, such as underfloor heating. Timber has the ability to accumulate quite fast and therefore heating the air is more preferable. Even though the system

was not fully suitable for timber as it heats the material and with timber air heating is more preferable, the system of underfloor heating has been chosen due to financial considerations. The lower mass as material for wood also posed a significant learning experience whereas the project team encountered difficulties with the design and layout, particularly concerning the installation of a lift and its frame, which is highly sensitive to noise. The client of the project has been involved with the construction design with regard to noise, as the project lead opted for concerns with regard to noise pollution for residents. The client stated the following:

'It is generally preferable not to position a lift adjacent to living spaces. In timber construction, we struggled to manage the noise and its impact on living spaces within the design, especially in cross-sections where many façades were staggered due to roof terraces or overhangs.

2. Timber performance and quality

INST2.6 The need to provide extensive documentation and evidence of compliance with local regulations on timber performance and quality

The performance and quality of timber in apartment complexes has been continuously be compared to the performance and quality of using concrete in the traditional way of building.
One of the main challenges with building timber complexes is the water management. As building with concrete does not pose risks of being wet, which can easily be dried, this is not the case for timber. The most significant lesson the project team learned from Ambachtslaan was to avoid using hollow timber floor elements and instead should opt for solid floor elements to ensure proper water management, such as the effective drainage of water. As lesson learned was that proper water management of timber buildings during the construction phase is essential. With water management the focus should be on ensuring that the building is wind- and watertight, as moisture trapped within the wood can lead to rot. The project team learned for the next timber projects to use solid CLT (Cross-Laminated Timber) floor panels and these floor elements should be thoroughly sealed to be watertight.

In addition, regulatory compliance and adherence to standards were found to pose significant challenges in this timber project. The commercial manager pointed out that the existing regulatory framework is often more favorable to concrete construction, leading to making procedures unnecessarily difficult for timber projects. Herein the manager in this timber project shared experiences of encountering unexpected regulatory hurdles that delayed project timelines. For instance, the project team was subject to providing extensive documentation and evidence of compliance with local regulations but also testing the wood elements added complexity to the approval process. Another instance was the performance of concrete buildings with regard to current building codes and the phenomenon that timber has to meet the same performance and quality score as concrete. The commercial manager opted the following in practice:

'Regarding sound insulation, we assessed the regulations to understand the level of noise disturbance that would be acceptable, recognizing that the standard allows for a relatively high percentage of complaints. To mitigate this, we implemented an additional 5 dB of soundproofing, which is a significant increase as sound intensity rises exponentially. This enhancement was made to reduce the likelihood of complaints and ensure compliance with the acoustic requirements. However meeting the standards of concrete with regard to level of noise disturbance was difficult for this project, as concrete itself as a material scores very high above the minimum of the building code on insulation, whereas timber have to be adjusted excessively in order to meet the same standard. Herein I think a necessity lays for ongoing dialogue with regulatory bodies to ensure that standards evolve in line with advancements in timber construction practices. '

INST2.7 Perception, acceptance & true believe in timber buildings by stakeholders, internal colleagues as well as by external clients and resident users (support base)

The commercial manager also highlighted the specific way the society and customers are used to living in houses build from materials such as concrete. This incorporates the feeling of how these materials delivers certain insulation of acoustics in their housings. Event though timber can meet such insulation standard related to the current habitual feeling of residents, it makes it difficult when engineering happens solely with timber as material standing alone. The contractor pointed out that they will monitor how the engineering decisions perform in reality. As an instance the commercial manager pointed out the following:

'We plan to conduct surveys before the residents move in to understand their expectations, and then again after a year to gather feedback on their experiences. This is particularly important because we have noticed that some potential residents were hesitant about living in a wooden building. While we invited them to view the model apartment, many ultimately decided against it, citing concerns about noise as the primary issue. Although we ensure that all regulations are met, and in many cases exceeded, it is impossible to completely eliminate noise in an apartment complex, whether it is constructed from wood or concrete. Residents in concrete buildings also occasionally experience noise disturbances, such as when a neighbor plays loud music or installs hard flooring.'

With regard to the sunstaiability performance of timber, the project manager stated that much of the existing regulations are still tailored to concrete construction. For example, the design must comply with guidelines like the Building Decree (Bouwbesluit) in the Netherlands, which still considers the end-of-life value of wood to be primarily incineration. This regulatory framework is according to the project manager not fair and poses engineering challenges, as the construction regulations in the Netherlands are more stringent than in other countries. In practice this has lead to additional testing and delivering burden of proof due to the fact that instances were still unfamiliar of the performance of timber and inherently led to asking additional questions that typically would not arise with concrete construction. Therefore it is clear that the regulatory framework is not yet adjusted to fully embrace timber construction in the residential construction industry.

3. Economic viability

INST2.8 Willingness and buffer to invest in innovative timber projects with regard to learning costs of pilot project

The economic viability of Ambachtslaan have proven to be a pilot project in the basis. This has shown as the project required a significant amount of investments from the contractors' side and therefore not yielding towards a positive business case. Herein the phenomenon of guaranteeing the continuity of an organization, where the traditional way of building must remain a part really shows, as stated by the commercial manager. The director highlighted that timber construction was approximately 20% more expensive than traditional methods, which instantly poses a challenge for the profit margin on a timber construction project. Given that this was our first project of this kind, the project team underpinned that they learned a great deal and the investment of both the time as money has been worth it as there have been anticipated that the organization have not fully reinvented the wheel yet and will not get everything right on the second attempt either, but after three or four projects, the solid understanding will be established. In addition to the the director foresees that the economic viability of building with timber will gradually take place by stating the following:

'Affordability remains a challenge, especially in the private market where consumers are not yet willing to pay extra sustainable building practices such as timber. I believe that traditional construction costs will increase, while timber construction may become slightly cheaper. As we see fewer workers available for on-site construction, prices are likely to rise, and the introduction of potential CO_2 taxes

will further drive costs, leading to a convergence in pricing between traditional and timber construction.'

INST2.9 Availability of funding by the client for research and piloting on innovative timber construction projects

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Another financial aspect was financial compensation resulting in support on the economic aspect of the timber project. The contractor has been granted with funding by the client, as the client had certain availability and willingness to support financially with the project in order to deliver a positive project in the end. The project manager highlighted this as follows:

'We worked closely with the client in a transparent manner, allowing access to our financial records and vice versa. The client invested significantly, contributing approximately two million euros for 56 apartments, which is considerable. This investment reflects their belief in timber construction and their commitment to playing an active role in realizing this vision. Additionally, the project has succesfuly secured the MIA (Environmental Investment Allowance) subsidy, which is expected to yield a net benefit of 1.1 million euros for the client. However for us as a contractor this benefit will not appear on the project balance sheet, as it is applied as a deduction from corporate tax but acts as motivation for the client to choose for timber projects.'

INST2.10 Continuity of an organization, where the traditional way of building still must remain a part

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From the client's side the project lead representing the client of Ambachtslaan pointed out that as a housing corporation, they construct buildings that are intended to last for 50 years. Compared to the construction time which would be 1.5 years this shows that the asset is relatively long in their portfolio as a housing corporation. even though the construction itself may take only 1.5 years. This longevity of the timber building has formed various challenges that are related to residents, housing modifications, and maintenance aspects. It's crucial that these factors need to align with the maintenance that is suitable for timber as a material and poses new questions for the housing corporation as they are typically used to maintenance for concrete buildings. The client highlighted these concerns and their investment strategy as follows:

'In our investment strategy, we have adopted a new method of real estate calculation, incorporating residual value, which was a key factor in our investment decision. For instance, the housing project still retains a certain residual value after 50 years. While we applied conservative parameters, we considered factors such as the reuse of timber and prefabricated stairwells, which are integral to the project's sustainability. We also faced global risks, such as rising timber prices due to the onset of war in Ukraine. We had to absorb these risks, and I had to justify new investment figures to the board and supervisory council twice. This is a responsibility we bear, with validation and review at every stage.'

INST2.11 Outweighing higher construction costs by using financial compensation on timber projects

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In this mid-rise timber project, the investment in learning on the project through implementing sustainable measures and the new construction methods with timber has led to certain high construction costs for the contractor. The commercial manager has highlighted that while the initial costs are currently higher for us as a contractor, the building itself results in long-term benefits such as reduced energy

consumption within the building and lower maintenance costs. Even though the contractor is not responsible for the building in the maintenance phase, this outweighing of expenses is allocated at the client's portfolio. Herein as mentioned earlier the use of subsides has been incorporated in this timber project which helped the client to finance the timber project from their perspective. In line with this the commercial manager advised the following:

'In order to achieve affordability, we must embrace certain standards and move away from custom solutions for every project, especially in areas like bathrooms. By standardizing and industrializing certain aspects, we can develop a more consistent and cost-effective approach. Affordability is crucial, and while offering some design freedom, we should limit it to aesthetic choices while adhering to factory-driven principles. This approach allows us to offer a cost-effective solution, providing clear comparisons between custom and standardized options. This also requires careful consideration of new projects by the commercial organization and the managing board of the organization to determine the feasibility of certain timber construction projects.'

4. Risk assessment and management

INST2.12 Involvement client in innovative timber designs preferably in a Bouwteam then in Design & Build construction contracts for demarcating liability

The risk assessment for Ambachtslaan has been conducted through an opportunities- and risks register. Herefore support from BAM Infra, who are more experienced in identifying risks was given. The potential opportunities and risks for this timber project are identified and documented through two risk sessions with a large team.
The identification of opportunities and risks started with defining eight overarching themes, that were: safety, client relationship, location & environment, contract management, technology, partners, project team and design. Most risks and uncertainties have been found in the themes client relationship, project team, design and location & environment. A list of the identified risks and opportunities of these main themes are given in table 6.5.

Identified project indicators	Risk or opportunity	Risk ranking	(Mitigating) Measure
Integration of shell construction with prefabricated wooden elements, such as ceilings	Opportunity	High	Prefab elements presented to client and approved by client. Documenting floor construction/finishing in Technical Description
Active participation of client in development plan and design	Opportunity	High	Search for optimizations/client flexibility
Inadequately demarcation of responsibilities, primarily due to unfamiliarity with the construction method, and leading to unforeseen measures, construction failures and increase in costs	Risk	High	Transference - Financial item, investigate and discuss further plan elaboration with client
Not receiving approval from competent authorities on the timber design due to unfamiliarity of government in legislation and regulations with wooden structures, leading to delay and unforeseen additional measures	Risk	Medium	Reduction - In consultation with inspection authorities at an early stage, also record how the data should be supplied (is reporting sufficient?)
Arise of issues concerning fire safety and noise requirements when timber construction nodes are not accounted for in the existing certification standards, necessitating further corrective actions	Risk	Low	Acceptance
Misalignment and miscommunication between assembly teams Haring CH/S-Pod due to language barrier leading to (legal) conflict	Risk	Medium	Acceptance - Allocation and contracting AIV BAM with Haring and verification of contracts by procurement department
Poor water management with water intrusion into timber elements in the construction phase leading to damages and delay	Risk	Low	Acceptance

Table 6.5: Identified risks and opportunities for Case 2

The first opportunity identified in Ambachtslaan was the integration of prefabricated wood elements in the construction shell, such as ceilings. This would lead to manufacturing and assembling one whole timber element in Switzerland by Haring that reduces overall costs for the timber elements in the apartments. The measure taken by the project team was to present the design with prefab elements to the client and thereafter getting approval for the design modification. The client had a demand to document the floor construction and assembling details in the Technical Description of the project and deliver that at the end of the project to the client.

The second opportunity that have been implemented is the active participation of clients in the development plan and design of the project. Initially the project has been carried out in the design-build context, whereafter soon in the design the client has been involved in certain design considerations and choices due to the newness of the technology. This opportunity at the same time leads to transferring the risk of inadequately demarcating of responsibilities as stated in table 6.5 towards the client as happened in Ambachtslaan. From the client's perspective of Ambachtslaan the following consideration has been overthought:

'In a design-build context, you assume additional responsibilities, including accountability for the design and construction process. This can be risky for us as the client due to financial entanglements which can result in unfavorable situations, therefore careful consideration is needed to decide whether to accept or reject these design and build responsibilities. In the early stage of the project we revised the design to ensure it met our functional requirements. However, when it comes to technical aspects, knowledge, and data, it's crucial to assess whether the design and construction process can be adequately managed. This also led to the agreement of financial allowances in conducting research and piloting Ambachtslaan for timber construction practices.'

INST2.13 Project management on alignment in work culture with international partners

Furthermore, two risks identified in the timber project regarding the unfamiliarity of timber in legislation and regulations have been pointed out. Firstly the risk was present that the timber design will not receive approval from the municipality leading to unforeseen additional measures that have to be taken. This risk was ranked as medium and therefore the mitigation measure of consulting with inspection authorities at an early stage and by recording how the data and burden of proof should be supplied, has been carried out. Secondly the risk of arising issues concerning fire safety and noise requirements for the apartment complex was present when the timber construction nodes are not accounted for in the existing certification standards, where corrective actions will be required.

One risk on project management that have been identified as medium but have shown to be an extreme high risk is the misalignment and miscommunication between assembly teams of the involved manufacturing parties Hering CH and S-Pod. The main challenge that occurred was related to language barriers during contract negotiations with our Swiss partner. This risk has been mitigated through mainly acceptance, through engaging a translation agency and receiving support from our legal department. However the geographical distance that made it more difficult to meet face-to-face with the partners in combination with COVID-19 pandemic was challenging in this timber project. Moreover, the director of BAM Wonen highlighted the difference in work culture that have lead to partial misalignment of the building procedures as highlighted in the following quote:

'Along the project we noticed there were cultural differences; while we are accustomed to a team-oriented approach where responsibility is distributed, Hering, by nature, is a more hierarchical company, where decisions ultimately rest with the director of the manufacturer. In terms of project management, one key lesson we've learned is the importance of taking on the role of the primary constructor ourselves. Initially, we relied on our partner Hering as the knowledge holder, with them essentially acting as the structural engineer. However, we have since realized that we need to be the principal constructor, developing the primary model and having the timber supplier fit their components within it, while maintaining clear responsibility for the final outcome. Hering will primarily focus on the engineering aspects related to their specific contributions, but the project often encounters issues, particularly when the supplier, Binderholz, delivers the skeletal structure without including internal partition walls.'

INST2.14 Securing cross-references and knowledge transfer from the first timber construction projects

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The last risk that was ranked as a low risk, but was one of the main reasons for delay in the project during the operational phase. The risk identified was poor water management that leads to water intrusion and eventually poses delays and damages in the construction itself. As stated earlier in the section on timber performance, water management during the construction phase is of crucial importance. In practice that means that the supply of wood elements have to be on-time for delivery and assembly within the required time to construct the elements wind and waterproof. This have not been the case during construction of the apartment complex and in combination with the heavy rainfall this have led to water intrusion in the timber floor elements and as reaction immediate actions for drying and solving the water problems were necessary. The impact of moisture during the operations have been highly undermined as stated by the project manager, and turned out to be significantly greater than the project team had anticipated, leading towards a delay of 8 months in construction time.
Through the risk assessment, management and lessons learned the project team Ambachtslaan and the end responsible director stated that securing cross-references and knowledge transfer from this first timber project towards upcoming timber apartment complexes is of vital importance to ensure project success on timber projects in the future. Moreover, the commercial manager emphasized that understanding the unique risks associated with timber construction and managing the risks through either mitigating measures that are implemented and acted accordingly is essential for successful project delivery. As concluding mark the director of BAM Wonen highlighted the essence of controlled upscaling with innovative construction techniques such as building with timber and prefabricated elements. This

has been pointed out in the following instance:

'Looking forward, it is vital to learn from these experiences. If faced with another timber construction request, we might have to reconsider the approach unless we can apply lessons learned. The collaboration was successful, and it is essential that the client recognizes our expertise and follows our advice on design and structure in timber construction, given its limitations compared to concrete. However, with proper planning from the outset, many possibilities exist, though making changes afterward becomes extremely difficult.'

5. Network formation and coordination - stakeholder management

INST2.15 Alignment of shared ambitions on sustainability and conveying project goals throughout the project's construction phases

The collaboration between client and contractor, but also internal stakeholder management of the project team on Ambachtslaan have been one of the main leading factors in project delivery and getting the lessons learned out in a constructive manner.
Firstly the collaboration of the client and contractor has been of utmost importance as both parties maintained their shared ambitions on the sustainbale aspects of the project and conveying these ambitions to the project team. This was vital particularly for technically-minded individuals who might revert to familiar methods when challenges arise. From a client's perspective the following on collaboration have been stated:

'In our partnerships, we prefer to work with collaborators with whom we can maintain a sustainable relationship, even though we are not strictly bound by performance agreements. The design-build approach has evolved into a collaborative team effort, where decisions are made jointly, and responsibilities are carefully weighed. Although there have been moments where responsibilities were contested, the project has also involved significant behind-the-scenes work, especially in detailing, acoustics, and building physics.'

The client mentioned that the design-build process carries a high-risk profile for builders, but if they can manage it, they will sign the contract. However, if the risks are too great, it may be necessary to seek an alternative arrangement with shared risks. This approach has allowed us to gain better control over the project and ensure that our sustainability ambitions are met.

INST2.16 Putting forward driven leaders that truly believe in the transition and the future perspective of timber & enthuse their environment

At the start of this project, when looking at the initiation and motives of starting such an innovative project was due to the driven leaders within the organization. In this case the director showed the courage to dive into a new timber project taking on the challenge which was in line with the organization's strategy and the believe he had in the transition where timber was part of the future perspective. The commercial manager stated the following in line with this statement:

'It was critical that, despite any initial setbacks, someone stayed dedicated to pursue that goal relentlessly, urging everyone to push just a little farther beyond their comfort zones. This was driven not only by the team, but also by management, notably the director, who was a major advocate of innovation. He has been active in programs such as 'De Zwijger,' which focus on a future-oriented view of the construction sector, demonstrating a dedication to genuine improvement that is still visible today. In

fact, when I think about it, we had a lot of leeway in deciding how to proceed. There was constant communication with management about our progress, but the basic goal was clear: we wanted to do something completely unusual, outside our regular scope. I was given significant freedom to construct this idea as long as we followed the specified standards. It was critical that we could still attain our goals and that the decisions we took were justified.'

INST2.17 Finding the sweet spot between the pace of upscaling timber projects and reinventing the timber wheel

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Currently, the transition of timber is acknowledged by the project team to be in the early adaptors phase and the parties are not yet in a full transition with timber construction. From dialogues the engagement with clients and stakeholders have found that their concerns often relate to capacity issues or problems that require rework. The project team pointed out that if we can demonstrate that moving toward a timber-based approach can eliminate these inefficiencies, we will gain more supporters. For future network formation and collaboration specifically on timber projects, the adoption rate does not have to be rushed as stated by the director as follows:

'Not everyone needs to adopt timber construction immediately. I prefer to proceed cautiously, undertaking a series of projects in succession to refine the approach before scaling up. I am not concerned that not everyone is enthusiastic now, as I believe it is only a matter of time before the benefits become widely recognized. At this stage, we are still gathering knowledge, but as we progress, the discussion around timber construction will become easier, and clients will likely approach us for solutions. We must continue to seek out clients willing to collaborate on this journey, ensuring they share our vision and are open to the suggestions we make.'

6.4. Concluding remarks Timber Case 2: Ambachtslaan

In the previous section, the instances from practice with regard to the project Ambachtslaan Veldhoven have been described. In the following part for each of the instances, the impact on project success as control of the project team over the measure will be derived. The quadrants are already explained in the first case study and therefore the defined instances of the first case are immediately given. These instances have been inserted through the descriptive analysis in the previous section. The result of this analysis is plotted in the matrix table 6.6 consisting of the defined four quadrants.

Herefrom it can be concluded that the focus of instruments and measures on the timber project De Ambachtslaan as seen in Quadrant 4: 'Focus', the right upper quadrant have been on the overarching categories: **leadership, managerial levers, and business processes**.

Classification of Impact			
	High impact	• INST2.2 - Allocation of responsibilities research and piloting on construction technique between contractor and client • INST2.5 - Design optimization and adoption upon conducting research with designing in timber • INST2.6 - The need to provide extensive documentation and evidence of compliance with local regulations on timber performance and quality • INST2.9 - Availability of funding by the client for research and piloting on innovative timber construction projects • INST2.12 - Involvement client in innovative timber designs preferably in a Bouwteam for demarcating liability	• INST2.4 - Shift towards timber inherently leads to incorporating both standardization and industrialization • INST2.7 - Perception, acceptance & true believe in timber buildings by stakeholders, internal colleagues as well as external clients & resident users (support base) • INST2.8 - Willingness and buffer to invest in innovative timber projects with regard to learning costs of pilot project • INST2.10 - Continuity of an organization, where the traditional way of building still must remain a part • INST2.13 - Project management on alignment in work culture with international partners • INST2.14 - Securing cross-references and knowledge transfer from the first timber construction projects • INST2.15 - Alignment of shared ambitions on sustainability and conveying project goals throughout the construction phase • INST2.17 - Finding the sweet spot between the pace of upscaling timber projects and reinventing the timber wheel
	Low impact	• INST2.11 - Outweighing higher construction costs by using financial compensation on timber projects	• INST2.1 - Ensuring compliance with Dutch Building Codes • INST2.3 - Converting design from concrete into wood while adhering to traditional design choices • INST2.16 - Putting forward driven leaders that truly believe in the transition and the future perspective of timber & enthuse their environment
		Low control	**High control**
	Control/Ease of Implementation		

Table 6.6: Overview instances of Case 2: Abmachtslaan Veldhoven from practice in four quadrants

6.5. Case 3: Development of neighborhood in timber

6.5.1. Project description and scope

The third case envisions a part of a sustainable, green urban neighborhood in The Netherlands. The neighborhood integrates the new and old city and also incorporates a balance of urban and natural environments. The urban plan for the project is guided by the municipality's frameworks and ambitions, aiming to connect the new and old parts of the city and ensure seamless integration with the surrounding area. The plan envisions a sustainable, green neighborhood tailored to future residents' desires, fostering a healthy living environment that encourages movement and social interaction. It addresses elevation differences to ensure accessibility and emphasizes flexibility to adapt to changes. Key points include enhancing connections with the existing city through a new bicycle bridge, promoting sustainability by integrating green spaces encouraging energy-efficient living, and creating a healthy environment with ample walking and cycling routes.

6.5.2. Case study documents

The third timber case is analyzed by using the following project and tender documents:

- The information of the tender provided by the client
- Bid and selection documents submitted by the municipality and awarded tender design
- The written assessment of the tender bid provided by the client

In addition, also interviews have been conducted with related project stakeholders that were responsible for the selection criteria and the tender content as well as the tender design and its elaboration

- The experiences and practical instances provided by the project manager, that was responsible for the further working out the tender design into executable construction designs towards production and assembly of the project.
- The experiences and practical instances provided by the client, in this case the real estate developer. The interview was conducted with a project developer of the involved real estate organization.

Stakeholder	Organization	Function	Phases involved
Contractor	BAM Wonen	Project Manager	Design – Execution
Client	AM	Project Developer	Design – Execution

Table 6.7: Conducted interviews for Case 3: Leeuwepoort Utrecht

As stated by the conducted interviews with the main stakeholders of this project, the two-sided view of the selection criteria, taken measures and design is viewed. This implies that for this case the perspective of the contractor as the clients have been taken into account.

6.5.3. Project selection criteria

The project was asked out by the municipality as a tender and involved a comprehensive selection procedure with five phases. The municipality has high ambitions in the field of circular construction as they want to achieve 50% circularity in the built environment by 2030. Here the development of a neighborhood by incorporating mainly timber as construction material aligns with this ambition and even more challenges participants to think in circular buildings and innovations.

In the tender, the participants were required to draft a plan for qualitative selection, including a sketch design with essential details such as text descriptions, program, parking balance, eye-level or 3D impressions, situational drawings, relevant sections, facade images, floor plans, and material specifications. Explicitly in this tender, the sustainability component must cover several aspects such

as descriptions of energy concepts, GPR building calculations, circular construction strategies, MPG calculations, bio-based material usage, healthy urban living, green and ecological aspects, and water retention calculations.

Figure 6.5: Impression case study development of neighborhood in timber

Tender award criteria and bid evaluation

The submitted plans in this tender were evaluated on three overarching criteria, respectively: urban planning and image, sustainability, financial land bid, and program criteria. Herein the following part the detailed selection criteria are explained for each of the three.

A. Urban planning & image (75 points)

The first criterion of this tender where the bids are evaluated on is urban planning & image. The main goal of this criterion is to ensure the suitability of the designs with the intended appearance of the city district and that it fits the environment where the location is situated. Herein the following aspects are documented:

1. Integration with the urban plan and public space connection. This criterion assessed how well the proposed plan integrates with the existing urban plan and connects with the related public spaces. In addition the examination of the bids is focused on seamlessly the design blends in the quality plan and how it enhances the connectivity within the community.
2. Compatibility with existing architectural style and plans. The evaluation of this aspect focused on how the new design complements the existing architectural styles and aligns with current development plans. The architectural style was already described in the tender documents, where the requirements was that the buildings should be fitting in the thirties architectural style where the facade should include bricks.
3. Architectural cohesion and differentiation. In this aspect, there was looked at architectural coherence within the development while also encouraging diversity. Therefore the goal was to achieve a balanced mix where buildings were both visually cohesive and distinct from one another. Inherently the aim was to add elements that characterize the neighborhood.

4. Aesthetic appeal and quality of materials. Within the category urban planning & image a sub-criterion was the visual attractiveness of the proposed design and the quality of materials that are used. The tender aimed for the use of high-quality materials and meticulous detailing which eventually would contribute to the overall aesthetic and longevity of the buildings.
5. Quality of the terrain design. The last sub-criterion in this category was evaluated on the design of the internal areas, that focuses on the functionality and quality of green spaces, communal areas, play areas, and parking facilities.

B. Sustainability (60 points)

INST3.1 Tender appeal & presence of timber as construction material in urban planning & development

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The second award criterion is sustainability which played a significant role in this timber project. Herein three sub-categories have been distinguished in the tender with all each of the three earning 20 points, leading to a total of 60 points for the category sustainability. This was respectively around 40% of the total amount of points that could be earned, resulting in a significant part of the evaluation. The following aspects were considered in this award category:

Circular building (20 points)

1. Innovation bio-based building, adaptability, and high-quality reuse. The first criterion focused on the use of innovative bio-based building materials and the adaptability of the structures for future use. Inherent to these aspects was the incorporation of high-quality reused materials, that must promote sustainability within the project and additionally focuses on resource efficiency based on the principles of Citydeal Circular and Conceptual Building.
2. Compliance with MIA/VAMIL circular housing regulations. The proposed bid design must meet the framework as described by the Dutch MIA/VAMIL regulations for circular housing. Herein certain requirements are part of the assessment including the use of circular materials which ensures that the designs are projected to both environmental and economic sustainability.
3. MPG shadow price. One of the core performance indicators was the use of MPG (Milieu prestate gebouwen) shadow price in this tender. The reason this was introduced is to steer the contractors in searching for designs that minimize the environmental impact The focus here is on minimizing the environmental impact, by considering financial constraints. The basis of assessment is that contractors can reach the lowest MPG shadow price the better the environmental performance of the building is.
4. Volume percentage of bio-based materials. This aspect assesses the extent to which bio-based materials are used in construction and aims for a higher amount of bio-based materials incorporated into the design in order to achieve great commitment to sustainable building practices from the participants. This aids for using timber as construction material along with other bio-based materials as for instance in insulation. Noticeable is that in this tender also the in the tender itself timber is appealed through the criteria and therefore steers and motivates the market in developing sustainable timber designs in both dwellings as apartment complexes.

Healthy urban living (20 points)

1. Healthy indoor climate. The proposed plan were evaluated on ensuring that the indoor environment promotes health and well-being for the future residents. The focus of the interior should therefore be on air quality, natural light, and overall comfort.

2. Climate adaptation in outdoor spaces. This aspect evaluates how the outdoor spaces must be designed in order to fit current expectations on climate adaptation, which means that the designs should be resilient for managing storm water, reducing heat islands, and enhancing resilience.
3. Healthy lifestyle and community interaction. In the category of sustainability also the residents itself are considered in the criteria. This criterion looks at features that encourage physical activity, social interaction, and a sense of community, such as walking paths, sports facilities, and communal areas.
4. Use of clean sustainable building materials. Aligned by the circular building criterion, this sub-criterion has been formulated to incorporate the use of non-toxic, environmentally friendly building materials.

Ecology and greenery (20 points)

1. Strengthening indigenous ecology. In the sub-category of ecology nature inclusive design bids are awarded with points that enhances local biodiversity and native plants that are of support in the direct neighborhood.
2. Ecological connectivity with the surrounding environment. This aspect evaluates how well the development connects with existing natural habitats, which aims in facilitating the movement of animals in wildlife and ecological processes.
3. Green roofs and native ecology facades. An interesting criterion on ecology is incorporating green roofs but also (partly) facades when feasible within the sustainable design.
4. Habitats for specific species. As the last aspect within the sub-category of healthy urban living is to create housing opportunities for region related species, such as house sparrows and hedgehogs need to be incorporated. The aim of this criterion is to enhance overall biodiversity and conservation of the animals already living in the neighborhood.

C. Financial ground offer (10 points)
Besides the sustainability award criterion, the tender bids were also evaluated based on the highest financial offer for the land above the minimum required amount. This criterion is in most cases part of the award criteria and aims for economic viability and financial commitment by the bidders, from the perspective of the municipality who has putted the tender in the market.

D. Program (10 points)
The last award criterion for this sustainable tender was on program. Specifically this category focuses on the differentiation and suitability of housing prices within the specified categories. Subsequently the bidders should incorporate a chapter where they discusses the alignment of which housing categories they want to facilitate in the neighborhood, which can vary from intended typology, quality and size of the housing. Inherently the bid should ensure a diverse and appropriate mix of housing options that meet community needs.

6.5.4. Evaluation Case 3: Development of neighborhood in timber

1. Construction techniques and technology

INST3.2 Commitment to advanced building methods and sustainability with new cutting-edge construction techniques

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The key principles of the development of the project Leeuwepoort with regard to construction techniques has been the emphasis on modular building and adaptability in the neighborhood. The municipality of Utrecht has formulated the tender as highly ambitious and sustainable project by creating a future-proof and adaptive part of Utrecht. As already described in the tender award criteria, the focus

on both sustainability and one layer deeper that is translated towards the use of bio-based materials shows the commitment to the municipality in stipulating their goals on reducing environmental impact. The tender bid as submitted by the contractor involved the use of cutting edge construction techniques such as the use of advance wooden post-and-beam structure with CLT floors in the apartments. This eventually eliminates the need for a concrete core, resulting in a more sustainable design. Furthermore in the grould-level houses, the design has been engineered with load-bearing timber frame walls with wooden beam floors, whereas the facades are coupled with prefabricated straw-based elements. Herein specifically the Strotec's EcoCocon prefab HSB system, where the timber elements are filled with compressed straw, proposes a fire-resistant (nearly non-combustible) bio-based solution in this timber project. This system, coupled with the extensive use of timber for structural elements, reduces material usage by approximately 10% through optimized modularity.

A benefit of using timber in the design shows that a certain flexibility can be reached through implementing column placements that are adaptable to various spatial needs. All the timber elements and components are insisted to be prefabricated in the fabric to ensure precision and efficiency of building with timber and eventually reduce construction time on-site which is favorable for minimizing the impact on the neighborhood.

The project also emphasizes demountability, another benefit of using timber where cons where construction elements can easily be dismantled and reused, due to the use of bolt and screw connections. The assembly methods and procedures that creates the opportunity for next use after the timber elements' lifetime or changes purpose are showed in figure 6.6. This approach does not only enhances the efficiency and flexibility of the building process but also aligns with the principles of a circular economy that has been requested in the tender.

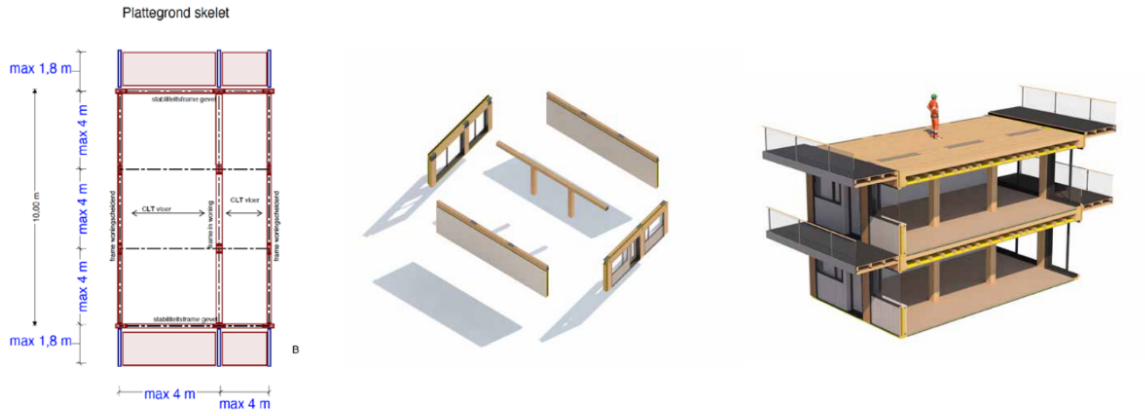

Figure 6.6: Structural modular timber elements and assembly

INST3.3 Misalignment between the tender bid and design phase for execution on timber projects

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After winning the tender and proceeding to the elaborated design phase, the project developer took the project over from the development manager. As the project developer was not involved in the tender, logically the developer and contractor dived into the tender documents and the related design requirements as stipulated by the municipality of Utrecht. After recalculating certain design parameters and related design costs the project developer came to the following insight:

'Indeed, there were some concerns raised from my side regarding the ambitious nature of the project. A lot of promises on innovative construction techniques and solutions has been made in the tender, and now the question enholds whether we can actually fulfill them and whether we are capable of sufficiently develop to meet those demands. While in the tender underlying calculations have been made,

they were often equally ambitious, making the project very difficult to keep it feasible.'

In the design of both the apartment complexes and dwellings in Leeuwepoort certain considerations have been incorporated at the very start. There was significant attention given to the structural integrity ensuring that the load-bearing structure was properly aligned with the subdivision and supporting structure in the floor plans. In line with this reasoning certain differences between designing with timber and concrete has been found. The project manager stated the following:

'There is indeed a difference between timber and concrete construction. With timber, you have to build more vertically aligned structures, due to factors like vibrations and load distribution. You must think more in terms of blocks, like Lego, stacking them directly on top of each other. With concrete, you can sometimes create cantilevers and other architectural features. It was crucial that we build the apartments directly on solid ground and not on some intermediate structure.'

INST3.4 Support of (academic) research in making design choices on new timber construction techniques

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In the timber project Leeuwepoort the project team had the capability to rapidly adopt the new construction methods in the quite conventional construction sector. This has been pointed out by both the project manager as project developer as only a few timber projects likewise are in the design phase and only one other timber project has been delivered which meant that Leeuwepoort as one of the biggest timber projects of constructing a neighborhood in timber was quite big and challenging on scale. Herein the project team sought actively for emerging innovative construction techniques and technical trends in timber by conducting practical research through graduation topics of students specifically relevant for Leeuwepoort. So one of the researches that have been conducted was which type of floor construction with different materials is favorable for apartment complexes and which for dwellings. Herein several construction layers such as only hardwood floors, but also hybrid floors with a wet layer of concrete in combination with timber has been considered. These investigations have resulted in a list of recommendations on the specific floor design Leeuwepoort while complying with regard to crucial technical requirements of timber on for instance sound insulation and fire safety.

2. Timber performance and quality

INST3.5 Misalignment of the design principles of the new timber concept in relation to the tender design and knock-out criteria

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The performance and quality of the design in the project of Leeuwepoort comes from the use of sustainable bio-based credentials with mainly timber for the supporting structure and the use of flax and straw for insulation and modified wood for the façades. By using these carbon sequestrated initiatives as requested in the tender the project stores 1.5 times more CO_2 than is emitted during the production of all building materials over their lifecycle as stated in the tender bid. In addition, the project also incorporates recycled materials, such as reclaimed bricks and reused glass, thereby minimizing the environmental footprint and turning construction waste into valuable resources.

As stated in the section about the tender award criteria and bid evaluation of Leeuwepoort most of the points could be earned on the theme sustainability, which involves circular building, healthy urban living and ecology & greenery. Specifically on circular building both the apartment complexes as dwellings were expected to meet the BENG2 to be zero, which means being energy neutral with 100% sustainable energy generation, such as through photovoltaic panels. During the design phase the ambition to use the timber building concept Flow of BAM Wonen has been incorporated, where the strengths of flexibility and adaptability of the timber concept connected seamlessly in the design of Leeuwepoort except from the performance in terms of energy efficiency. Herein the project developer

and client of the contractor highlighted:

'During the design phase of Leeuwepoort I expected that certain aspects of the timber concept would have been more thoroughly explored, to the point where project-specific adjustments could be given in a quick scan within a short period of time, but that was not the case. Upon discussing the feasibility of the timber concept and analyzing the suitability on the dwellings that were going to be build, we stumbled upon certain boundary conditions of the concept, which namely did not match the requirements of our tender. As the concept has been promoted to be very flexible in design we assumed that this also applied for the energy performance and herein there can be concluded that the optimization step and expansion of the timber concept still needs to be made.'

3. Economic viability

INST3.6 Limitation on design alterations when cost overruns in the design phase occur due to project's innovative nature and unfamiliar construction techniques

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During the tender the economic aspects have been considered and mentioned in the bid, but not in detailed depth. Nevertheless, the main issue that occurred in the design phase as described by the project developer was that the tender design ended up being 10-15% more expensive than initially projected. The only justification that could be provided from the project team was that they were dealing with pure innovation and unknown construction techniques resulting in higher quoted costs and any additional failure costs.
The project team made specific design alterations and differentiation of the initial tender bid in order to minimize the building costs as all design parts came into place. An instance was the alteration of the building design from the apartment complexes from four stories into three, while making it slightly deeper, which significantly optimized the construction costs. In addition, the project manager of Leeuwepoort elaborated on the specific design optimizations for the construction costs:

'We have considered focusing more on apartment buildings as this is where the cost versus revenue issue is most pronounced. One of the solutions proposed was to remove the underground parking garage and design a parking deck instead, to stay within the project's ambitions and feasibility. However, the discussions with the municipality have been challenging, especially when it comes to altering the installation concepts, although they do accept these changes provided the environmental indicators remain unchanged.'

Even though the project is large in scope and scale considering that both the development as construction responsibilities are laid at the collaborating parties and the combination of apartment complexes and dwellings, the project team initially assumed that they could easily shift design choices and optimizations in order to keep the project within the limits of feasibility. However this turned out to be disappointing as the project team encountered binding restrictions on both the design and freehold prices of the apartments and dwellings. On top the division of the number of houses and the purchase of land was out of proportion, which meant that the land could not be optimally used making Leeuwepoort a complex endeavor.

INST3.7 Termination of project due to unfeasible business case presented by the contractor

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As highlighted by the project developer, changing certain requirements in the tender resulting in a more favorable design has been carried out in consultation with the municipality. An instance therefrom is the following statement by the project developer:

'We won the tender based on timber and sustainability, so stepping away from bio-based materials is challenging. However, we are exploring the possibility of constructing some homes with sand-lime brick, especially the more expensive ones, as it offers more design flexibility.'

Both the contractor and direct client pointed out that it could also be possible that such development projects as Leeuwepoort might eventually become unfeasible. This is true for timber construction, just as it is for traditional building methods. Herein pushing the affordability vs. feasiblity towards the boundaries and deciding when to halt the project is also part of a strategic growth plan. This end-decision eventually lies at the management directors of BAM Wonen. Another viewpoint is that when the timber project Leeuwenpoort does not come to fruition, it would pose significant challenges for subsequent projects.

4. Risk assessment and management

INST3.8 Inadequate risk identification and diversification at the start for determining a quick-scan on feasibility of timber project

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With regard to the category risk assessment and management, this timber project has been a challenge from the start of the project. This si the case because risk management and addressing potential challenges in the project has only been investigated at the start of the tender. These risks were unfortunately more generally proposed then project specific.

After the tender, the involved project developer stated that unfortunately no further investigation or attention has been made on the risk assessment and management of mitigation measures therefrom. Therefore the list of risks is not included for specifically this timber project Leeuwepoort. As an explanation of this occurence is that the project team did not really think about the importance of identifying risks even more in an innovative project trajectory. This eventually was also not standardized as a requirement in the project management process. According to the project manager, the risk of unforeseen costs and failure costs have been undervalued as stated in the following instance:

'Risk diversification has not been fully applied to the Leeuwenpoort project. We have four buildings, and we are constructing all four with timber. I suggested that we could build two with timber and two with sand-lime brick to mitigate risk, but the choice was made to proceed entirely with timber. This poses financial challenges, particularly with the timber-frame apartments, which are not yet economically viable.'

5. Network formation and coordination - stakeholder management

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INST3.9 Effective use of ongoing discussions leading to partnerships between construction companies and (experienced) timber suppliers outside of The Netherlands

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Effective use of internal networks and knowledge transfer have occurred throughout the start of winning the tender towards the design phase. The internal networks and knowledge have been fostered through the timber construction team within the contractor's organization. Herein several collaborative discussions and advisory consultations have been planned with experts on for instance timber apartment complexes and the industrialization team for the quick scans on exploring the new timber building concept and its suitability for Leeuwepoort. It occurred that the project team of Leeuwepoort received advice and was tipped off to several international manufacturers of timber which the contractor already had ongoing discussions for possible collaborations. The project developer stated that building relationships and trusted partnerships is of vital importance for the first steps in building with wood as their experience and expertise form the knowledge base for us to attach on quickly and share the lessons learned for our upcoming timber projects. The instance that the project developer gave that showed their integrity and serious search for like-minded partners in the timber industry, was:

'With Leeuwepoort we knew that we had to pioneer by completing the first large-scale timber project including a neighborhood and as shared through lessons learned in practice it is important to bridge the barriers of partnering up with manufacturers as big as us and demonstrating our seriousness by visiting their factory in Austria.'

INST3.10 Identification and incorporating of knock-out criteria in tender during an innovation trajectory - e.g. fully understanding the client's needs and wishes

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In this case, the real estate developer and contractor act as one party, whereas the AM is the direct client of the BAM Wonen and the municipality of Utrecht is the client for both parties. The involvement and engagement of the client leads to the development of a collaborative network which is essential in coordinating the responsibilities of the builder but also the support and assistance the client can provide herein. As already stated in the section about economic viability, the success of Leeuwepoort is allocated to finding the optimum feasibility vs. affordability within the executed design. Herein certain alterations and adjustments on the design of the timber apartments and dwellings are necessary to be made in order to find that optimum. The trajectory of both innovating and designing is not linear and therefore asks for guidance and informing the involved parties timely so that no misunderstandings leading to failures will occur. The alterations from the project team are continuously presented and tested with the client to see if they are approved, which in practice leads to actually pushing the boundaries of what is possible.

6.6. Concluding remarks Timber Case 3: Leeuwepoort

In the previous section, the instances from practice with regard to the project Leeuwepoort Utrecht have been described. In the following matrix for each of the instances, the impact on project success as control of the project team over the measure is derived. The quadrants are already explained in the first case study and therefore the defined instances of the first case are immediately given. These instances have been inserted through the descriptive analysis in the previous section. The result of this analysis is plotted in the quadrant matrix as seen in table 6.8 consisting of the defined four quadrants.

Herefrom it can be concluded that the focus of instruments and measures on the timber project De Ambachtslaan as seen in Quadrant 4: 'Focus', the right upper quadrant have been on the overarching categories: **managerial levers and business processes**.

In the following, Chapter 7 will give the insights and instances derived from the remaining interviews that have not been included in the case studies. These were interviews mainly conducted with transition makers in the Dutch timber industry and consist of the same structure, where instances will be explained and thereafter as a result the quadrant matrix is crafted in order to find the most determining instruments and measures from practice.

Classification of Impact			
	High impact	• INST3.1 - Tender appeal & presence of timber as construction material in urban planning & development • INST3.2 - Commitment to advanced building methods and sustainability with cutting-edge construction techniques • INST3.3 - Misalignment between the tender bid and design phase for execution on timber projects • INST3.4 - Misalignment of the design principles of the new timber concept in relation to the tender design and knock-out criteria • INST3.6 - Limitations on design alterations when cost overruns in the design phase occur due to project's innovative nature and unfamiliar construction techniques • INST3.7 - Termination of project due to unfeasible business case presented by the contractor	• INST3.8 - Inadequate risk identification and diversification at the start for determining a quick-scan on feasibility of timber project • INST3.10 - Identification and incorporating of knock-out criteria in tender during an innovation trajectory – e.g. fully understanding the client's needs and wishes
	Low impact		• INST3.4 - Support of (academic) research in making design choices on new timber construction techniques • INST3.9 - Effective use of ongoing discussions leading to partnerships between construction companies and (experienced) timber suppliers outside of the Netherlands
		Low control	**High control**
	Control/Ease of Implementation		

Table 6.8: Overview instances of Case 3: Leeuwepoort Utrecht from practice in four quadrants

7

Findings interviews

7.1. Methodology interview set-up

The semi-structured interviews with practitioners that has affinity, knowledge, and experience with building in timber specifically in the Dutch construction industry serves as one of the primary sources of data in this thesis. As aiming to gather in-depth information, this kind of interview is appropriate for the thesis because it allows the interviewee to freely express their view in their own words, which facilitates much comprehensive information to occur (Yin, 2014).

The overview of interviewees is demonstrated in **??**. Furthermore, the informed consent form can be found in appendix B, and the semi-structured questions that have been formulated for the interviews are showcased in appendix C. In total seventeen interviewees has been interviewed, who has been divided into five different categories. The first three categories are divided by the case studies, where the following division is made:

- Case study 1. Herein the interviewees consists of two practitioners from the construction company BAM Wonen, and the other two were representatives of the client in this specific timber project.
- Case study 2. For the second case study, interviews were conducted with two practitioners of the construction company BAM Wonen, and the other interview was held with a representative on the clients' side.
- Case study 3. In the third case study both the practitioner of the construction company BAM Wonen as well as the client AM real estate developer has been interviewed.

The fourth category of interviews consists of practitioners, drivers of the transition, knowledge guarantors and sharers, and institutes that want to connect and direct the market towards the transition in timber. The practitioners are active in the initiatives Convenant MRA (Metropool Regio Amsterdam), Bouwcampus, Building Balance and BuiltByNature.

The fifth and last category of interviewers that has been grouped, are diverse practitioners within the construction company of BAM Wonen, who either has direct decision-making power or have high-influence in the inter-organizational transition towards timber. The practitioners diversify from lead industrialization, towards sponsor and responsible lead for production, realization and assembly.

In this research Interpretative Phenomenological Analysis (IPA) is employed to analyze the transcript data from the interviews. IPA concern with examining subjective experience of the respondent. As the respondent makes sense of the phenomena, the researcher tries to make sense of the participant's perspective based on their "lived experience" (Smith, Flowers & Larkin, 2009). The interpretative engagement, hence, involves the process of sense-making and reflective practice of both the respondent and the researcher. Hence, this approach is suitable for this study as the perspective of all respondents, based on their experience in or with the construction industry, is significant to reflect the implementation of timber building practices in this particular sector.

For data analysis, the interviews are firstly transcribed and ready to be coded. The coding process was followed with several readings through the interview's transcript to search for words that are repeated to identify the preliminary code. The transcript and coding were then read through again to conceptualize the emerging theme. The emerging theme was finally clustered into a group of themes after common features in terms of meaning were identified. Following Creswell (2018), each theme is supported by the exemplary of the original transcript to illustrate the participant's perspective. This illustration allows the reader to have a clearer understanding of the respondent's reaction and able to reflect on their perspectives on the implementation of timber building practices in the construction industry. To enhance the validity of the research, the coding and theme were checked and re-check against the interview to ensure that they adequately and appropriately represent the essence of the respondent's experience and perspective of the transition towards timber.

Herein observing their perspective and the diversity of viewpoints in the transition towards timber will give insights into the social-technical key factors, barriers, and instances from practice by implementing timber in construction projects and the transition from the early adaptors' face towards large-scale implementation in the future.

7.2. Findings interviews

To analyze the data from the 17 semi-structured interviews, a systematic approach was employed to structure the information into meaningful categories. This process involved three key stages: identifying the first-order concepts, e.g. the instances including those from the case study, thereafter combining these into second-order axial themes, and finally, grouping them into overarching aggregate categories.

7.2.1. Market influence

INST4.1 Adaptation of legislation and regulations on timber and acceleration of approval processes for timber projects

According to the director of Build By Nature, laws and regulations have direct impact on the transition towards timber and the speed the transition will be ongoing in the upcoming years. At the same time regulatory is one of the main challenges in this transition, due to the fact that when national regulations become stricter, compliance becomes obligatory. An example herein is the performance indicator of buildings such as Performance of Buildings (so-called MPG), which is currently not sufficiently discriminatory. Even more currently traditional concrete buildings meet the MPG better than similar timber constructions making it more difficult for market parties to maneuvering in the level of the playing field in regulatory frameworks. In line with this argument, the director stated the following:

'There is a pressing need for leadership at the ministerial level to drive regulatory changes and financial support for timber construction. If a minister, similar to Hugo de Jonge, were to strongly advocate for this shift, it would significantly accelerate progress. Local governments are also crucial since the national government does not develop zoning plans or manage land use. Municipalities are perhaps the most decisive players in this process. They must prioritize timber construction in their policies, tenders, and agreements.'

Additionally, the chain initiator of timber building practices from Building Balance, underpins the research the organization has been conducting on the approval process of timber projects with regard to verification and implementation of design principles and requirements. If the aim is to promote timber construction, yet the regulations do not support it, he stated that identification of which policies can be leveraged to stimulate this sector is necessary. With the various researches conducted by Building Balance in relation to laws and regulations have shed light on how timber is assessed during selection processes in a project. For example, if timber construction is not included in an environmental plan, and a related proposal is submitted, it will not be evaluated on that criterion. Therefore Building Balance has received grants to conduct research on measuring and modeling the process of projects built with mainly timber. Herein a validation from the municipality is received, which confirms that the model aligns with post-construction outcomes. The chain initiator of this initiative highlights the following:

'The standardization and getting approvals on timber designs in an efficient manner means that all the critical steps have been meticulously checked off. In terms of certification, some early adopters, particularly in timber construction, have obtained system approvals, which is noteworthy in advancing the approval process in timber construction projects, especially for market parties and eventually the transition as a whole.'

INST4.2 Creation of market alignment by designing timber concepts and products to meet specific technical requirements and constraints while integrating stakeholders needs and preferences

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The crucial factor of ensuring market alignment is one of the challenges that has been pointed out in the interview with a project lead from the Convenant Metropoolregio Amsterdam (MRA). The project lead stated that timber innovative products are often designed from a technical perspective where meeting specific technical requirements and constraints is top priority. However, the integration of stakeholder needs and preferences is the critical factor that ensures market alignment. This is an iterative and sometimes complex process, requiring continuous refinement and adjustment of the timber concept while stimulating the ongoing discussions between market parties. The alignment of the residential market takes form in initiatives such as regional agreements like Bouwstroom 1.0 and 2.0 in the south of the Netherlands. Herein municipalities, clients and contractors have signed an agreement for incorporating industrialized construction methods in housing projects. Subsequently, one type of industrialized construction method is the use of industrialized timber concepts and therefore poses an opportunity where suitability and acceleration of the transition towards timber building practices can form.

INST4.3 Collective advancement besides individual performance

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As stated in the second case study, the timber project Ambachtslaan in Veldhoven highlights the importance of learning from lessons learned and being open to improvement. According to the director of BuiltByNature this willingness to share experiences and improve not just individually but across the sector is crucial for our collective advancement. In the following instance stated by the chain initiator of Building Balance, this collective advancement is pointed out:

'Despite this, many builders are still developing their systems independently, without fully recognizing that they are part of a larger transition. Greater collaboration and a shared commitment to the broader goals are needed. This is evident in many areas, such as the introduction of digital techniques and parametric modeling, which are costly but necessary. Such innovations require both in-house expertise and external partnerships.'

The collective advancement of timber building projects has been stimulated by the Convenant Metropool Regio Amsterdam (MRA), where an initiative has been set up to reach 20% of timber building projects within the region of municipalities in and around Amsterdam. The current status of this goal has been challenging to be reached due to the various identified market barriers. As the deadline in the end of 2025 nears, the director of BuiltByNature states that the MRA hopes to achieve around 10%, as we currently are at approximately 4%. Additionally, the director states as one of the barriers the following with regard to the lower uptake from the Convenant MRA:

'However, it is crucial to understand that many projects are still in the exploratory or tender phases. The preparation of a housing project is far more complicated than often assumed. Too often, initial tenders in the exploratory phase withdraw due to insufficient belief in the business case. As a sector, we must address this. I hope that, for example, if the tender for the Nelson Mandela neighborhood progresses, by the latter half of next year, parties will commit to it, and construction might begin in 2026. However,

many projects require a push, as developers tend to revert to traditional methods when challenges arise.'

7.2.2. Operational challenges

INST4.4 Clear allocation of shift in responsibilities as product owner and communication channels in new process

The main challenge that has been addressed by the deputy director at BAM Wonen, responsible for the production, assembly and delivery is the integral way of working with clear communication channels and allocation of tasks. The new timber concept leads to new process of working and communication between the involved teams. This is the case as an extra layer has been added in the traditional engineering's process of residential construction projects. In the traditional way of building with concrete concepts the owner of the concept has been allocated at the production units within the project team. However with the new timber concept, the responsibility as product owner has shifted towards the industrialization team who as a team adds a new layer between the tender team and project team. In this new process certain questions arise like who is responsible for decision-making on project's feasibility and has the authority to set boundaries whether certain project adjustments are allowed. Henceforth maintaining the integral project approach and working uniformly within the lines of communication are of importance.

The deputy director noticed that at the very start of the first timber projects the process of allocating responsibilities and communication channels have been secured, however miscommunication and noise has formed as for instance a real estate developer from AM has noticed an architect's design and directly contacts the industrialization team, bypassing the intended communication channel. During the first projects and more often these nuisance occur, which causes miscommunication and distribution of misinterpretation of information that eventually creates unnecessary complications.

INST4.5 Cohesive approach from engineering towards production and assembly

Secondly maintaining a cohesive approach from engineering towards production and assembly has been highlighted as a challenge by the deputy director. Now with the new timber concept, the connection between transport logistics, assembly protocols resulting in controlling moisture management is even more vital when comparing it to the traditional project management process of concrete buildings. This is due to the fact that building with a new timber concept requires complete set of aspects such as engineering expertise, detailed serviceability, and higher product quality, which eventually results in a more complex assembly process. As an instance, the deputy director noted the following:

'Challenges in production and assembly, such as coordinating construction flows to allow seamless transitions from one project to another, are significant. Initially, I believed that Flow could handle much more flexibility, and while this is true to some extent, a more gradual approach would have been more effective. Starting with simpler projects and assembly methods before adding complexity would have fostered the change towards different way of working and inherently a changing mindset, which would have avoided the need to backtrack.'

7.2.3. Industrialization lessons learned

INST4.6 Maintaining organizational alignment as change managers within the industrialization team

One of the main responsibilities by the industrialization team is the development of the timber concept as a product and launching the best possible solution for residential use. At the same time the

team members of the industrialization team had been given the responsibility resembling the role of a change manager, which comes along ensuring that the teams decisions also engage the organization's broader context throughout the process. Taking upon this responsibility is essential for sustaining new working methods throughout different layers within the organization while keeping the higher goal in mind. In a traditional sector such as the construction industry the tendency for individuals to revert to traditional roles and methods will occur. Even though progress in the development of the concept has been made, sometimes people would fall back into old habits, necessitating conversations to realign with new agreements. This has been pointed out by the industrialization lead in the following instance:

'When I reflect on our success over the last year, I can easily say that having experienced team members who can emphasize our accomplishments is vital. The team spirit allowed us to keep moving forward despite setbacks. Herein it was critical that we all worked together to persuade the rest of the team to embrace these changes because relapsing to old habits with engineering choices and design was easily made but had major consequences. This was the case as one team member not following along the same line of thought could undo our hard work. The most important component, in my opinion, is ensuring that everyone at the table feels heard and is encouraged to talk candidly about the issues they experience. Herein as industrialization lead I have the responsibility to build a collaborative atmosphere. At the same time, I know that building an open culture within the organization and maintaining expectation management is crucial for continual improvement, where not just we as the industrialization team are the pivot in the process, but the entire organization'

INST4.7 Rendition of maturing in processes and timber product over time

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According to the deputy director of BAM Wonen, the rendition to maturing in the processes and the timber concept within the organization still have to take place. The rendition have to take form in the timber concept converting to a affordable product with the aesthetic appeal and project fit. Just as the internal references of construction companies the concrete casting processes have been utilized and evaluated multiple times. As the timber concept is developed, evaluations and documentations requires advancement and inherent adjustments from the evaluations. Herein the chain initiator of Building Balance notes:

'Making industrial construction a success requires simultaneous resolution of all components that contribute to success. A product that is affordable but lacks aesthetic appeal, or vice versa, will not succeed. Therefore, addressing all these factors concurrently is essential, though time-consuming, and not everyone fully grasps this.'

INST4.8 Timely involvement of the commercial organization and initiatives to upskill existing knowledge and workforce

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One lesson learned in managerial levers and business processes is the timely involvement of the commercial organization. The lead of industrialization within the construction company acknowledges that the team has overlooked that importance of involving the internal commercial organization, the unit who is responsible for acquiring tenders and projects by aligning the client's wishes with the timber concept, from the beginning and moreover regularly consulting those with technical expertise. The industrialization lead highlighted the following wherefore:

'During the development of the timber concept it is crucial to modularize efficiently, focusing on broad concept requirements to fine details over time. Indeed, the collaboration between the two streams, the engineering and the commercial teams I've mentioned earlier works well in most cases. However, there are instances where one stream is unaware of the activities in the other, leading to communication breakdowns. Unfortunately, this has necessitated going back to clients on several occasions to inform

them that we couldn't deliver as promised, which is particularly challenging when a commitment has already been made, generating tension with the client.'

On the other hand, the commercial organization faced challenges with the technical ins and outs of the timber concept which is mainly crucial when acquiring tenders or projects by selling products instead of custom projects. Therefore internally there have been pointed out that it is crucial that the colleagues within the commercial teams understand where the feasibility in the concept lies and understanding the concept in detail by making it your own. Only when the colleagues understand the reasons behind certain design choices a product such as a timber concept can be fitted towards the client demand. This has been mentioned by the director of BAM in the following quote:

'Selling a product differs significantly from selling a project. For instance, when an architect is at the table, it might be necessary to repeatedly explain the limitations of our offering. Some elements might not be feasible, which can be difficult for some commercial professionals to grasp, creating a tension that needs to be managed.'

7.2.4. Affordability

INST4.9 Assessing projects affordability to the appropriateness of the chosen timber system

Affordability and economic viability has mostly been mentioned in the interviews as highly limiting factor for deploying timber projects. From the viewpoint of the chain initiator of Building Balance, affordability is closely tied to the appropriateness of a timber system that has been chosen in the concept. In reality a timber concept and reference design has been established to reach standardization due to the manufacturing the processes and product through industrialization. Herein the concept has the leading role in setting the design boundaries and does not fit every type of project. Herein gaining clarity about what kind of projects are suitable for the concept and are more or less in line with the principles in visual quality plans, tender requests is crucial when assessing the project's affordability and feasibility. This has been as instance by the chain initiator in the timber transition:

'If the wrong system is selected for a particular case, it will likely not be cost-effective. I believe that achieving affordability requires thorough consideration of the system, including logistics and supply chains. However, to account for all these factors in the preliminary design phase (VO), substantial expertise in house is necessary but not always the most obvious factor where construction companies act upon. This includes for instance the involvement of a cost expert who can provide a comprehensive assessment of the system, taking into account both its advantages and disadvantages, and determining its overall economic viability. Unfortunately, finding a cost estimator capable of such a nuanced evaluation on timber projects or a new concept is rather challenging.'

INST4.10 Identification of potential cost-saving opportunities from the outset

As stated by the director cost efficiency leading to affordability from the contractor can be achieved if the production capacity in the factory is utilized to its full capacity. If a factory operates at only 60% capacity, the remaining 40% represents a loss, so achieving at least 80% utilization is critical. Currently, construction companies stumble upon this challenge of reaching the number of ground-level houses set as target and maintaining it. Eventually the cost savings are directly related to the evenly distribution of projects throughout the year in order to avoid overwhelming in the production capacity. The ultimate aim is to ensure a steady production flow. Herein estimating and converting the cost-saving opportunities to tangible financial benefits will support monetizing the financial indicators of the timber concept. This instance has been given by the deputy director:

'It is crucial to identify potential cost-saving opportunities from the outset in the first timber projects that

we are currently running. For instance, a benefit of building with timber is the reduced construction time on site. But how can one accurately estimate the potential speed of construction and the associated financial gains? While it is often claimed that timber construction is faster, it is therefore essential to quantify this acceleration and the corresponding cost savings. For example, when we know that completing a project two months earlier can result in significant financial benefits this will quantify the unique buying reason we have for our concept.'

INST4.11 Incorporation of a new perspective on the respective timber business case

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Furthermore, a new perspective on the initial timber business case can lead to insights that supports the business case in the longer run, by not only looking at profit on the short time. The market, including institutional investors are aware of the fact that timber construction is more expensive and recognizes their willingness to invest accordingly. The affordability factor is more challenging for social housing providers, where rental prices are regulated. Henceforth taking the responsibility to broaden the outlook of the business case has been highlighted by the chain initiator to be an opportunity:

'In this context, a report that we commissioned, with contributions from Built By Nature, focuses primarily on construction and establishment costs. However, as we found from a comprehensive business case, a lot more factors should be incorporated by market actors. These factors are for instance lifecycle analysis, residual value, and maintenance costs of the building. I believe that a true business case is thus much broader, but this report specifically examines cost structures, identifying potential areas for influence and control. This represents one of the key opportunities but hurdles of the market which we found through research.'

7.3. Concluding remarks Findings Interviews

In the previous section, the instances from practice with regard to the remaining interviews are explained. In the following part for each of the instances, the impact on project success as control of the project team over the measure will be derived. The quadrants are already explained in the first case study and therefore the defined instances of the first case are immediately given. These instances have been inserted through the descriptive analysis in the previous section. The result of this analysis is plotted in the matrix table 7.1 consisting of the defined four quadrants.

Herefrom it can be concluded that the focus of instruments and measures on the timber project De Ambachtslaan as seen in Quadrant 4: 'Focus', the right upper quadrant have been on the overarching categories: **managerial levers and business processes**.

In the following, Chapter 8 the Discussion of this study will be given. Herein mainly the findings from the previous chapters including the case studies, interviews, and literature review will be combined. This will eventually lead to finding the resulting socio-technical categories derived from practical instances. In addition, the findings in this study will be validated through comparison with the scientific literature review conducted in Chapters 3 and 4.

Classification of Impact			
	High impact	• INST4.1 - Adaptation of legislation and regulations on timber and acceleration of approval processes for timber projects	• INST4.2 - Creation of market alignment by designing timber concepts and products to meet specific technical requirements and constraints while integrating stakeholders needs and preferences • INST4.3 - Collective advancement besides individual performance • INST4.7 - Rendition of maturing in processes and timber product over time • INST4.9 - Assessing projects affordability to the appropriateness of the chosen timber system • INST4.10 - Identification of potential cost-saving opportunities from the outset • INST4.11 - Incorporation of a new perspective on the respective timber business case
	Low impact		• INST4.4 - Clear allocation of shift in responsibilities as product owner and communication channels in new process • INST4.5 - Cohesive approach from engineering towards production and assembly • INST4.6 - Maintaining organizational alignment as change managers within the industrialization • INST4.8 - Timely involvement of the commercial organization and initiatives to upskill existing knowledge and workforce
		Low control	**High control**
	Control/Ease of Implementation		

Table 7.1: Overview instances of remaining interviews from practice in four quadrants

PART V
DISCUSSION, CONCLUSION AND RECOMMENDATIONS

8

Discussion

In chapters 6 and 7 the results of the embedded case study and findings of the interviews have been given. In this chapter, respectively the discussion part, the data will be analyzed through characterization and categorization. Herefrom a comparative analysis with the earlier conducted literature in this thesis will be carried out.

8.1. The instances: categorized and characterized

Firstly the collected instances in the case studies and interviews are categorized through data structuring, whereas the aim is to define what (type of) measures are influencing the success of timber projects.

8.1.1. Categorization of instances

Upon collecting and analyzing the instances from practice in the three cases and the remaining interviews that are not covered in the case study, the researcher found three distinctive categorizations in which the instances can be categorized. The first categorization involves the phenomenon of leadership. The second category is distinguished to be managerial levers. The third and last category found is the business processes. A further explanation of these three categories is given in the following part.

Leadership

First of all instances around the theme of leadership have been found. The instances related to this theme are the following two instances:

INST2.16 Putting forward driven leaders that truly believe in the transition and the future perspective of timber & enthuse their environment

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INST4.6 Maintaining organizational alignment as change managers within the industrialization phase

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The theme around leadership for the transition towards timber building practices concerns first of all the management team, which consists of directors and their influence as decision-makers on the strategic level of deploying timber building practices as a construction company. But the actors in this category also include change managers within the organization who act like so-called 'inter-organizational entrepreneurs' who have the ability and motivation to innovate with timber building practices.
The phenomenon of leadership in this theme focuses on the leaders that stipulate an organization's

strategy which directly reflects the business processes and projects that are according to the set ambitions, goals, and missions. Herein the incremental steering of direction and motivations stems from, where guidance and making an impact are inherently related. In line with this, the director responsible for the residential business unit quoted the following:

'It was critical that, despite any initial setbacks, someone stayed dedicated to pursuing that goal relentlessly, urging everyone to push just a little farther beyond their comfort zones. This was driven not only by the team but also by management, notably the highest director, who was a major advocate of innovation.'

Managerial levers

Secondly, the category of managerial levers has been identified by the researcher. Managerial levers are used for the organization to strive and to make an impact through actions. It therefore provides a way to influence and guide the performance and behavior of teams within an organization. In addition, such levers support alignment in systems, resources, activities, and people to achieve the organization's objectives.
Through the instances, five distinct sub-categories within the category of managerial levers are found. These categories and related examples of the instances found in practice will be explained below.

1. **Missions, goals, and strategy**. The first managerial lever is the sub-category missions, goals, and strategy. This sub-category focuses on the specific strategy the construction company in this case has stipulated and formulates the directly linked goals and missions of the organization's ambitions towards their clients through alignment. In line with this, the project manager quoted the following:

   'In our partnerships, we prefer to work with collaborators with whom we can maintain a sustainable relationship, even though we are not strictly bound by performance agreements. The design-build approach has evolved into a collaborative team effort, where decisions are made jointly, and responsibilities are carefully weighed.'

   The instances from practice that are categorized in this sub-category are the following two instances:

   Shift construction techniques from project-based approach to conceptual (timber) design approach

   Alignment of shared ambitions on sustainability and conveying project goals throughout the construction phase

2. **Structure and systems**. The second sub-category within the socio-technical theme 'managerial lever' is structure and systems. Herein the focus is on the organizational structure which focuses on the processes in the different teams, hierarchy, and roles but also the type of communication channels and reporting lines. The structure envisions how the tasks are divided, coordinated, and supervised across the organization, whereas certain autonomy in the project teams is therefrom an instance. The systems part involves an organization's procedures and processes that include supporting systems such as digital tools and platforms that secure the knowledge and experience related to construction projects. These systems support the organization's operations and decision-making. In line with this, the adjunct director quoted the following:

'The new timber concept leads to a new process of working and communication between the involved teams. This is the case as an extra layer has been added in the traditional engineering process of residential construction projects. In this new approach, it is crucial to maintain a clear structure, safeguard procedures, and ensure their consistent adherence, to preserve an integral project approach and maintain uniform lines of communication.'

Two of the following instances have been categorized in this managerial sub-category:

The need to provide extensive documentation and evidence of compliance with local regulations on timber performance and quality

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Adaptation of legislation and regulations on timber and acceleration of approval processes for timber projects

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3. **Resource allocation**. The third managerial lever identified is resource allocation. This lever refers to how an organization distributes its resources, which are for instance time, money, or personnel. The resources could either be applied to construction projects, and business units, but also to development initiatives. In this sub-category effective resource allocation is crucial, as the most critical areas of the business processes can receive the necessary support therefrom in order to achieve organizational goals. Supporting this, the commercial manager quoted as follows:

"In our investment strategy, we have adopted a new method of real estate calculation, incorporating residual value, which was a key factor in our investment decision. For instance, the housing project still retains a certain residual value after 50 years. This is a responsibility we bear, with validation and review at every stage.'

Two examples of instances that are categorized in the sub-category resource allocation are the following:

Willingness and buffer to invest in innovative timber projects with regard to learnings costs of pilot project

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Outweighing higher construction costs by using financial compensation on timber projects

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4. **Organizational learning and knowledge development**. The fourth sub-category found in the instances is organizational learning and knowledge development. Herein the focus is dedicated to how the organization acquires, stores, and retains new knowledge and the extent to which the knowledge is adapted in business processes and systems. In addition, the extent to which knowledge is distributed and shared within the organization through communication channels or systems shows how valuable information is accessible to the colleagues who need it. This is derived in the following quote from the following quote as stated by the industrialization lead:

'We underwent an innovative trajectory in the past few years, where the importance of organizational learning and the application of specialized expertise has shown its importance. The advancements in design optimization and timber construction technologies required integrating

knowledge of construction principles, building physics, and prefabricated elements, all while ensuring compliance with the building code.'

Two instances found in this category are given below.

Adoption rate of new timber construction methods in a conventional construction sector

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Shift towards timber inherently leads to incorporation of both standardization and industrialization

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5. **Organizational culture**. The fifth and last sub-category in the overcoupling category of managerial levers is organizational culture. Organizational culture contains a set of shared values, beliefs, and norms that influence how employees behave and interact. Herein culture shapes the work environment and directly influences the employee's motivation, collaboration, and overall performance. In line with organizational culture, the project manager of a timber project quoted the following:

   'We plan to conduct surveys before the residents move in to understand their expectations, and then again after a year to gather feedback on their experiences. This is particularly important because we have noticed that some potential residents were hesitant about living in a wooden building'

   Herefrom two instances in this sub-category are as follows:

Perception, acceptance & true believe in timber buildings by stakeholders, internal colleagues as well as external clients and resident users (support base)

Support of (academic) research in making design choices on new timber construction techniques

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Business Processes

The remaining overcoupling category that has been identified by the research is business processes. The difference between managerial levers and business processes is that business processes are the activities or steps that have to be taken in order to carry out the formulated strategy and achieve organizational goals. Specifically, business processes formulate operational workflows, and tasks and therefore answer the 'how' question in the day-to-day execution of tasks within an organization. As a clarification, managerial levers outline the environment and sketch the organizational environment, while business processes are the activities that take place in this organizational environment.
In the category business processes, five distinct sub-categories have been identified. In the following section, a description of each sub-category will be given, provided with a couple of instances categorized in this sub-category.

1. **Initiation & decision-making.** The first sub-category observed in the overarching category of business processes is initiation & decision-making. Herein it is found that the extent to which new initiatives and ideas are initiated and decisions are made accordingly whether to proceed with a project or initiative is taking place in transitions. This involves the early stages where problems are defined, and upon these observations strategic decisions on what is the best course are made.

Here from the commercial manager quoted the following:

'From this timber project, we secured a win, and that truly acted as a catalyst for future opportunities. As a result, I noticed that our involvement in inquiries increased significantly. Suddenly, instead of being placed on a long-list of potential sustainable projects, we were directly shortlisted for potential timber projects'

In the sub-category initiation & decision-making the following two are identified:

Early shift construction techniques incorporating sustainable building practices with timber

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Spin-off strategic decision undertaking timber project serving as a catalyst for future opportunities and building legitimacy

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2. **Portfolio management**. The second sub-category found is portfolio management, which focuses on the composition of initiatives, tenders, and projects within an organization. The type of projects that are selected at the stage gate ensures alignment with the organizational strategy that have been stipulated and therefore certain projects need to be prioritized and chosen in order to balance internal resources and to assess risks to maximize overall value. This involves the early stages where problems are defined, and upon these observations strategic decisions on what is the best course are made. In line with this, the project manager quoted the following:

'We also faced global risks, such as rising timber prices due to the onset of war in Ukraine. We had to absorb these risks, and I had to justify new investment figures to the board and supervisory council twice. This is a responsibility we bear, with validation and review of the projects in the portfolio whether the return on investment is still feasible at every stage.'

In this sub-category, the following instance from practice is found:

Continuity of an organization, where the traditional way of building still must remain a part

---

3. **Development & implementation**. The third category within business processes is the tasks of development & implementation. This involves the process of designing, creating, and as outputs new products, services, or systems have to be put into action. Herein the choices made on design adjustments or optimizations and whether these will be implemented or not are considered. This is derived from the following quote as stated by the industrialization lead:

"We started the design by integrating the column-and-beam system directly into our floor plans, indicating where columns and beams would be located. Initially, this seemed feasible, but as we progressed, we encountered increasing difficulties, particularly in terms of acoustics and the routing of utilities. We continuously sought to resolve these issues until it became evident that our initial approach was flawed, prompting us to restart the design process resulting in an interactive feedback loop and development process.'

The two instances related to development & implementation are given below.

Converting design from concrete into wood while adhering to traditional design choices

Finding the sweet spot between the pace of upscaling timber projects and reinventing the timber wheel

4. **Project management**. As the fourth category project management has been identified. Inherently when projects are acquired and proceed project management is of importance in order to achieve a feasible design within the set budget. This involves the processes of managing the scope, planning, cost, quality, and risks that align with the project's objectives. As stated by the project manager the following quote underpins this identified category:

   'Overall, we encountered few obstacles, except for the costs, which remained challenging in this business case. When we started with this tender, the costs for the timber concept were not yet clear. As a metaphor, we essentially had a toolkit with a wrench and a small hammer, and we had to provide a price. This was the main discomfort and challenge for this timber project, as no one really had a firm grasp on the financial aspects of the project. This was the primary issue.'

   In this sub-category the following two instances are found:

   Feasibility vs. Affordability - viable business case

   Conducting a detailed risk analysis and assessment with corresponding mitigating measures prior to starting the innovative timber design

5. **Commercialization**. The fifth and last sub-category within business processes is commercialization. Commercialization is of importance when bringing a new product or service to the market, which is the case with a new timber concept. The related processes are therefore identifying the unique selling points and unique buying reasons for a product, developing marketing strategies, and managing the introduction of the product in the market. Herein the ultimate goal is to ensure successful adoption and profitability for an organization. This is derived from the following quote as stated by the commercial manager:

   'We recognize that ensuring market alignment is a crucial challenge in the development of timber innovation. While meeting technical requirements is essential, integrating stakeholder needs and preferences is key to achieving true market alignment. This requires ongoing refinement of the timber concept and continuous engagement with market parties to foster collaboration and drive the transition towards timber building practices.'

   Three related instances of commercialization are given below.

   Network formation with knowledgeable external partners and building strong relationships

Misalignment between the tender bid and design phase for execution on timber projects

Creation of market alignment by designing timber concept and products to meet specific technical requirements and constraints while integrating client's needs and preferences

8.1.2. Most determining types of instances

The total set of 50 instances found in the case studies and interviews are elaborated in table 8.1 for the first case study on DeKwekerij Doetinchem, in table 8.2 the categorization of the second case study Ambachtslaan Veldhoven, in section 8.1.2 the results for case study 3 Leeuwepoort Utrecht and lastly in table 8.4 the categorization of the external interviews. Herein a total overview of all instances that influenced the transition towards timber and the categorization and characterization of these instances, as defined in the previous sections, is given. The tables show the distinctive character of each instance, where instances are not mutually exclusive, which means that they can be characterized by multiple distinguishing categories. As for instance a measure can be categorized in the category of leadership and also fit in the category of a managerial lever by the characteristic of organizational learning & knowledge. As stated in section 8.1.1 the table shows for each instance the indicated categorization and characterization in the categories leadership, managerial levers, and business processes. With this overview, there can be defined what (type) of instances are determining in the transition towards timber building practices.

From the overview in table 8.1, table 8.2, section 8.1.2 and table 8.4 in the bottom row the total amount of instances found in the specific categories are summed. The amount of instances per category is given below.

From these numbers, the proposition can be given that a whole variety of characteristics occurs within the set of instances that influence the transition towards timber. table 8.5 makes clear that the most important categories are project management, development & implementation, and organizational learning & knowledge with respectively the highest amount of instances found in that category.

As shown in table 8.5, it is depicted also that measures that do not prevail in the transition towards timber are leadership (only 2 instances found in that category), organizational culture (a total of 5 instances), initiation & decision-making (a total of 5 instances) and portfolio management (only 1 instance present).

8.2. Synthesis

So far this chapter has covered the characterization of the set of instances and the related categories one layer deeper. In this section, the goal is to combine the previous results of the matrices in the case study and the tables with the categories in order to draw conclusions in line with the results.

8.2.1. Merging all parameters

The parameters in this thesis that will be further analyzed are derived from the quadrant matrix overviews from the case studies and the tables which are summarized in Section 8.1.1.

The quadrant matrices consist of the categories Classification of impact on the y-axis and & Control/Ease of implementation in the x-axis as shown in table 6.3, table 6.6, table 6.8 and table 7.1. In this overview the data, which was the investigated instances of all three cases considered) have been lumped together and shifted primarily based on the quadrant approach. Therefrom the two parameters have been analyzed, which are Impact and Control. This quadrant approach can be viewed as four different possible combinations of the parameters, which are quadrants 1 to 4, with the combinations: low impact - low control, low-impact - high control, high impact - low control & high impact - high control. Furthermore, additional parameters have been found upon analyzing the instances, these are considered upon characterizing and categorizing the instances. The parameters can be found in table 8.1, table 8.2, section 8.1.2, and table 8.4. In summary, the three overarching categories are: leadership,

Instance			Characterization & categorization											
			Leader-ship	Managerial Levers					Business Processes					
Case/ interview	Nr.	Description		Mission, goals & strategy	Structure & systems	Resource allocation	Organizational learning & knowledge	Organizational culture	Initiation & decision-making	Portfolio management	Development & implementation	Project management	Commercialization
DeKwekerij	INST1.1	Shift construction techniques from project-based approach to conceptual (timber) design approach		X							X		
DeKwekerij	INST1.2	Early shift construction techniques incorporating sustainable building practices with timber		X					X		X		
DeKwekerij	INST1.3	Adoption rate of new timber construction methods in a conventional construction sector					X						
DeKwekerij	INST1.4	Lack of robust frameworks for timber project assessment			X								
DeKwekerij	INST1.5	Feasibility vs. Affordability – viable business case										X	
DeKwekerij	INST1.6	Assumptions and uncertainties in financial matrix converted from concrete in wood										X	
DeKwekerij	INST1.7	Increase failure costs due to undertaking an overly complex timber construction project for an initial pilot										X	
DeKwekerij	INST1.8	Spin-off strategic decision undertaking timber project serving as a catalyst for future opportunities and building legitimacy							X				X
DeKwekerij	INST1.9	Conducting a detailed risk analysis and assessment with corresponding mitigating measures prior to starting the innovative timber design										X	
DeKwekerij	INST1.10	Mitigating novel high-impact risks through acceptance										X	
DeKwekerij	INST1.11	Coordinating new processes of internal network formation and task transfers			X		X						
DeKwekerij	INST1.12	Network formation with knowledgeable external partners and building strong relationships				X							X

Table 8.1: Characterization and categorization of case study 1: DeKwekerij Doetinchem

Case/ interview	Nr.	Description	Leader-ship	Managerial Levers					Business Processies				
				Mission, goals & strategy	Structure & systems	Resource allocation	Organizational learning & knowledge	Organizational culture	Initiation & decision-making	Portfolio management	Development & implementation	Project management	Commercialization
Ambachts-laan	INST2.1	Ensuring compliance with Dutch Building Codes									X	X	
Ambachts-laan	INST2.2	Allocation of responsibilities research and piloting on construction technique between contractor and client				X						X	
Ambachts-laan	INST2.3	Converting design from concrete into wood while adhering to traditional design choices									X	X	
Ambachts-laan	INST2.4	Shift towards timber inherently leads to incorporating both standardization and industrialization		X	X		X				X		
Ambachts-laan	INST2.5	Design optimization and adoption upon conducting research with designing in timber									X		
Ambachts-laan	INST2.6	The need to provide extensive documentation and evidence of compliance with local regulations on timber performance and quality			X							X	

Case/ interview	Nr.	Description	Leader-ship	Managerial Levers					Business Processies				
				Mission, goals & strategy	Structure & systems	Resource allocation	Organizational learning & knowledge	Organizational culture	Initiation & decision-making	Portfolio management	Development & implementation	Project management	Commercialization
Ambachts-laan	INST2.7	Perception, acceptance & true believe in timber buildings by stakeholders, internal colleagues as well as external clients & resident users (support base)		X				X					
Ambachts-laan	INST2.8	Willingness and buffer to invest in innovative timber projects with regard to learning costs of pilot project				X			X				
Ambachts-laan	INST2.9	Availability of funding by the client for research and piloting in innovative timber construction projects				X						X	
Ambachts-laan	INST2.10	Continuity of an organization, where the traditional way of building still must remain a part		X						X			
Ambachts-laan	INST2.11	Outweighing higher construction costs by using financial compensation on timber projects				X						X	

Case/ interview	Nr.	Description	Leader-ship	Managerial Levers					Business Processies				
				Mission, goals & strategy	Structure & systems	Resource allocation	Organizational learning & knowledge	Organizational culture	Initiation & decision-making	Portfolio management	Development & implementation	Project management	Commercialization
Ambachts-laan	INST2.12	Involvement client in innovative timber designs preferably in a Bouwteam for demarcating liability										X	
Ambachts-laan	INST2.13	Project management on alignment in work culture with international partners										X	
Ambachts-laan	INST2.14	Securing cross-references and knowledge transfer from the first timber construction projects					X						
Ambachts-laan	INST2.15	Alignment of shared ambitions on sustainability and conveying project goals throughout the construction phase		X								X	
Ambachts-laan	INST2.16	Putting forward driven leaders that truly believe in the transition and the future perspective of timber & enthuse their environment	X										
Ambachts-laan	INST2.17	Finding the sweet spot between the pace of upscaling timber projects and reinventing the timber wheel	X				X				X		

Table 8.2: Characterization and categorization of case study 2: Ambachtslaan Veldhoven

Case/ interview	Nr.	Description	Leader-ship	Managerial Levers					Business Processies				
				Mission, goals & strategy	Structure & systems	Resource allocation	Organizational learning & knowledge	Organizational culture	Initiation & decision-making	Portfolio management	Development & implementation	Project management	Commercialization
Leeuwe-poort	INST3.1	Tender appeal & presence of timber as construction material in urban planning & development											X
Leeuwe-poort	INST3.2	Commitment to advance building methods and sustainability with cutting-edge construction techniques		X					X		X		
Leeuwe-poort	INST3.3	Misalignment between the tender bid and design phase for execution on timber projects										X	X
Leeuwe-poort	INST3.4	Support of (academic) research in making design choices on new timber construction techniques					X	X					
Leeuwe-poort	INST3.5	Misalignment of the design principles of the new timber concept in relation to the tender design and knock-out criteria									X		

Case/ interview	Nr.	Description	Leader-ship	Managerial Levers					Business Processies				
				Mission, goals & strategy	Structure & systems	Resource allocation	Organizational learning & knowledge	Organizational culture	Initiation & decision-making	Portfolio management	Development & implementation	Project management	Commercialization
Leeuwe-poort	INST3.6	Limitations on design alterations when cost overruns in the design phase occur due to project's innovative nature and unfamiliar construction techniques										X	
Leeuwe-poort	INST3.7	Termination of project due to unfeasible business case presented by the contractor							X				
Leeuwe-poort	INST3.8	Inadequate risk identification and diversification at the start for determining a quick-scan on feasibility of timber project										X	
Leeuwe-poort	INST3.9	Effective use of ongoing discussions leading to partnerships between construction companies and (experienced) timber suppliers outside of the Netherlands						X					X

Table 8.3: Characterization and categorization of case study 3: Leeuwepoort Utrecht

Case/ interview	Nr.	Description	Leader-ship	Managerial Levers					Business Processies				
				Mission, goals & strategy	Structure & systems	Resource allocation	Organizational learning & knowledge	Organizational culture	Initiation & decision-making	Portfolio management	Development & implementation	Project management	Commercialization
Leeuwe-poort	INST3.10	Identification and incorporating of knock-out criteria in tender during an innovation trajectory - e.g. fully understanding the client's needs and wishes										X	X
External interviews	INST4.1	Adaptation of legislation and regulations on timber and acceleration of approval processes for timber projects			X								
External interviews	INST4.2	Creation of market alignment by designing timber concept and products to meet specific technical requirements and constraints while integrating stakeholders needs and preferences									X		X
External interviews	INST4.3	Collective advancement besides individual performance		X				X					

Case/ interview	Nr.	Description	Leader-ship	Managerial Levers					Business Processies				
				Mission, goals & strategy	Structure & systems	Resource allocation	Organizational learning & knowledge	Organizational culture	Initiation & decision-making	Portfolio management	Development & implementation	Project management	Commercialization
External interviews	INST4.4	Clear allocation of shifts in responsibilities as product owner and communication channels in new process			X		X						
External interviews	INST4.5	Cohesive approach from engineering towards production and assembly					X					X	
External interviews	INST4.6	Maintaining organizational alignment as change managers within the industrialization			X			X					
External interviews	INST4.7	Rendition of maturing in processes and timber product over time					X				X		
External interviews	INST4.8	Timely involvement of the commercial organization and initiatives to upskill existing knowledge and workforce					X						X
External interviews	INST4.9	Assessing project affordability to the appropriateness of the chosen timber system									X		
External interviews	INST4.10	Identification of potential cost-saving opportunities from the outset									X	X	
External interviews	INST4.11	Incorporation of a new perspective on the respective timer business case		X		X	X						X

Table 8.4: Characterization and categorization of external interviews

managerial levers, and business processes. Whereas the five sub-categories of managerial levers are identified to be:

1. Mission, goals & strategy
2. Structure & systems
3. Resource allocation
4. Organizational learning & knowledge
5. Organizational culture

For the overarching category business processes, the additional set of five sub-categories are:

1. Initiation & decision-making
2. Portfolio management
3. Development & implementation
4. Project management
5. Commercialization

Upon combining all the instances in one set of data where the instances are categorized on all the parameters found in this research, resulted in a final overview that can be found in table 8.5.

From the thusly composed table, several conclusions can be drawn, which will be discussed in the following part.

Firstly it can be noticed that the fewest instances are found in the first quadrant (low impact - low control), which reflects the instances that have to be monitored. This can be reasoned due to the fact that in the case studies and interviews, the experiences and measures from practice do not focus on the actions that cannot be controlled and have significantly less impact on a project's success and transition towards timber in general.

The vast majority of the instances that are situated in the second quadrant (low control - high impact) are situated in the category of business processes. In ratio to the few instances found in managerial levers, it can be pointed out that business processes especially project management and commercialization have a high impact and influence on timber projects, but are rather low in control by the organization. The first is a logical outcome: in project management, there are certain aspects that are out of control by the project teams such as mitigation of risks that are novel and highly impactful, where only mitigation through acceptance or reserving a financial buffer are the solutions. In addition, as mentioned in several sections, affordability and a viable business case are underpinned as one of the main challenges during a timber project, which underscores the low control a project's team has on possible initiatives or availabilities of funding by the government or clients for piloting timer projects, but the rather high impact it has on the project's success. Certain aspects in project management are uncontrollable which can be concluded are project costs, misalignment between the timber concept either within a tender/project or with the tender requirements as stipulated by the municipality, and unfavorable laws and regulations. Also, commercialization is noticed to be outstanding in the quadrant of low control and high impact, which can be explained by the uncontrollable nature of whether strategic decisions result in a positive spin-off as a catalyst for future opportunities with timber projects. Furthermore, the shift of engaging the client and interested parties more in the design process, even more preferably in a Bouwteam, is difficult to control as this phenomenon is also new for the clients within the construction industry and poses challenges on how to demarcate liability of new innovative projects.

Noticeable is that the sub-category project management within business processes are situated in both low-control, as mentioned in the previous section but also in the third quadrant (high control - high impact). This can be explained due to the fact that in a timber project, certain influence with so-called 'rotary knobs' can be exerted by choosing suitable partnerships which align with the organization's ambitions for sustainability and converting those to shared agreements on the project's success. Also, performing an adequate risk assessment by identifying and diversifying the most impactful risks, which serves as a quick scan on the feasibility of a potential new timber project.

Characterization & categorization

Case/ interview	Nr.	Leader-ship	Managerial Levers					Business Processes				
			Mission, goals & strategy	Structure & systems	Resource allocation	Organizational learning & knowledge	Organizational culture	Initiation & decision-making	Portfolio management	Development & implementation	Project management	Commercialization
Q1 Monitor: Low Control – Low Impact												
Ambachtslaan	INST2.11				x						x	
TOTAL Q1:		-	-	-	1	-	-	-	-	-	1	-
Q2 Manage: Low Control – High Impact												
DeKwekerij	INST1.3					x						
DeKwekerij	INST1.4			x								
DeKwekerij	INST1.8							x				x
DeKwekerij	INST1.10										x	
DeKwekerij	INST1.13							x			x	x
Ambachtslaan	INST2.2				x						x	
Ambachtslaan	INST2.5									x		
Ambachtslaan	INST2.6			x							x	
Ambachtslaan	INST2.9				x						x	
Ambachtslaan	INST2.12										x	
Leeuwepoort	INST3.1											x
Leeuwepoort	INST3.2		x					x		x		
Leeuwepoort	INST3.3										x	x
Leeuwepoort	INST3.5									x		
Leeuwepoort	INST3.6										x	
Leeuwepoort	INST3.7							x				
External interviews	INST4.1			x								
TOTAL Q2:			1	3	2	1	0	3	-	3	8	4

Case/ interview	Nr.	Leader-ship	Managerial Levers					Business Processes				
			Mission, goals & strategy	Structure & systems	Resource allocation	Organizational learning & knowledge	Organizational culture	Initiation & decision-making	Portfolio management	Development & implementation	Project management	Commercialization
Q3 Optimize: High control – Low impact												
DeKwekerij	INST1.9										X	
Ambachtslaan	INST2.1									X	X	
Ambachtslaan	INST2.3									X	X	
Ambachtslaan	INST2.16	X										
Leeuwepoort	INST3.4					X	X					
Leeuwepoort	INST3.9						X					X
External interviews	INST4.4			X		X						
External interviews	INST4.5					X					X	
External interviews	INST4.6			X			X					
External interviews	INST4.8					X						X
TOTAL Q3:		**1**	**-**	**2**	**-**	**4**	**3**	**-**	**-**	**2**	**4**	**2**
Q4 Focus: High control – High impact												
DeKwekerij	INST1.1		X							X		
DeKwekerij	INST1.2		X					X		X		
DeKwekerij	INST1.5										X	
DeKwekerij	INST1.6										X	
DeKwekerij	INST1.7										X	
DeKwekerij	INST1.11			X		X						
DeKwekerij	INST1.12				X							X
Ambachtslaan	INST2.4		X	X		X				X		
Ambachtslaan	INST2.7		X				X					
Ambachtslaan	INST2.8				X			X				
Ambachtslaan	INST2.10		X						X			

Ambachtslaan	INST2.13									x	
Ambachtslaan	INST2.14					x					
Ambachtslaan	INST2.15		x							x	
Ambachtslaan	INST2.17	x				x					
Leeuwepoort	INST3.8									x	
Leeuwepoort	INST3.10									x	x
External interviews	INST4.2								x		x
External interviews	INST4.3		x				x				
External interviews	INST4.7					x			x		
External interviews	INST4.9								x		
External interviews	INST4.10								x	x	
External interviews	INST4.11		x		x	x					x
TOTAL Q4:		**1**	**8**	**2**	**3**	**6**	**2**	**2**	**1**	**8**	**8**	**4**

Table 8.5: Overview of instances characterized with all parameters

Two sub-categories that are observed to originate only in high controlled environments, which are leadership in the managerial lever and portfolio management in business processes. Even though the instances found in these two categories are sparse, the two instances that are there are situated in quadrants three and four, which are both in the high control category. The interviews point out that leadership happens in a well-defined organizational structure with clear lines in authority and responsibility. This is the case especially for decision-making during the stage gate whether a timber project will be proceeded with or not. In line with this portfolio management is directly related to the selection of timber projects from the start and often is decided in a systematic and data-driven environment. Herein standardized procedures for the selection are present that include a focus on what type of projects, resource allocation, and risk performance tracking that can be controlled throughout the process.

The quick wins are situated in the third quadrant 'Optimize' (high control - low impact). Herein two categories are noticed to have the most instances, which are organizational learning & knowledge in the managerial lever category and project management in the business processes category. For the fourth quadrant (high control - high impact) the vast majority of instances that are highly impactful and within controllable reach, are: mission, goals & strategy, organizational learning & knowledge, development & implementation, and project management. It can be concluded that none of the instances within the identified categories do dominate and therefore vary in the four earlier-mentioned categories.

8.2.2. Conclusion Chapter 8 Discussion

This section discussed the interdependence of all parameters found in this research. Herein the various sort of categories are identified and presented, which shows the variety of characteristics that are present in the transition towards timber building practices. In essence, a distinction between the impact of the parameters the extent of control, and the extent of impact has been made. In addition, the remaining perceived overarching categories are leadership, managerial levers, and business processes. Whereas managerial levers and business processes each have five distinctive sub-categories. All parameters presented have been merged into an overview where conclusions are drawn. In the following section of the discussion, these findings will be further interpreted by comparison and validation with the literature.

8.3. Literature validation

In this section, the validation of the data and findings will be discussed. Firstly, the approach for validation will be given. Hereafter the comparison with the existing literature and literature research conducted earlier in this thesis are showcased. Finally, in the last section the results of validation and the thesis model are given.

8.3.1. Validation approach

The validation of the key findings from this research will be conducted by comparison with existing literature and the earlier literature research that has been conducted in this research. The approach incorporates three certain validation aspects. The first category to validate the findings is corroboration, which involves systematically identifying where the research data supports the literature. Herein areas of reinforcement and agreement are highlighted as how the findings support and validate previous research. Secondly, contradiction will be coming in, herein areas of divergence with the existing literature will be identified. In addition, there will be discussed the reasons for these discrepancies, such as differences in context, methodology, or sample could be. The third and also last type of validation focuses on extension, which indicates where this research's findings provide new insights that are currently not covered in the framework or literature and where certain extensions or refinements can be pointed out.

8.3.2. Validation Leadership

First of all, leadership has been found as an overarching category during the transition toward timber, due to the fact that project teams within the construction industry are initially led by driven leaders who truly believe in the transition and the future perspective of timber. These leaders create an innovative environment by filling in the role of change managers within the early adaptors phase of deploying an innovation, whereas in the timber case, there have been found that the region director initiated the first timber project within the organization and showed the courage to experiment and reinvent the so-called 'timber wheel'. As stated by Woolthuis et al. (2010) an organization that is undergoing a transition the need for system building entrepreneurs is crucial. Several characteristics of system-building entrepreneurs are that they are willing to create a new network of willing players outside of the existing ventures and they are 'ahead of the game' as they find that most regulations are barriers to innovation and voluntarily set new standards (Woolthuis et al., 2010). Furthermore, this role of leadership incorporates the capability to persuade others to change their mindsets and behaviors on sustainability and feel that partnerships with the vested industry are counterproductive.

Leadership has been observed to originate only in highly controlled environments, therefrom interviews have highlighted that leadership happens in a well-defined organizational structure with clear lines in authority and responsibility. This is shown in the sub-category of decision-making and initiation where at the start of defining the focus of timber projects the directors of an organization hold the decision-making authority on whether a tender or project will proceed and what the requirements herein are. Herein it is found that decision-making structures within an organization evolve at the micro-level and reinforcement of new products should happen high in the hierarchy, where inherently also the individual attempts to enforce or resistance from within the business has to be heard and acted upon when the management team thinks that is reasonable (Tushman & O'Reilly, 2002).

8.3.3. Validation Managerial Levers

The theory on socio-technical systems in complex environments stemming from Bostrom and Heinen (1977) consists of social- and technical systems for either technical projects or products. The two sub-categories of the managerial levers that are found in this research support this study on socio-technical systems. As stated by Bostrom and Heinen (1977) two systems can be distinguished, which are firstly technical systems that focus on the engineering side of the innovation in order to provide anticipatable and reliable interactions between user input and the system's output. This system consists of firstly the component physical systems such as tools and devices and secondly of tasks that are related to techniques, procedures, and knowledge used by the involved project teams. The found parameters and categories in this research do fit in this technical system, wherein the component physical system can be directly related to the two sub-categories structure & systems and resource location within managerial levers. The other component tasks in the technical system, the relatedness is noticeable for the sub-categories portfolio management, development & implementation, and project management.

In the theory of Fischer and Herrmann (2011) also the social system is incorporated, which consists of the components structure and people. Due to the fact that structure focuses on the organizational environment, the sub-categories of mission, goals & strategy and organizational culture reinforce this component. For the component people in the socio-technical system, the remaining sub-categories in the managerial levers and business processes can be assigned, which are organizational learning & knowledge management, organizational culture, initiation & decision-making, and commercialization. These sub-categories altogether form the cognitive and social aspects that are present in timber building practices.

The identified managerial levers do in certain aspects correspond with both the influencing conditions as building blocks of the TIS framework of Ortt and Kamp (2022). The categories within the managerial lever outline the organizational environment and what influences are used to strive and make an impact within the construction industry. These levers are capable of influencing, guiding, and justifying the performance and behavior of project teams. Moreover, these managerial levers support alignment in the organization's systems, resources, activities, and people to achieve the organizational objectives. In the study of Ortt and Kamp (2022) the conditions that influence the TIS building blocks, the so-called influencing conditions, explain the problems in the formation of the TIS building blocks and therefore indicates where the causes for barriers to deploying new innovative practices in the industry. The TIS building blocks form a set of levers, but also processes that are inherently necessary when aiming for large-scale diffusion of an innovative product.
In the following section for each of the sub-categories in the overarching category managerial lever there will be described where the corroboration with existing literature has been found.

1. **Mission, goals & strategy**
   It is found that the shift toward construction techniques from a project-based approach toward a conceptual (timber) design approach is taking place, whereas this aligns with the organization's strategy and goals to build with mainly timber as construction material and therefore reducing the environmental impact during the whole project's life-cycle. The need for this shift has been highlighted by Ribeirinho et al. (2020), whereas the main reason for reducing carbon emissions leads to lightweight building materials within large prefabricated elements and modules. Herein contractors, developers, and manufacturers must specialize in technical end-user segments by utilizing repetition and eventually producing efficiently leading toward feasibility and affordability. At the same time the shift towards timber as a construction material inherently led to the shift of both standardization and industrialization which is reinforced by the study of Santana-Sosa and Kovacic (2022). However, it can be said that currently the production processes in the construction industry are not yet industrial and experts predict that the tipping point still has to come where labor costs for humans are becoming increasingly high in comparison with robots and better infrastructure.

   Even though the strategy and goals are present and stipulated, it is found that the continuity of an organization is inherently important, which means that for construction companies making the switch to timber building practices in one go is unfeasible and therefore the traditional way of building with concrete must still remain a part of the business operations till the profit features come to fruition.

2. **Structure & systems**
   Currently the structure and system that defines the construction industry is rather traditional considering conventional contract forms and lack of robust frameworks that poses significant challenges in innovative trajectories as the transition towards timber building practices. The environment where the contractors are operating in causes confinement in the compliance contractors are currently trying to deploy innovative timber pilot projects as the regulatory instances and legislation are not adjusted towards the equitable standards of timber building practices. According to the stakeholder analysis performed in the literature review, the market and system failure framework shows that a total of six network actors are essential and the interplay between these stakeholders on the transition towards timber. The viewpoint of producers, where contractors are part of, supports this action channel where the regulatory dutch government needs to create and enforce building regulations that favor sustainable materials like timber.

   Also there is found that a cohesive approach from the start of the timber project with both

communication channels internally with the involved teams as well as the outer relations with partners and the client is a condition for construction companies in order to successfully set up timber pilot projects. Herein the preference has been outspoken from both the client's side as well as the contractor's viewpoint to merge into a Bouwteam kind of construction where the client and contractor mutually come to an agreement with assigned responsibilities on the design and execution. Moreover currently the system consisting of uncertainty and interdependence between tasks and actors, construction in fact is a complex product system that is due to the fragmentation of specialisms and operational dependencies, where clients are forces to communicate with a number of different parties throughout the building process (G. M. Winch, 2001). Therefore Gosselin et al. (2018) argues that the traditional design-bid-build system that separates design and the building steps, does not fit when deploying timber projects that inherently consists of novel challenges and is subject to piloting characteristics. The contemporary business literature of Tykkä et al. (2010) promotes a change in thinking from the idea that only products have value to one in which value is created in business systems but innovation involves a whole new approach of both organizational structure and system for the production and delivery of services.

3. **Resource allocation**
   The allocation of resources which are mainly important for construction companies have shown to be in costs. Practice shows that timber projects currently are higher in construction costs, not only due to the material, but moreover due to the investments expressed in costs for the pilot project that incorporates innovative measures. As mentioned by Geraedts et al. (2014) there is still insufficient business economic perspective for a shift towards more sustainability-oriented offering and moreover insufficient incentives to drastically reduce avoidable costs, the so-called failure costs, affecting the viable business case. The business case is already rather challenging to achieve and although the inherent character of innovation comes with initial financial investments, the question remains whether construction companies are willing to cover such costs and if a healthy buffer remains. When considering dimensions of innovation with innovation as a process or outcome, the piloting of timber practices results in innovation as an outcome on mainly economic viability. Eventually in practice the decisive factor is the viable business case in the end. Arguments that oppose that economic value only lies in the viable business case and maximizing profit has been highlighted by Woolthuis et al. (2010), stating that the residential construction industry is not 'footloose', which means that timber building practices creates benefits for regions, customers and also knowledge and experience that can be built up and fostered. It would be interesting to take a look at the costs on short-term and long-term and whether the long-term perspective is only allocated at clients rather than at construction companies (Frödell et al., 2008).

4. **Organizational learning & knowledge**
   As found in the sub-category of organizational learning & knowledge the majority of instances can be pointed out as quick wins for the organization. One important aspect where the adoption rate of construction companies is situated, is the supporting of (academic) research in making design choices on new timber construction techniques, which is found to be in high control of the project's teams, so easily implemented and can have an impact on the project's success. Furthermore, there have been found that the main lessons learned with regard to learning processes, is the clear allocation of the shift in responsibilities as product owner and communication channels in the new construction process. In the transition towards timber within the organization an extra layer has been added between the tender team and the project team, due to the fact that the industrialization team of the timber concept carries the responsibility as the owner. Henceforth the approach of integral teamwork and cohesive approach from engineering toward production and assembly has been pointed out as a quick-win by making things clear and agreements transparent by systematically developing communication lines, production lines, and responsibilities secured in project teams and systems whenever there is doubt arises upon this matter.

   With regard to knowledge development, Woolthuis et al. (2010) points out that entry and upscaling of timber practices for construction companies are hampered by a number of factors including high initial investment of time and costs with regard to knowledge development. In addition, the application of innovative knowledge requires a fundamentally different inter-organizational

behavior behind the door of project teams. As risks and uncertainties are inherent to innovation, people tend to minimize them by sharing information with one another or by making it up with additional project costs (Rogers et al., 2014). As found by Blayse and Manley (2004) through providing organizational knowledge sharing and lessons learned on projects as a matter of fact relationships are initiated that are important because they can facilitate the flow of knowledge through interactions and transactions between individuals and firms in order to safeguard the project and lower risks and uncertainties.

5. **Organizational culture**
   The organizational culture as described from practice is that open culture is fostered and overall the autonomy of decision-making on project-level is allocated at project's teams rather than high in the hierarchy at the management levels. Also operating from aligned shared values as stipulated in the companies' strategy has been experienced to be support the innovative character the project teams are undergoing with the transition towards timber and the higher purpose that is kept in mind. From the TIS framework of Ortt and Kamp (2022) the organizational culture is linked towards the building block innovation-specific institutions that consists of culture, norms and routines, which are embedded in the minds of people and actors. In line with the findings, the study of Lindbergh (2009) found that the overall organizational culture have to support the cross-functional application of project management practices, encourages strong cross-functional collaboration and communication, and aligns projects with the organization's overall strategic objectives. The hindrance of transitioning towards timber is possibly allocated within the organizational culture due to the fact that the performance gap may be caused, not by a lack of technical job knowledge, but by conditions in the organization's culture that influence the person's ability to take effective action in situations, work with peers, support, help and cooperate, defend organizational objectives, and persist despite obstacles (Motowidlo et al., 2014).

8.3.4. Validation Business Processes

In the findings, the overarching category of business processes is identified. This category involves the activities and steps that have to be taken in order to carry out the formulated strategy and achieve organizational goals. It therefore answers the 'how' question related to the needed next steps to be taken by construction companies consisting of business processes. As stated in the previous section the theory of Bostrom and Heinen (1977) underpins the tasks that are necessary in both the social- as technical systems. Noticeable in the TIS framework of Ortt and Kamp (2022) both the influencing conditions as the TIS building blocks do not focus on the actual business processes from practice, which will be further elaborated on in the section of extension existing literature. In the following part for each of the sub-categories in the category business processes will be explained in relation to the existing literature.

1. **Initiation & decision-making**
   Related towards leadership is the business process initiation & decision-making within an organization, especially the selection at the gate of timber construction projects. The decision-making factors whether to proceed with a timber project is based on several factors such as the business case, continuity of an organization and available resources and is therefore directly related to the other four business processes in the same category. A steering force of acquiring timber projects even though the business case does not seem economically viable is the expected spin-off that must happen when focusing on building legitimacy and delivering the first timber projects.

   There can be stated that decision-making on innovative new pilot projects does not only stem from tangible resources or achievements but also includes the appropriateness of actions because for the sake of the stipulated strategy and vision. The same holds for decision-making in the context for clients on timber projects, as there is found that lead clients such as housing corporations also undergo similar decision-making process of whether to take upon the opportunity of constructing a timber project, which is a matter of weighing (expected) factors hopefully leading to the desired outcome. In the conducted literature review in this thesis little can be found related to decision-making and initiation of timber projects, from both construction companies as clients.

2. **Portfolio management**
   As in the data only one instance has been found on portfolio management does not mean to underrate the role portfolio management has on the transition towards timber. The instance found in this sub-category, has been mentioned earlier in the discussion, which is that continuity of an organization where the traditional way of building still must remain a part. Herein there can be stated that currently as timber is in the early adaptors phase within the construction company, the ratio of timber projects in the portfolio in comparison with traditional construction projects with concrete. As found in the tender documents, almost always the criteria stands whether reference projects are present within the portfolio of the construction company in the pre-qualification of the tender. This means that in order to participate in a tender that envisions sustainability as the main component for the bidders, references and legitimacy are being approved. In addition there been highlighted that all the timber projects currently acquired have been granted due to the fact that the focus of the tender is on sustainability or evenmore on the use of bio-based materials rather than awarding on the best price. So there can be concluded that a focus of quality and especially sustainability aspects in tender requests are beneficial for advancing deployment of timber building practices. For this sub-category of portfolio management the same holds as initiation & decision-making where little emphasis has been put in the literature research resulting in less validation whether this is the case from a scientific point of view.

3. **Development & implementation**
   The sub-category of development & implementation covers the vast majority of instances and have been found to be highly impactful and within controllable reach that influence the transition towards timber. As the innovation trajectory of developing a timber concept stems from a technical design and perspective, the emphasis is situated on starting with timber design purely in timber and therefore without converting tradition design choices and letting go of the design rationale that has been the course of design events in the past decades. Putting the emphasis and taking the time to develop a concept by reinventing the earlier called 'timber-wheel' does pay off when implementing new construction techniques within a traditional sector. However at the same time the extent of patience and incorporating a long breath is inherently present when adopting timber as construction material in a traditional construction sector which is due to the slow-to-change nature of the sector as found by Gann (1995).

   Another crucial implementation criterium is the perception of clients and customers where the design must be aligning with, this highlights a dilemma that has been pointed out from practice. Certain design choices and therefore the requirements of the timber concept are misaligned with the tender design according to the given requirements and the so-called knock-out criteria. An instance herefrom is that energy neutral dwellings are the norm in the tender, however due to the choice of installations and heating system this can hardly be met by the concept. From the studies of Ribeirinho et al. (2020) there is found that development and implementation of timber in the construction industry, the focus on establishing productive production networks where collective development stands central. In order to establish this network the industry must get past barriers and challenges which include lack of standardization, a lack of willingness and inclination to collaborate, a lack of sharing of proprietary knowledge and systems and variants in the organizational structures and platforms used for production (Ribeirinho et al., 2020).

4. **Project management**
   By far the most instances have been found in the sub-category of project management, which involves the business processes of managing the project scope, planning, costs, quality and risks that align with the project's objectives. There is noticed that project management are directly related to all the five categories within the managerial levers category as the instances given are mutually shared with one or more sub-categories in the other categorization. Project management poses inherently a dilemma between feasibility and affordability as found in both practice as literature. As stated by Moore and Doyon (2023) deploying timber in a project is more than just a technical solution and in fact requires deep structural changes that asks for a push and pull strategy within project management. This strategy indicates that when one main factor within project management is being pushed forward, the other factors have to be pulled along to match

the pace the factors are progressing. A successful project means that all related factors as scope, planning, costs etc. have to be aligned and considered carefully upon taking actions to pull for instance the planning forward forward when the other factors such as quality and risks are not sufficiently bench-marked yet.

From the start of the design phase there have been stated that the technical implications of timber pose limitations in the flexibility and adaptability of timber projects (Blaß & Sandhaas, 2017). In this research there is found that the limitation of design with timber as the construction material are not located in the material properties itself but in project management the challenge is noticed to be in complying with the regulations and ensuring the design meets the Dutch Building Codes through extensive documentations and evidence for timber performance and quality. The limitations of the material itself have been stated from practice that can be mitigated through understanding how to design with timber and where the structural strengths of timber possibly lay and how to design accordingly instead of the impossibilities what cannot be achieved with timber.

From practice there haven been repeatedly noticed that misalignment between the tender bid and the actual project design can be concluded as the far most limiting factor when maintaining the level of playing field between a feasible design and staying within the designated project's budget. This is due to the nature that tender bids tend to offer all possibilities reaching far above the requirements in the tender, without taking into account cost-effectiveness by proposing so. Herein fulfilment of what has been promised results in limiting design alterations when cost overruns in the basis design is already occurring due to the project's innovative nature and unfamiliar construction technique. This misalignment has not been notified in the earlier conducted literature research and can be seen as an extension towards the existing findings.

Several cost opportunities that supported the timber cases from practice were the availability of financial compensations in form of subsides and the availability of funding by the client for aspects such as additional research and piloting for the timber projects. However the identification and use of these cost saving opportunities has been limited in practice whereas the project team primarily focused on reducing the costs through design alterations. This is highlighted by Geels (2004) as the practical instance of the trade-off between social and technical systems between the client and contractor. There can be concluded that the contractor is primarily focusing on the tangible output, which is the technical operations with regard to the timber concept and considers less the role of what the client can take upon in case of financial aspects when the business case is unfavorable for the contractor. An open dialogue when the contractor faces such stringing situations and does not have options in manoeuvring the project towards a positive outcome is something that the client will also concern. Important to note is that the openness in sharing their resources and willingness of the client to cooperate is an assumption herein.

5. **Commercialization**

Commercialization have been found as one of the underexposed category within the transition towards timber by both the practice as literature. In practice there can be stated that the transition from project-based approach towards product-based approach as supported by Ribeirinho et al. (2020) asks for new commercial approaches within the construction industry. As highlighted by the commercial organization the acquisition with a timber concept differs from what they have been doing previously, due to the fact that the goal is to sell the product by knowing the unique selling points and unique buying reasons towards the client rather than fully adhering to the client's requirements, needs and wishes as is the case with selling a project. Before the project would be suited and adjusted accordingly to the project's requirements and the quality-price ratio will be the decisive factor, whereas with acquisition of projects for the timber concept focusing on quality rather than price is recommended.

This shift also switches the mindset of the client within the construction industry whether improved quality and future-perspective on the residential buildings is worth the investment. Noticeable is the client-contractor relationship within the construction industry, where commercial-off-the-shelf reasons to buy the product is often perceived skeptically. This is due to the principle-agent phenomenon where the principle, in this case the client that consists over the information is disadvantage over the agent, the contractor. The client is often aware of their position of composing under less information and that the contractor is the most experienced party with regard to construction techniques and concepts. This is however part of commercialization and the trust

that has to be gained through dialogue and deeply understanding where the client satisfaction factors but also worries are located and proposing measures accordingly to those. An instance found in the literature is the perception of the unsafe nature of building with wood and the technical implications that occur while building with it. This has been found as initially negative perceptions on timber by clients and customers, but through clear consultations to answer those worries through highlighting that the expertise and knowledge is there within the company and taking them to an actual timber project these worries are often solved.

8.3.5. Extension validation literature

The findings of this research with regard to the managerial levers can be stated that the five subcategories are not mutually exclusive, which indicates that an instance or measure is interrelated with multiple managerial levers at one time. Certain connections can be derived from table 8.5 where mutual connections and occurrence of the three overarching categories are found in the same practical instance. An example therefrom is that the instance: 'Finding the sweet spot between the pave of upscaling timer projects and reinventing the timber wheel' is categorized in all three overarching categories, respectively the leadership category, but also the sub-category organizational learning & knowledge from the overarching category managerial levers and development & implementation subcategory within business processes. In table 8.2 a majority of the instances are mutually categorized in multiple sub-categories in three overarching categories. In the framework of Ortt and Kamp (2022) the connections between the influencing conditions and TIS building blocks are not specified in detail, as the researchers acknowledge that all connections between the two sets of parameters are possible and certain connections are more likely than others. Herein a divergence in the findings of this research can be pointed out in relation to the research conducted by Ortt and Kamp (2022), where the extension of the research findings is situated in that the relations between the influencing conditions and the TIS building blocks from the transition towards timber building practices are drawn and specified.

The aspects that adds to the current TIS framework of Ortt and Kamp (2022) are allocated at mainly the identified business processes category in this research. Although the influencing conditions and building blocks of the TIS framework combines both social- and technical factors with deployment of an innovation, the evolvement of the conditions and blocks over time is neglected. An instance herefrom is the influencing condition knowledge and awareness of technology that is formulated as a static condition that directly influences the product performance and quality of an innovation. There have been found from practice that this condition can be enhanced through organizational learning and knowledge expansion where the extent of adopting new techniques influences the dynamic nature of evolution of a product over time. In addition the social aspect within the TIS framework considering the influencing condition macro-economic and strategic aspects influencing the network formation and coordination herein leadership, initiation & decision-making authorities, portfolio management and project management as decisive factors in whether innovative projects are proceeded with and what the findings on actual projects are not covered in the TIS framework. Therefore the findings upon these sub-categories in the managerial lever extends the TIS framework by adding insights from practice with regard to macro-economic and strategic aspects.

Lastly the TIS framework of Ortt and Kamp (2022) mainly takes the perspective of construction companies, whereas the findings in this research also considers the perspective of construction companies, but also viewpoints of the six main stakeholders within the transition towards timber building practices and most importantly the client perspective have been incorporated. As the residential construction market is characterized as both fragmented and dynamic the objective to take multiple viewpoints within the transition is justified. The viewpoints of the lead stakeholders do add on the current TIS framework with insights on action channels that are open to the stakeholder, the probability of participation and manner of doing so, and their influence as a product of resources and participation.

8.3.6. Results validation literature

The previous findings and validation of the existing literature shows that the technical aspects correspond with the defined physical system within the socio-technical regime as studied by Bostrom and Heinen (1977). The identified characteristics in this study that reinforce the technical system of Bostrom and Heinen (1977) are structure & systems and resource allocation within the overarching category of managerial levers. Subsequently the technical system of tasks related to this study's sub-categories portfolio management, development & implementation, and project management. In the other dimen-

sion, the social system, the relatedness with structure as defined by Bostrom and Heinen (1977) is found to be with characteristics of mission, goals, & strategy, and organizational culture. The people dimension, forming the cognitive and social aspects in the framework is identified to fit this study's sub-categories of organizational learning & knowledge management, organizational culture, initiation & decision-making, and commercialization.

Upon this analysis, a model has been crafted that integrates the determining characteristics as found in this study and highlights the key factors influencing the transition towards timber in the residential construction industry. As found through validation of the thesis model with the TIS framework of Ortt and Kamp (2022), the influencing conditions correspond with the overarching categories leadership, managerial levers, and business processes with the intertwined characteristics when looking a layer deeper. Subsequently, it is found that the TIS building blocks form the dimensions of an innovation, where two types of dimensions have been distinguished: innovation as a process and innovation as an outcome. Herein the building blocks that result in innovation as a process, are: timber performance & quality, risk management & assessment, and network formation and coordination. The actual outcomes of the innovation, as well as the key dimensions identified in the transition towards timber, are: timber construction techniques and technology and economic viability. These findings form the thesis model as shown in figure 9.1.

Actionable recommendations or in this case the considered triggering questions leading towards actions that can be asked through each of the influencing conditions, which leads to the desired innovation outcomes can be set up. In FIGURE NUMBER the activating questions related to the overarching category managerial lever create the open dialogue on how innovation can be incorporated into an organization. These type of questions has the aim of creating space for holding an open dialogue that allows the personnel within an organization to discuss either the barriers or opportunities they see in incorporating timber in projects throughout the project's lifecycle (e.g. from acquisition towards project management and upon delivery of the timber project).

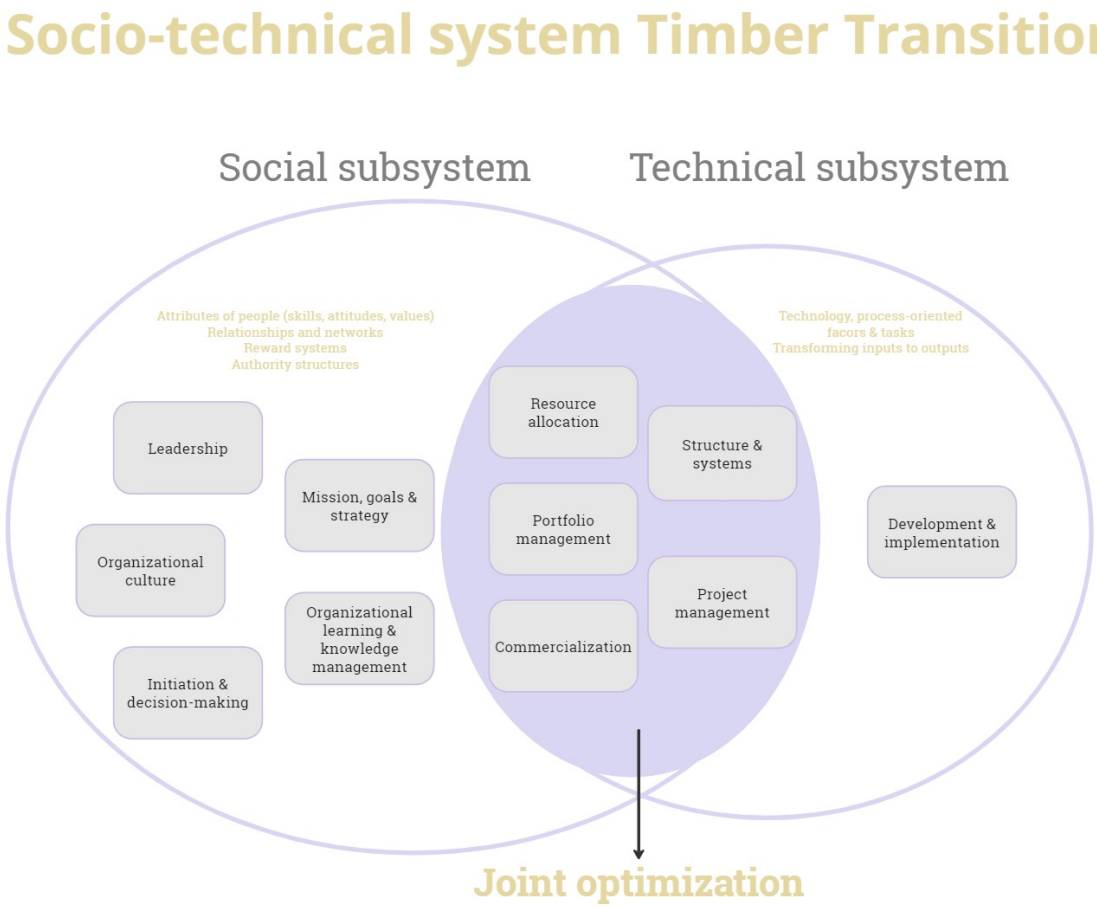


Figure 8.1: Thesis model crafted from findings categories and characteristics of transition towards timber building practices

8.4. Limitations of the research

Although carefully considering the chosen research methodology and the earlier mentioned limitations in the methodology chapter, the limitations of this research has been critically assessed once more. In the following part the limitations of the research with regard to the case study, interviews and results are discussed.

Limitations case study and interviews

First of all the sample size of the case studies has been limited to a total of three timber case studies. Herein a limitation was that two out of three cases of the timber projects were situated in the design phase, whereas not the whole project's life-cycle could be assessed. This can be explained due to the fact that the first timber projects with conceptual building within the construction company have only recently been adopted and are in the early stages of the project. However this limits the extension of the results regarding the operational phase.

Secondly the scope of the case studies have been limited with regard to differentiation of tender requirements. There is found that the chosen timber cases, explicitly sustainability has been the main defined criteria that leads to awarding the tender. Other than that the tenders could not be identified where other tender criteria were mainly considered and therefore limits the study towards a certain kind of 'biased' tenders.

Regarding the interviews conducted, the total amount of 17 interviews has led to a comprehensive set of instances. Herein a limitation that can be identified is that interviewees of outside the construction

industry but who are relevant for the transition towards timber, for instance insurers, banks or timber suppliers are not present in this set. This could pose a limitation of the study where not all viewpoints of the stakeholders related to the residential construction industry are taken into account.

In line with the limitation on interviews, the type of clients that have been interviewed can be biased, as they already have been involved in a timber project with the construction company and therefore only shows the viewpoint of lead clients that are making the move towards the first timber pilot projects. Therefore it is a limitation where the viewpoints of potential clients, who are interested but do not have made the step yet, such as institutional investors or insurers, are not included in the study.

When conducting a research where certain sensitive topics related towards the company as financial or inter-organizational challenges are part of the research, a so-called social desirability bias can cause certain limitation. This bias within the organization leads to the phenomenon that participants in an interview are affected by the awareness of the sensitivity of the topic and therefore affecting and disclose the information in their answers.

A limitation in the scope of the interviews could be pointed out that specifically socio-technical factors are being asked and considered while conducting the interviews. Even though new insights and certain refinements could be gathered, this could possibly lead to limiting the described instances by interviewees.

Limitations results

With regard to interpretation of the results in this research interpretation bias can be present when categorizing the instances in the quadrant matrices and also in characterizing them into the identified overarching categories. Herein the researcher wants to point out that especially in analyzing and characterizing the instances in relation to the parameters the extent of influence and the extent of impact can contain bias. This limitation is tried to be minimized through validation with the earlier conducted literature research, where certain categories could not fully be verified as the aspects could not be validated in the literature research.

In the instances found from practice, certain instances resulted in only a few practical experiences that have been identified in the interviews. These few instances can possibly pose a limitation where conclusions are drawn from, which has been acknowledged in the same section by the researcher.

8.5. Concluding remarks Discussion

We found that timber transition in The Netherlands can be enabled by incorporating a process consisting of five steps in total that takes into consideration the multifaceted and complex nature of the residential construction industry. These steps are explained in the following part.

8.5.1. Resource allocation

Firstly, in this study we highlight the process of resource allocation that acts as an enabler on the transition towards timber. Herein resources represent a combination of products or facilities that are subject development of timber which can respond to different pressures from early adaptors niches and landscapes. Similarly, Smith, et al. (2005), describes resource allocation as the "adaptive capacity" of the regime which argues that the higher the external pressures to the regime, the more is required from resources "defending" the regime, facilitating its adaptability. From our empirical study we highlight that resource allocation enablement exists in all three socio-technical themes, as shown in Figure 1. For example, leaders use resources through decision-making where alignment on the vision, mission and strategy of an organization is crucial, and facilitates development of timber innovation through allocation of financial incentives, personnel and organizational learning capacity through trainings. In order to create the innovative environment, managers rely on the deployment of resources through motivating and empowering their team by driving performance, and supporting incentive structures, but also decision-making tools derived from lessons learned. Within business processes resources are used with the intention to streamline operations and procedures, support collaboration within the organization but also with the external lead clients, and resources are enhancing the adaptability of processes subject to change.

8.5.2. Commercialization

Secondly, commercialization has been found as an enabling process within the transition towards timber by both the practice and literature. In practice there can be stated that the transition from project-based approach towards product-based approach as supported by Ribeirinho et al. (2020) as they ask for new commercial approaches within the construction industry. We found that this relates to the value proposition of the timber product that a company offers to meet the market demand through focusing on enabling wood expertise, adaptability and seeking collaboration. As highlighted by the commercial interviewees the acquisition with a timber concept differs from what they have been doing previously, due to the fact that the goal is to sell the product by knowing the unique selling points and unique buying reasons while matching these with the client's requirements, needs and wishes as is the case with selling a project. The study of Doganova & Eyquem-Renault (2009) and Fjeldstad & Snow (2018) highlights the power of business models around commercialization which applies platform-centric value network logic, allowing companies to explore markets and realize their innovations by gradually shaping the social and technical slants of new ventures. Herein commercialization is identified to be directly related with the overcoupling socio-technical factors of leadership, managerial levers and business processes as it requires the alignment of technical capabilities of timber with social, organizational, and market demands.

8.5.3. Portfolio Management

As third process in this study, portfolio management is found to enable the transition towards timber whereas part of the business model the key activities and focus have to made clear in upon shaping the portfolio of timber projects. Herein there can be stated that currently as timber is in the early adaptors phase within the construction company, the number of timber projects in an organization's portfolio in comparison with traditional construction projects is rather small. Herein Loorbach et al. (2010) underscores the balance between stability and change the transition towards timber has on the composition of the portfolio, and that companies currently are facing a high degree of uncertainty because of ill-defined problems and an insufficient knowledge base on how to change their portfolio in accordance with the continuity of their business processes through leadership and managerial levers. Through portfolio management this study identified the need for companies to continuously monitor the progress of timber projects and gather as much data in order to make informed decisions on whether to continue, scale or pivot efforts which aligns with the weighing of factors. This can ensure effective alignment of the companies' objectives and changing market dynamics.

8.5.4. Structure & Systems

We found as fourth process the enabler is allocated at structure & systems, indicating the environment where the contractors are operating in causes confinement in the compliance contractors are currently trying to deploy innovative timber pilot projects as the regulatory instances and legislation are not adjusted towards the equitable standards of timber building practices. Moreover, currently the system consisting of uncertainty and interdependence between tasks and actors, construction in fact is a complex product system that is due to the fragmentation of specialisms and operational dependencies, where clients are forces to communicate with a number of different parties throughout the building process (Winch, 2001). Therefore Gosselin et al. (2018) argues that the traditional design-bid-build system that separates design and the building steps, does not fit when deploying timber projects that inherently consists of novel challenges and is subject to piloting characteristics. Also, there is found that a cohesive approach from the start of the timber project with both communication channels internally with the involved teams as well as the outer relations with partners and the client is a condition for construction companies in order to successfully set up timber pilot projects. Herein the preference has been outspoken from both the client's side as well as the contractor's viewpoint to merge into a Bouwteam kind of construction where the client and contractor mutually come to an agreement with assigned responsibilities on the design and execution. Tykkä et al. (2010) promotes a change in thinking from the idea that only products have value to one in which value is created in business systems but innovation involves a whole new approach set up by leaders and levers for both organizational structure and system fin the production of timber and delivery of services. It can be concluded that the enabling process of structure & systems are directly related to the socio-technical factors leadership, managerial levers, and business processes.

8.5.5. Project Management

There is a need to understand the way project management is changed through transitioning towards timber, where the balance between feasibility and affordability has been identified to be the evident challenge in timber projects. As stated by Moore and Doyon (2023) deploying timber in a project is more than just a technical solution and in fact requires deep structural changes that ask for a push and pull strategy within project management. This strategy indicates that when one main factor within project management is being pushed forward, the other factors have to be pulled along to match the pace the factors are progressing. A successful project means that all related factors as scope, planning, costs etc. have to be aligned and considered carefully upon taking actions to pull for instance the planning forward when the other factors such as quality and risks are not sufficiently bench-marked yet. From the start of the design phase there have been stated that the technical implications of timber pose limitations in the flexibility and adaptability of timber projects (Blaß & Sandhaas, 2017). In this research there is found that the limitation of design with timber as the construction material are not located in the material properties itself but in project management the challenge is noticed to be in complying with the regulations and ensuring the design meets the Dutch Building Codes through extensive documentations and evidence for timber performance and quality.

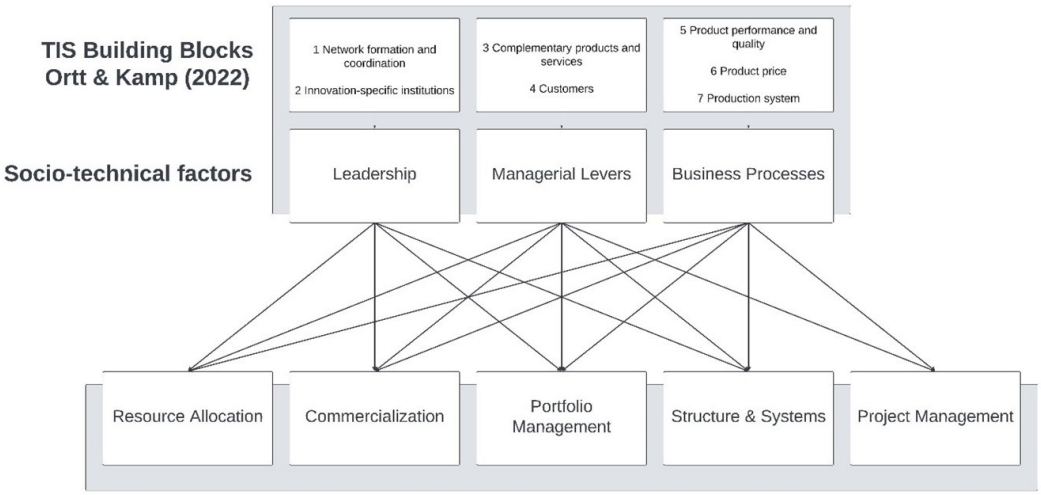


Figure 8.2: Relationship between socio-technical factors and enabling processes

The relationship between the identified socio-technical factors and the TIS framework of Ortt & Kamp (2022) are shown in appendix H1. In the category leadership, the related TIS building blocks are allocated at high-over strategic factors which are network formation and coordination and innovation-specific institutions. The managerial levers found in this study craft the conditions where the transition towards timber is operating in, which are complementary products and services, and the (lead) customers and clients. Lastly as described in the findings the business processes are contingent towards actual operational procedures of transitioning towards timber, resulting in the relation towards product performance and quality, product price, and production system of the TIS framework.

In addition, the relations between the socio-technical factors and the enabling processes are given by the drawn arrows. Herein the socio-technical factors managerial levers and business processes are each one found to be related to all the enabling processes e.g. resource allocation, commercialization, portfolio management, structure & systems, and project management. For leadership mutual relations are identified for all the enabling processes, except for project management. In this study there is found that leadership does not explicitly have a direct relationship with project management as managing projects is a distributed function across various actors in the network rather than concentrated in a single role of leaders. This aligns with Mintzberg's (1979) notion that decision-making power is distributed among all levels of the hierarchy, reflecting a more decentralized leadership approach.

In the following, Chapter 9 the Conclusion and Recommendations of this study will be given. In the Conclusion, the answers to the supporting research sub-questions will be given, leading towards answering the main research question of this study. Furthermore, the dissemination of this study will be explained at the end of the Conclusion chapter.
As a result in the recommendations chapter both theoretical and practical contributions and actionable recommendations are explained in detail.

9

Conclusion

This chapter involves the conclusion of this research. Firstly in Section 9.1 a short recap of the research design is given. Following, Section 9.2 gives the conclusions to the sub-research questions. At last in Section 9.3 the conclusion to the main research question of this research will be answered.

9.1. Recap of research design

Starting with recapitulating the defined research questions, the following main research question have been formulated for this research:

How can a socio-technical framework add value on the multifaceted and complex interplay of key factors, conditions, and actors in the residential construction industry in order to collectively drive the transition towards large-scale deployment of timber building concepts?

In order to answer the main research question adequately, four deepening sub-questions will be examined in this research. The sub-questions are the following:

Sub-questions:

1. What is the current status and role of innovative timber construction practices in The Netherlands?
2. What are the key socio-technical drivers, barriers, conditions, and actors that involve large-scale implementation of timber building practices in The Netherlands?
3. What (type of characteristics) are determining in distinctive timber building projects in relation to the modified TIS building blocks?
4. How do these determining characteristics influence the transition towards timber building practices in The Netherlands?
5. How to integrate the determining socio-technical characteristics through a strategy framework in order to provide actionable recommendations for the deployment of timber building practices?

The main goal of this research is to identify the key socio-technical factors and essential actors, that influence the large-scale implementation of new timber-building practices in The Netherlands, by taking a market perspective. Furthermore, this study will focus on gaining insights into the complex interplay of actors, conditions, and dynamics contributing to the emergence of markets for timber building practices that result in moving out of the early adaptors phase as the current status is.

This study on the key socio-technical factors that influence the transition towards timber is relevant for several reasons.

First of all, currently the deployment of timber building practices in The Netherlands is underdeveloped despite the potential benefits of timber, such as the impact on climate change, less carbon-intensive production, and the flexibility to be upcycled, reused, and recycled.

Secondly, in existing literature the emphasis on innovation from a technical perspective has been researched, however, research on incorporating also the social aspect of timber innovations has not been performed. This study therefore emphasizes the use of innovation diffusion theories to improve the adoption of timber from a Technical Innovation System (TIS) perspective.

Lastly, contractors including the company that facilitates this research which is namely BAM Wonen, are highly interested in the opportunities and chances that are identified in deploying their new timber concept in the residential market. At the same time, the organization poses several challenges and lessons learned, where they realize that the role of both project teams as the way of working with and acting with clients shifts towards a new approach. Herein the challenge of aligning a new innovative product with the requirements of the market and satisfying the client's needs and wishes, in this case, the topic of this research, is highly important for the construction company.

9.2. Conclusions to sub-research questions

In this section, the conclusion of the defined sub-questions for this research will be answered.

SQ1: What are the key socio-technical drivers, barriers, conditions, and actors that involve large-scale implementation of timber building practices in The Netherlands?

The first sub-question is answered by conducting extensive literature research on the social-technical regime where several factors are present that either initiate or hinder the transition towards timber building practices in The Netherlands.

This analysis showed that the market of crucial actors within the residential construction industry consists of six stakeholders in total: producers (e.g. timber building contractors & suppliers), the regulatory Dutch government, lead clients & consumers, partners (e.g. architects & co-makers), knowledge providers (e.g. universities & research institutes), and specialist service providers (e.g. insurers, consultants & banks). It can be stated that currently, the market does not have the full incentive and willingness to shift from the familiar common traditional building approach with concrete towards innovative building structures of timber construction, which is seen as too complex and too risky.

The main barriers to construction in timber are identified and allocated in all construction phases of a typical residential project. When differentiating social and technical aspects of the innovative transition towards timber, the social barriers are situated in the perception of clients and consumers where they fear the unknown, the so-called fear of cold water. Subsequently, the shift towards timber buildings inherently requires contracting new partnerships and therefore forming networks that are not established yet. Herein the social barriers are deeply rooted in the dilemma of the push for sustainable strategic goals where constructing with timber is part of the solution and bearing the risks and uncertainties due to limited experience with the technique. Subsequently, the social aspect related to the current market structure and system of the residential construction industry poses barriers. Firstly due to the fact that the industry is fragmented and involves several different specializations that operate in-

dependently, resulting in a slow adoption rate of introducing new products and techniques (at the start). Secondly, the laws and regulations in the Dutch Building Codes are not adjusted accordingly to the use of timber with regard to CO_2 emissions of the entire life cycle and energy performance indicators. This leads to the barriers identified in the technical regime of the transition, where the main barrier is situated in the innovative nature of reinventing the timber wheel through research on technical implications when designing with timber and in the operational phase when assembling timber elements. Within a construction company, establishing the technical requirements for building with timber and adopting it on the first timber pilot projects, goes through an iterative loop of trial and error. Overarching it is found that both the social- and technical barriers are inherently related to financial constraints that are present in all the phases of a construction project, but mostly during the design and execution phase of a timber project.
On the other hand building with timber does not occur without several drivers that form the motivation and initiation of timber projects. The social drivers mainly start with the given that more construction companies within the residential sector shift towards reducing their CO_2 emissions and therefore need to stipulate and implement a sustainable strategy in the upcoming years. The driver herein is reducing their environmental impact carbon footprint through transforming their operations. Herein it can be stated that timber is not the actual solution or outcome of the main drivers that lay at clients and construction companies, but is an instrument in order to achieve the higher goal. Another social driver is the benefits timber has on adding social value through psychological merits for the users, and also the aesthetically pleasing features timber has upon constructing with it. Furthermore, the technical drivers of building with timber allocated at the advancement the timber techniques have been undergoing the past few years and still have to come, which makes it technically more feasible to construct with the material. In addition, the characteristics of building with timber initiate opportunities where beneficial material characteristics can be implemented in an innovative manner within projects, where materials such as concrete and steel cannot fathom to. Examples herein are the extent timber as lighter weight material has in supply, and herein the major opportunity to manufacture off-site and the matter of fact that the material has multiple ways to be renewed, reused, or upcycled.

The socio-technical conditions that are crucial for the transition towards timber shows to be novelty and usage. The idea of product innovation calls for a close alignment of markets, products, and technology with the goal of increasing aggregate value towards the whole construction chain. Therefore the timber products developed from a technical perspective inherently must be subject to market interaction where client's perspectives are considered. Another condition for the successful deployment of timber concepts is the importance of incorporating feedback loops between development stages since it is not an isolated occurrence but rather the result of contact and collaboration between players in the public and private sectors. Herein the importance of marketing that focuses on innovation has been emphasized.

SQ2: What (type of socio-technical characteristics) are determining in distinctive timber building projects in relation to the modified TIS building blocks?

The data gathering and structuring process has been conducted through interviews and through analysis on a set of three timber case studies. For each case study the instances that influence the timber project and eventually determine the success of the project are selected and discussed in order to provide answers to the remaining subquestions, respectively SQ2, SQ3, and SQ4. In addition, the goal of gathering the instances from practice is to gain more insights into the most determining factors with the transition towards timber, leading towards necessary next steps with regard to quick wins, optimizations, and monitoring.

The characterization of the instances has been identified and evaluated by dividing them into four quadrants:

1. Quadrant 1 'Monitor': instances with low control and low impact
2. Quadrant 2 'Manage': instances with high impact, but low control
3. Quadrant 3 'Optimize': instances with low impact, but high control

4. Quadrant 4 'Focus': instances with high impact and high control

Herein the instances and measures situated in Quadrant 4 'Focus', are examples of key factors in the transition towards timber, due to the fact that these instances are in high control of the project's team and at the same time result in high impact and influence on the project's outcome.

Thereafter a total set of instances has been crafted and analyzed. As a result of the analysis, the researcher extracted the instances into findings that are categorized and characterized accordingly. The overarching categories found with the instances are: leadership, managerial levers, and business processes, as shown in figure 9.1 below.

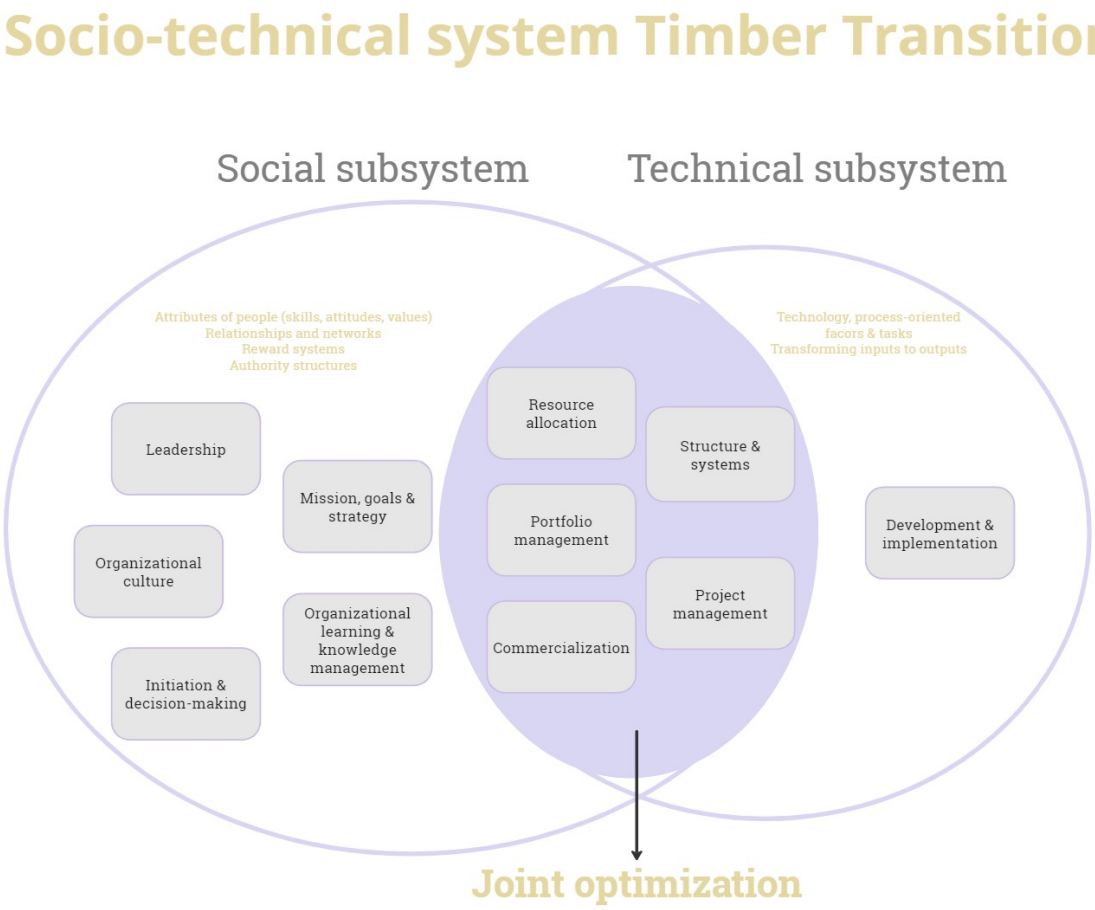


Figure 9.1: Thesis model crafted from findings categories and characteristics of transition towards timber building practices

In line with the characterizations of the findings, the researcher formulated a total set of 10 characteristics. Whereas leadership remains one overarching category, and both managerial lever as well as business processes consist of five sub-categories (characteristics). It can be pointed out that both the categorizations as well as these characteristics are not mutually exclusive, resulting in instances that can occur in more than one category or characteristic at one time and that the list might not necessarily be limited to the ten characteristics. The final set of characteristics are the following:

Managerial lever

- Mission, goals & strategy

- Structure & systems
- Resource allocation
- Organizational learning & knowledge
- Organizational culture

Business processes

- Initiation & decision-making
- Portfolio management
- Development & implementation
- Project management
- Commercialization

SQ3: How do these determining characteristics influence the transition towards timber building practices in The Netherlands?

Upon answering which of the identified characteristics and categories influence the transition towards timber building practices have the most influence, the combination of all the parameters has resulted in the following conclusions.

It is found that the instances with the highest impact and within the control of a project's team upon proceeding with a timber project are situated in several characterizations, respectively mission, goals & strategy, organizational learning & knowledge, development & implementation, and project management. It can be concluded that none of the instances within the identified categories dominate and therefore vary in the four identified categories. Herein the condition is found that a push-and-pull strategy is inherently important for these 'Focus' categories where simultaneous alignment and development have shown to be effective through a project's success. Upon adjustment or enhancement of one of the characteristics, the interrelated characteristics are subject to change (either for the bad or good).

The fewest instances found in the whole set of findings are allocated in Quadrant 1 (low impact - low control), therefrom only a couple of leadership instances and portfolio management related to decision-making of timber projects within an organization are found in the total set. Nevertheless, it can be said that leadership performance in managing the portfolio of a construction company highly influences the initiation & decision-making on whether to proceed with timber projects and the pace and likewise timing of upscaling timber projects within the organization's portfolio.

The vast majority of instances that are highly impactful for a timber project but are rather low in control by the project's team are situated in the category of business processes. Therefrom it can be concluded that the most determining key factors in a timber project are the categories of project management and commercialization.

Project management has shown to be the most determining sub-category within the timber cases, which can be concluded from the allocation of the majority of instances in both Quadrant 2 (low control - high impact) and Quadrant 4 (high control - high impact). It is found that project management has a direct influence on the so-called 'rotary knobs' of a project where feasibility and affordability have been identified as key factors. These rotary knobs are technically (tangible) from nature, e.g. scope, planning, cost, quality, and risks that need to be aligned with the project's objectives, but are also directly influenced by social aspects, especially in the alignment of scope between client's requirements with the feasibility of the project.

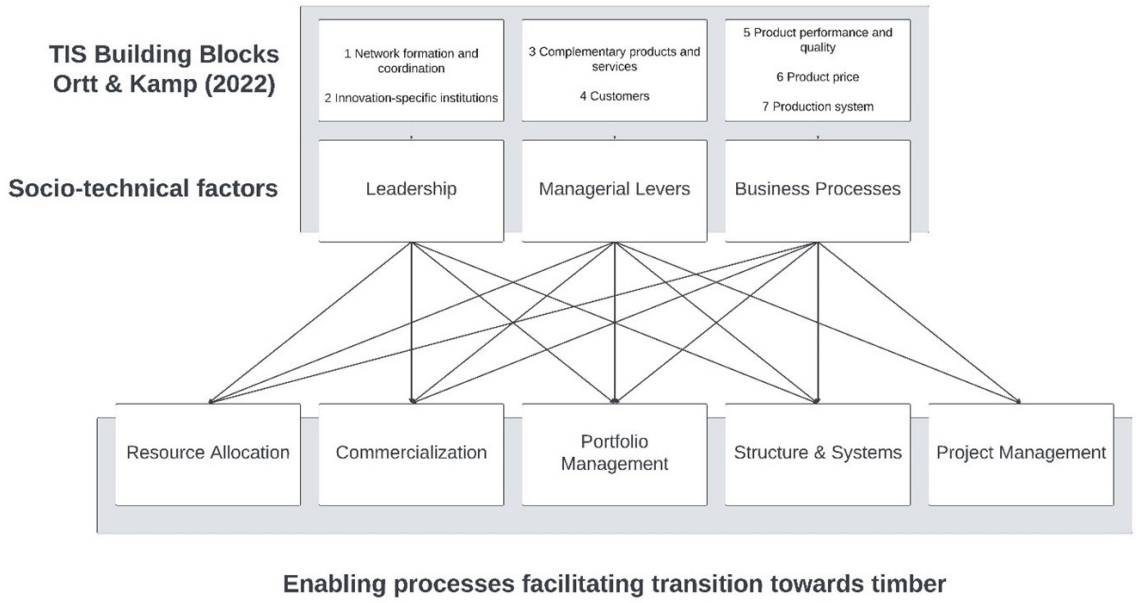


Figure 9.2: Relationship between socio-technical factors and enabling processes

SQ4: How can a socio-technical model be developed that integrates the determining characteristics in order to provide actionable recommendations for the deployment of timber building practices?

In order to answer this research question, the validation with previous research conducted on Technological Innovation System (TIS) frameworks and the socio-technical systems has been conducted and analyzed.

This analysis shows that the technical aspects correspond with the defined physical system within the socio-technical regime as studied by Bostrom and Heinen (1977). The identified characteristics in this study that reinforce the technical system of Bostrom and Heinen (1977) are structure & systems and resource allocation within the overarching category of managerial levers. Subsequently the technical system of tasks related to this study's sub-categories portfolio management, development & implementation, and project management. In the other dimension, the social system, the relatedness with structure as defined by Bostrom and Heinen (1977) is found to be with characteristics of mission, goals, & strategy, and organizational culture. The people dimension, forming the cognitive and social aspects in the framework is identified to fit this study's sub-categories of organizational learning & knowledge management, organizational culture, initiation & decision-making, and commercialization.

Upon this analysis, a model has been crafted that integrates the determining characteristics as found in this study and highlights the key factors influencing the transition towards timber in the residential construction industry. As found through validation of the thesis model with the TIS framework of Ortt and Kamp (2022), the influencing conditions correspond with the overarching categories leadership, managerial levers, and business processes with the intertwined characteristics when looking a layer deeper. Subsequently, it is found that the TIS building blocks form the dimensions of an innovation, where two types of dimensions have been distinguished: innovation as a process and innovation as an outcome. Herein the building blocks that result in innovation as a process, are: timber performance & quality, risk management & assessment, and network formation and coordination. The actual outcomes of the innovation, as well as the key dimensions identified in the transition towards timber, are: timber construction techniques and technology and economic viability. These findings form the thesis model as shown in figure 9.1.

Actionable recommendations or in this case the considered triggering questions leading towards

actions that can be asked through each of the influencing conditions, which leads to the desired innovation outcomes can be set up. In FIGURE NUMBER the activating questions related to the overarching category managerial lever create the open dialogue on how innovation can be incorporated into an organization. These type of questions has the aim of creating space for holding an open dialogue that allows the personnel within an organization to discuss either the barriers or opportunities they see in incorporating timber in projects throughout the project's lifecycle (e.g. from acquisition towards project management and upon delivery of the timber project).

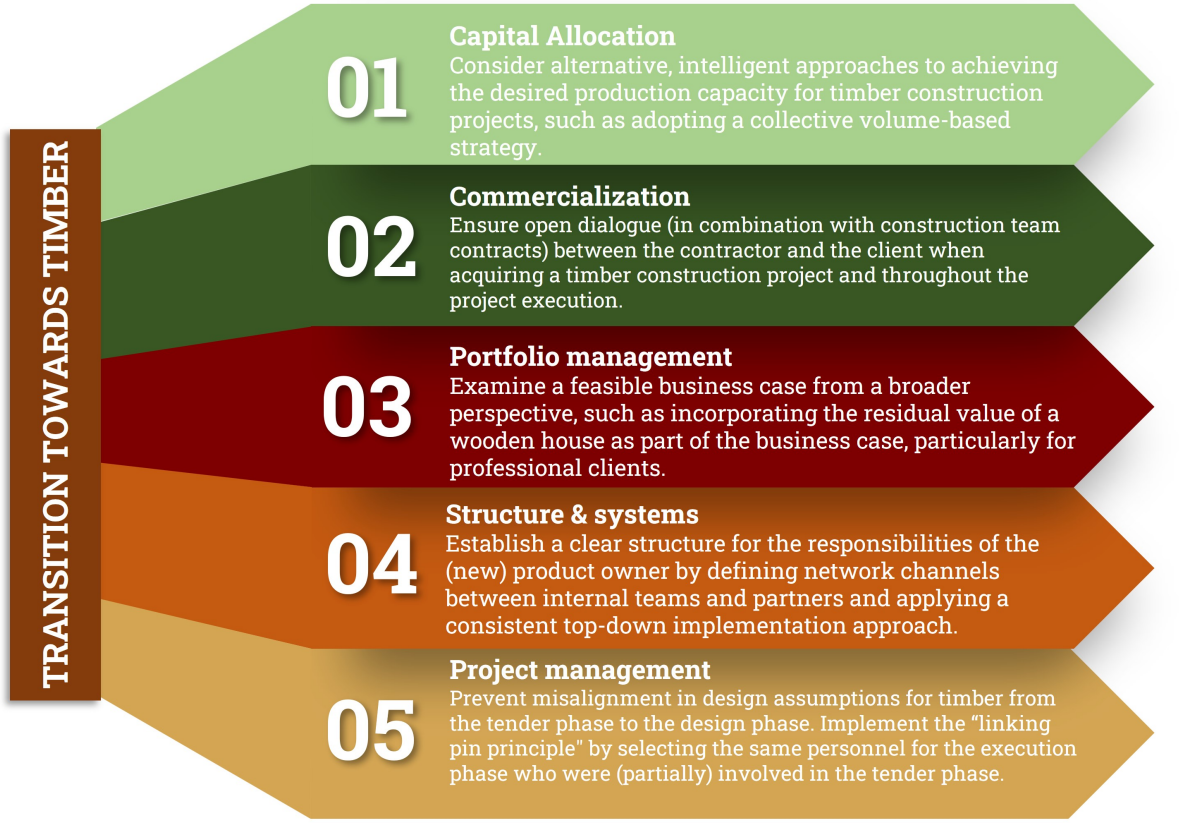


Figure 9.3: 5-step-strategy transition towards timber in residential construction industry

9.3. Conclusion main research question

The crafted socio-technical model consisting of the socio-technical factors, enabling processes and relations as described in the previous section adds value to the multifaceted and complex interplay of key factors, conditions, and actors in the residential construction industry through several concluding remarks.

The defined influencing conditions cover the factors and distinctive key factors that are crucial for the transition towards timber from a construction company's perspective. Even though the model is crafted from this point of view, the use of it can also be suitable for lead clients who, as found in this research, also undergo the same leadership influence, managerial levers, and business processes as the contractor is undergoing. As difference can be highlighted that the client inherently is not as much involved in product and project development as the contractor is as defined in the transition towards timber with regard to conceptualization and industrialization.

The added value of this model is situated in the completeness of the set of influencing conditions, where the organization can merge actionable outcomes or recommendations by asking the triggering questions that are associated with each of the categories.

As highlighted earlier in this chapter and through the findings, in order to deploy timber building concepts on a large scale, the simultaneous consideration of advancing multiple influencing conditions within the three overarching categories is recommended. This is due to the fact that the conditions are interrelated through connections that are not mutually exclusive, but rather multidirectional and interdependent. Herein the underlying connections provide insights for the actors within the regime when adjusting one 'rotary knob' and how that affects the other conditions.

9.4. Dissemination of Research

In this chapter, the dissemination of my research will be explained, detailing the various methods and activities undertaken to share and communicate the findings of my master's thesis. The primary aim of dissemination is to ensure that the insights gained from the study reach both practical and academic audiences effectively, fostering a broader impact.

To achieve this, the dissemination process was divided into two main avenues: practical and scientific contribution.

9.4.1. Practical Dissemination

- **Group presentations**
  Tenderbureau Meeting: Firstly, I presented my research findings to a group of six colleagues involved in supporting tender requirements for timber projects. This presentation focused on integrating the study's insights into the tendering process, highlighting key findings related to timber construction techniques and their practical implications.

  Commercial Teams Update Meeting: Secondly, I also delivered a presentation to 40 colleagues responsible for the acquisition, client contact, and tender phases of timber projects. This session emphasized the importance of design choices and tender feasibility and aimed to provide actionable insights that could impact decision-making processes in timber project acquisition.

- **One pager individual follow-up practitioners**
  Furthermore, I created and distributed one-pagers summarizing the key findings and recommendations of my study to all 17 interviewees. These documents were intended for dissemination within their respective teams. Feedback and responses received from these stakeholders were used to refine recommendations and enhance the implementation of findings within their teams.

- **Organizational storage thesis recommendations and report** An important aspect of practical dissemination involved storing the research paper within the SharePoint/Teams environment of the commercial organization. This strategic placement ensures that the findings are easily accessible to all relevant teams and departments within the organization. By integrating my research into the organization's digital infrastructure, I ensured that the findings are easily accessible to all relevant teams and departments within BAM Wonen. This contribution not only supports internal knowledge-sharing and decision-making processes but also promotes the adoption of timber construction practices by providing a readily available resource for future projects and strategic planning.

9.4.2. Scientific Dissemination

- **Research paper**
  In collaboration with my first supervisor, I authored a research paper that synthesizes my study into a comprehensive narrative. The paper outlines the main findings, explores the relationships between socio-technical factors, identifies enabling processes, and integrates these insights with the Technological Innovation System (TIS) framework. This work culminates in a proposed five-step implementation strategy framework for advancing timber construction practices.

- **Collaboration with BuiltByNature**
  In addition within the scientific dissemenation I reached out to BuiltByNature, an organization that maintains an extensive catalog of research focused on timber. I requested to publish my paper and master thesis report on their website and proposed a collaboration for further research. This partnership aims to complement ongoing studies on socio-technical factors affecting the transition to timber, providing additional data and insights to support their research agenda.

10

Recommendations

In this chapter, the recommendations for both further research as well as practice will be given. The recommendations are distilled from the interviews, data structuring analysis, and upon answering the research questions of this thesis.

10.1. Recommendations for further research

The recommendations that can be given for further research are given below.

1. This study mainly focused on the tender phase and design phase upon collecting the instances from practice. Therefore the key socio-technical factors found are predominantly derived in the early phase of a project. In order to broaden the perspective on these key factors and the categorizations with the detailed characteristics it would be interesting to take the operational phase upon delivery into consideration and analyse these stages. This could lead to new insights and enhanced assessment of the categories and characteristics that influences the transition towards timber.

2. In this research the dynamic nature of two TIS building blocks, respectively construction techniques & technology and economic viability have been identified and considered in the results. As the crafted TIS model consists of a total of five dimensions of innovation (e.g. TIS building blocks) it is relevant to conduct further research on the evolvement of these dimensions over time. Herein insights can be gained whether the building blocks are subject to changes over time and to which extent this happens.

3. It would add significantly to the insights of this research when further study in (European) countries is conducted wherein timber already has taken its speed out of the early adaptors phase. Predominantly in The Netherlands, the focus of this research has been identified to be in the early stage of adopting timber, the added value can be found in tangible next steps and lessons learned that are valuable for sharing and securing in the residential construction industry.

4. The framework of this study focuses on the interplay between socio-technical factors that both operate autonomously and dependently with each other. As found in the results the overarching identification of economic viability made its presence in this framework. Therefore it is interesting to broaden the perspective of the framework by incorporating the interplay of the so-called triple bottom line interdependency of socio-technical-economic factors. In addition to this recommendation, monetizing and evaluating the impact of the factors through tangible data in the timber cases would enhance the reliability of the results in this research.

5. The current study and TIS model have been adopted by taking a company's perspective. Herein

it would add value to the actual implementation of timber projects by taking a client's perspective. This would add new insights and also validate a couple of instances that have been given from a client's perspective that similar key socio-technical factors are also present for leadership, managerial levers, and business processes in their organization.

6. Lastly a recommendation can be given to conduct further research on the perceived barriers, drivers, and opportunities for specifically midrise buildings in the timber transition such as apartments. Herein light can be shed on how the deployment of different types of timber construction leads to similar or different perceptions of the key factors in relation to the TIS framework.

10.2. Recommendations for practice

The recommendations that can be given for the construction company are given below.

Several quick wins have been identified to implement in timber projects accordingly as derived from the instances mentioned in the case studies. These are explained in the following part.

- First of all, it is recommended to perform a (detailed) risk analysis and assessment considering the risk matrix adjusted towards timber building practices derived from the previous pilot projects. In line with this, it is recommended to hold a risk session with (experienced) project managers and the industrialization team to discuss and propose mitigating measures where relevant for timber projects, as this has been identified to be missing in the timber cases.

- For the project team especially in the design phase ensure compliance with Dutch Building Codes when optimizing the timber design by identifying at the start of the project the needed documents to provide evidence of compliance with local regulations on the performance and quality of the building. And stay away from converting design principles and choices as have been experienced with concrete into wood.

- Consider putting driven leaders or change managers in charge that can create alignment of business processes and throughout the layers of managerial levers upon decision-making. Subsequently, (key-)account managers are recommended to keep a clear eye on the current perception of the client on timber projects and perhaps the client's alignment with its stakeholders that influence their perception inherently.

- If possible enhance the support of (academic) research in the early processes of design optimization and timber construction techniques. Herein research for a designated period that is conducted within the organization can directly support the design choices made by the project team (f.e. implemented in Leeuwepoort).

- Ensure contracting (potential) partners with timber suppliers outside of The Netherlands through effective use of ongoing discussions of timber projects in early stages (f.e. implemented in Leeuwepoort). By doing this an initial network can be formed and expanded when the first pilot projects in timber seem successfully executed in collaboration with the partner.

- Invest more time in defining the clear allocation of shifts in responsibilities of the (new) product owner and designated communication channels between project teams and the industrialization team in the new process of working. This involves the steps of involving colleagues in becoming aware of the new process, making it discoverable for colleagues what it entails and actually the most obvious in top-down manner.

- Put more effort in making sure that there is a cohesive approach throughout the timber project's phases respectively tender, project design, project execution, and delivery. This can be achieved by selecting the same employees for the execution phase that was (partly) involved in the tender phase, the so-called linking pin principle. By doing this the background knowledge and alignment

of the tender design with the project design from the origin can be maximized (f.e. as pointed out in Leeuwepoort).

- Make sure to involve the commercial organization in the upcoming development initiatives on the timber concept and moreover in the development of a new midrise with conceptual building. Misalignment of a new timber product with the market can therefore be avoided.

- Apply strategy to win in tenders. A strategy to win in the context of tenders in construction projects has proved to include a systematic approach aimed at maximizing the chance of winning in a tender (e.g. as seen in Bouwstroom2.0). This means developing a comprehensive, targeted strategy that takes into account the specific requirements of the tender, the strengths of your own organization, and the needs of the client through in-depth tender analysis, (possible) competitor analysis, differentiation and value proposition, strategic partnerships, cost management, quality management, and risk management analyses.

In the following part, several focus points that are derived from this research that can be recommended are recommended.

- Put effort into developing a roadmap for the upcoming 5 years on timber projects. Important is the involvement of all colleagues at all levels and through a roadmap feedback loops can be incorporated through regular evaluation and adjustment of the roadmap based on progress and monitoring. Part of this is reporting on the progress of multiple timber projects with performance indicators upon achieving milestones but also important lessons learned in order to foster transparency and ownership throughout the organization.

- Investigate a viable business case in a broader perspective. As stipulated in all the timber cases, the economic viability of managing the projects could not be guaranteed, which asks for adding aspects of possible cost-efficient opportunities in relation to the benefits of building with timber. An instance herein is incorporating the residual value of a wooden house as part of the business case, especially for professional clients.

- In all cases ensure the open dialogue between the contractor-client relation upon acquiring a timber project and along the project execution. As mentioned by the practitioners of timber projects from both the contractor's side as well as the client's point of view, Bouwteam contract constructions are more suitable for innovative projects, where the first part of timber pilot projects are part of. This creates space for the client to be more involved in the design process, where allocation of responsibility and accountability also partly shifts toward the client, making it more viable for the contractor to experiment.

- Develop a quick scan tool to accurately analyze the trade-off between feasibility and affordability choices before proceeding with the timber project. Identifying, monetizing, and securing what has been either promised or decided to implement with project-specific alterations ensures alignment throughout the timber project and supports client satisfaction in the end.

- Do not lose the innovative learning capacity within the organization. The shift from a project-based approach towards (innovative) product-based approaches and shift towards sustainable building practices asks for priority of continuously innovating the timber product and inherent processes within the organization. The maturement of a product does not stop when the product has been established, improvements coming from feedback loops on executed timber projects need to be part of organizational learning and adoption.

- Accepting that in this early adaptors phase, the company is now building up learning capacity for pilot projects and that setbacks or investment costs are part of it. Recommended is to get the most out of the pilot projects by experimenting and upon success or not securing and sharing

knowledge and lessons learned.

- Considering alternative smart opportunities to reach the desired production capacity for timber projects through e.g. a shared volume approach. Investigation into whether sharing a factory with the aim to reach full capacity can be viable when it turns out that fulfillment in inter-organizational timber projects will be difficult in the coming years

References

Akan, M. Ö. A., Dhavale, D. G., & Sarkis, J. (2017). Greenhouse gas emissions in the construction industry: An analysis and evaluation of a concrete supply chain. *Journal of Cleaner Production*, *167*, 1195–1207. https://doi.org/10.1016/j.jclepro.2017.07.225

Assaad, R. H. (2024). Examining low-carbon material initiatives: Existing policies, impacts on the procurement of projects, current challenges, and potential solutions to reduce embodied carbon in the construction industry. *Journal of Legal Affairs and Dispute Resolution in Engineering and Construction*, *16*(2), 04523060.

Autelitano, E. K., Famiglietti, E. J., & Motta, M. (2023). Perception of timber. https://builtbn.org/knowledge/perception-of-timber-in-italy_scientific-review-report_polimi.pdf

BAM. (2022). Bam wonen zet nieuwbouw in beweging met innovatief woningconcept flow. Retrieved February 19, 2024, from https://www.bam.com/nl/pers/persberichten/2022/6/bam-wonen-zet-nieuwbouw-in-beweging-met-innovatief-woningconcept-flow

Bass, J. M., Beecham, S., & Noll, J. (2018). Experience of industry case studies: A comparison of multi-case and embedded case study methods. *Proceedings of the 6th International Workshop on Conducting Empirical Studies in Industry*, 13–20. https://doi.org/10.1145/3193965.3193967

Behera, P., Mohanty, R., & Prakash, A. (2015). Understanding construction supply chain management. *Production Planning & Control*, *26*(16), 1332–1350. https://doi.org/https://doi.org/10.1080/09537287.2015.1045953

Bélanger, F., Watson-Manheim, M. B., & Swan, B. R. (2013). A multi-level socio-technical systems telecommuting framework. *Behaviour & Information Technology*, *32*(12), 1257–1279. https://doi.org/10.1080/0144929X.2012.705894

Bergek, A., Jacobsson, S., Carlsson, B., Lindmark, S., & Rickne, A. (2008). Analyzing the functional dynamics of technological innovation systems: A scheme of analysis. *Research policy*, *37*(3), 407–429. https://doi.org/10.1016/j.respol.2007.12.003

Bergek, A., Jacobsson, S., & Sandén, B. A. (2013). 'legitimation'and 'development of positive externalities': Two key processes in the formation phase of technological innovation systems. In *The dynamics of sustainable innovation journeys* (pp. 55–72). Routledge. https://doi.org/http://dx.doi.org/10.1080/09537320802292768

Berry, S., Davidson, K., & Saman, W. (2013). The impact of niche green developments in transforming the building sector: The case study of lochiel park. *Energy policy*, *62*, 646–655. https://doi.org/https://doi.org/10.1016/j.enpol.2013.07.067

Blaß, H. J., & Sandhaas, C. (2017). *Timber engineering-principles for design*. KIT Scientific Publishing.

Blayse, A. M., & Manley, K. (2004). Key influences on construction innovation. *Construction innovation*, *4*(3), 143–154. https://doi.org/https://doi.org/10.1108/14714170410815060

Boelhouwer, P. (2002). Trends in dutch housing policy and the shifting position of the social rented sector. *Urban studies*, *39*(2), 219–235. https://doi.org/https://doi.org/10.1080/00420980120102939

Borges, A., & Radgen, P. (1997). Sorget-social and organisational issues in the adoption of advanced energy technologies in manufacturing. final report. https://publica-rest.fraunhofer.de/server/api/core/bitstreams/30300681-516c-4959-8fa5-36dec7c4060e/content

Bostrom, R. P., & Heinen, J. S. (1977). Mis problems and failures: A socio-technical perspective. part i: The causes. *MIS quarterly*, 17–32. https://doi.org/10.2307/249019

Bouwteam. (2012). De bouw in acties: Investerings- en innovatieagenda voor de woning- en utiliteitsbouw. Retrieved March 28, 2024, from https://www.eerstekamer.nl/overig/20120524/investerings_en_innovatieagenda/document

Bronsvoort, E., Veldboer, T., Fischer, A., te Slaa, A., & Kaptein, T. (n.d.). Bouwen aan een houten toekomst scenarios voor bouwen met klimaatpositieve materialen. Retrieved August 19, 2024, from www.circle-economy.com

Buchanan, A. H., & Abu, A. K. (2017). *Structural design for fire safety*. John Wiley & Sons.

Budiyanto, C., Prananto, A., & Tan, F. (2019). Designing embedded case study research approach in educational research. *Online Submission*, *3*(1), 1–18. https://doi.org/http://dx.doi.org/10.20961/ijpte.v3i1.15002

Cao, Z., Masanet, E., Tiwari, A., & Akolawala, S. (2021). Decarbonizing concrete: Deep decarbonization pathways for the cement and concrete cycle in the united states, india, and china. *Industrial sustainability analysis lab-Climateworks foundation*.

Carlsson, B., Jacobsson, S., Holmén, M., & Rickne, A. (2002). Innovation systems: Analytical and methodological issues. *Research policy*, *31*(2), 233–245. https://doi.org/10.1016/S0048-7333(01)00138-X

CBS. (2019). Greenhouse gas emissions down. Retrieved March 16, 2024, from https://www.cbs.nl/en-gb/news/2019/37/greenhouse-gas-emissions-down

CBS. (2023). Greenhouse gas emissions 9 percent lower in 2022. Retrieved March 16, 2024, from https://www.cbs.nl/en-gb/news/2023/11/greenhouse-gas-emissions-9-percent-lower-in-2022

Chastas, P., Theodosiou, T., Kontoleon, K. J., & Bikas, D. (2018). Normalising and assessing carbon emissions in the building sector: A review on the embodied co2 emissions of residential buildings. *Building and Environment*, *130*, 212–226. https://doi.org/10.1016/j.enbuild.2010.09.005

Cokins, G. (2009). *Performance management: Integrating strategy execution, methodologies, risk, and analytics*. John Wiley & Sons.

Copper8 & Metabolic-consulting. (n.d.). Circulaire bouw 2035: Aanzet tot een toekomstperspectief. Retrieved February 5, 2024, from https://open.overheid.nl/documenten/0730ec4d-4f4b-43a3-8aad-2747efc37b8b/file

Doyon, A., & Moore, T. (2019). The acceleration of an unprotected niche: The case of nightingale housing, australia. *Cities*, *92*, 18–26. https://doi.org/https://doi.org/10.1016/j.cities.2019.03.011

Dubois, A., & Gadde, L.-E. (2002). The construction industry as a loosely coupled system: Implications for productivity and innovation. *Construction management & economics*, *20*(7), 621–631. https://doi.org/https://doi.org/10.1080/01446190210163543

Economidou, M., Atanasiu, B., Despret, C., Maio, J., Nolte, I., Rapf, O., Laustsen, J., Ruyssevelt, P., Staniaszek, D., Strong, D., et al. (2011). Europe's buildings under the microscope. a country-by-country review of the energy performance of buildings. https://www.researchgate.net/profile/Dan-Staniaszek-2/publication/271200847_Europe's_buildings_under_the_microscope_A_country-by-country_review_of_the_energy_performance_of_buildings/links/56fd1eca08ae3c85c0c9bac7/Europes-buildings-under-the-microscope-A-country-by-country-review-of-the-energy-performance-of-buildings.pdf?_tp=eyJjb250ZXh0Ijp7ImZpcnN0UGFnZSI6InB1YmxpY2F0aW9uIiwicGFnZSI6InB1YmxpY2F0aW9uIn19

Edquist, C. (2004). Systems of innovation–a critical review of the state of the art. *Handbook of Innovation*, 181–208. https://www.researchgate.net/publication/313108466_Systems_of_innovation-a_critical_review_of_the_state_of_the_art

Eisenhardt, K. M. (1989). Building theories from case study research. *Academy of management review*, *14*(4), 532–550.

Ellsworth-Krebs, K. (2020). Implications of declining household sizes and expectations of home comfort for domestic energy demand. *Nature Energy*, *5*(1), 20–25. https://doi.org/10.1038/s41560-019-0512-1

European Parliament. (n.d.). Eu and the paris agreement: Towards climate neutrality. Retrieved August 19, 2024, from https://www.europarl.europa.eu/topics/en/article/20191115STO66603/eu-and-the-paris-agreement-towards-climate-neutrality

Fell, D. R. (2010). *Wood in the human environment: Restorative properties of wood in the built indoor environment* [Doctoral dissertation, University of British Columbia]. https://open.library.ubc.ca/media/download/pdf/24/1.0071305/1

Fischer, G., & Herrmann, T. (2011). Socio-technical systems: A meta-design perspective. *International Journal of Sociotechnology and Knowledge Development (IJSKD)*, *3*(1), 1–33. 10.4018/jskd.2011010101

for Standardization, E. C. (2011). Nen-en 15978 sustainability of construction works - assessment of environmental performance of buildings - calculation method. Retrieved April 17, 2024, from https://www.nen.nl/en/nen-en-15978-2011-en-165395

Fraanje, P. (2023). Groei industriële houtbouw in nederland. https://www.duurzaamgebouwd.nl/artikel/-article-groei-industriele-houtbouw-in-nederland

Frödell, M., Josephson, P.-E., & Lindahl, G. (2008). Swedish construction clients' views on project success and measuring performance. *Journal of Engineering, Design and Technology*, *6*(1), 21–32. https://doi.org/https://doi.org/10.1108/17260530810863316

Galindo-Rueda, F. (2019). Oslo manual 2018: Guidelines for collecting, reporting and using data on innovation. *National Bureau of Statistics of China, OECD-NBS International Training Workshop on Innovation Statistics. Xi'an, China*, 16–18. https://doi.org/https://doi.org/10.1787/24132764

Galli, R., Teubal, M., et al. (1997). Paradigmatic shifts in national innovation systems. *Systems of innovation: Technologies, institutions and organizations*, 342–370. https://www.researchgate.net/profile/Morris-Teubal/publication/248572128_Paradigmatic_Shifts_in_National_Innovation_Systems/links/5449bc700cf2ea6541341880/Paradigmatic-Shifts-in-National-Innovation-Systems.pdf?_tp=eyJjb250ZXh0Ijp7ImZpcnN0UGFnZSI6InB1YmxpY2F0aW9uIiwicGFnZSI6InB1YmxpY2F0aW9uIn19

Gann, D. M. (1995). Innovation in the construction sector. *Chapters*. https://doi.org/10.1016/j.jengtecman.2023.101747

Gaustad, G., Krystofik, M., Bustamante, M., & Badami, K. (2018). Circular economy strategies for mitigating critical material supply issues. *Resources, Conservation and Recycling*, *135*, 24–33. https://doi.org/https://doi.org/10.1016/j.resconrec.2017.08.002

Geels, F. W. (2004). From sectoral systems of innovation to socio-technical systems: Insights about dynamics and change from sociology and institutional theory. *Research policy*, *33*(6-7), 897–920. https://doi.org/10.1016/j.respol.2004.01.015

Geraedts, R., Wamelink, J., Bossink, B., Van Hoek, T., Drijver, M., Fraanje, P., Nienhuis, A., Tan, G., & Hulspas, D. (2014). Routekaart innovatieakkoord bouw: Eindverslag van het actieteam innovatie.

Gimenez, C., Sierra, V., & Rodon, J. (2012). Sustainable operations: Their impact on the triple bottom line. *International journal of production economics*, *140*(1), 149–159. https://doi.org/https://doi.org/10.1016/j.ijpe.2012.01.035

Gosselin, A., Blanchet, P., Lehoux, N., & Cimon, Y. (2018). Collaboration enables innovative timber structure adoption in construction. *Buildings*, *8*(12), 183. https://doi.org/https://doi.org/10.3390/buildings8120183

Goverse, T., Hekkert, M. P., Groenewegen, P., Worrell, E., & Smits, R. E. (2001). Wood innovation in the residential construction sector; opportunities and constraints. *Resources, conservation and recycling*, *34*(1), 53–74. https://doi.org/https://doi.org/10.1016/S0921-3449(01)00093-3

Grace, J. (2004). Understanding and managing the global carbon cycle. *Journal of Ecology*, *92*(2), 189–202. https://doi.org/https://doi.org/10.1111/j.0022-0477.2004.00874.x

Green, M. C., & Eric, K. (2012). The case for tall wood buildings how mass timber offers a safe, economical, and environmentally friendly alternative for tall building structure. Retrieved April 17, 2024, from https://cwc.ca/wp-content/uploads/publications-Tall-Wood.pdf?utm_medium=website&utm_source=archdaily.com

Grübler, A. (2003). *Technology and global change*. Cambridge university press.

Gustafsson, J. (2017). Single case studies vs. multiple case studies: A comparative study.

Gustavsson, L., Pingoud, K., & Sathre, R. (2006). Carbon dioxide balance of wood substitution: Comparing concrete-and wood-framed buildings. *Mitigation and adaptation strategies for global change*, *11*, 667–691. 10.1007/s11027-006-7207-1

Hafner, A., & Schäfer, S. (2018). Environmental aspects of material efficiency versus carbon storage in timber buildings. *European Journal of Wood and Wood Products*, *76*(3), 1045–1059. https://doi.org/https://doi.org/10.1007/s00107-017-1273-9

Häkkinen, T., & Belloni, K. (2011). Barriers and drivers for sustainable building. *Building Research & Information*, *39*(3), 239–255. https://doi.org/10.1080/09613218.2011.561948

Hardaker, G. (1998). An integrated approach towards product innovation in international manufacturing organisations. *European Journal of Innovation Management*, *1*(2), 67–73. https://doi.org/10.1108/14601069810217248

Hardin, D., Stephan, E. G., Wang, W., Corbin, C. D., & Widergren, S. E. (2015). *Buildings interoperability landscape* (tech. rep.). Pacific Northwest National Lab.(PNNL), Richland, WA (United States). https://doi.org/10.2172/1234792

Haroglu, H., Glass, J., & Thorpe, T. (2009). A study of professional perspectives on structural frame selection. *Construction Management and Economics*, *27*(12), 1209–1217. https://doi.org/https://doi.org/10.1080/01446190903233129

Hawkins, W. (2021). Timber and carbon sequestration.

Hellsmark, H., & Jacobsson, S. (2009). Opportunities for and limits to academics as system builders—the case of realizing the potential of gasified biomass in austria. *Energy Policy*, *37*(12), 5597–5611. https://doi.org/10.1016/j.enpol.2009.08.023

Henderson, J. R., & Ruikar, K. (2010). Technology implementation strategies for construction organisations. *Engineering, Construction and Architectural Management*, *17*(3), 309–327. http://dx.doi.org/10.1108/09699981011038097

Hough, R. (2019). Rethinking timber buildings seven perspectives on the use of timber in building design and construction. *ARUP: London, UK*, 2. https://www.arup.com/globalassets/downloads/insights/rethinking-timber-buildings.pdf

IEA, B. (2019). The critical role of buildings. *International Energy Agency*.

Ivanova, D., Vita, G., Steen-Olsen, K., Stadler, K., Melo, P. C., Wood, R., & Hertwich, E. G. (2017). Mapping the carbon footprint of eu regions. *Environmental Research Letters*, *12*(5), 054013. https://iopscience.iop.org/article/10.1088/1748-9326/aa6da9/pdf

Jacobsson, S., & Bergek, A. (2004). Transforming the energy sector: The evolution of technological systems in renewable energy technology. *Industrial and corporate change*, *13*(5), 815–849. https://doi.org/10.1093/icc/dth032

Janlert, L.-E., & Stolterman, E. (2008). Complex interaction. *ACM Transactions on Computer-Human Interaction (TOCHI)*, *17*(2), 1–32. https://doi.org/10.1145/1746259.1746262

Jiménez, P., Dunkl, A., Eibel, K., Denk, E., Grote, V., Kelz, C., & Moser, M. (2015). Evaluating psychological aspects of wood and laminate products in indoor settings with pictures. *Forest products journal*, *65*(5-6), 263–271. https://doi.org/https://doi.org/10.13073/FPJ-D-14-00003

Johannessen, J.-A., Olsen, B., & Lumpkin, G. T. (2001). Innovation as newness: What is new, how new, and new to whom? *European Journal of innovation management*, *4*(1), 20–31. https://doi.org/10.1108/14601060110365547

Johne, A. (1999). Successful market innovation. *Innovationsmanagement*, 163–170. https://doi.org/10.1108/14601069910248838

Jones, K., Stegemann, J., Sykes, J., & Winslow, P. (2016). Adoption of unconventional approaches in construction: The case of cross-laminated timber. *Construction and building materials*, *125*, 690–702. https://doi.org/https://doi.org/10.1016/j.conbuildmat.2016.08.088

Jović, S., Konstantinović, D., & Peško, I. (2022). Urbanisation as a tool for economic growth–novi sad the developmental city. *Advances in Civil and Architectural Engineering*, *13*(25), 1–13. https://doi.org/10.13167/2022.25.1

Kantola, M., & Saari, A. (2016). Project delivery systems for nzeb projects. *Facilities*, *34*(1/2), 85–100. https://doi.org/https://doi.org/10.1108/F-03-2014-0025

Kaufmann, A., & Tödtling, F. (2001). Science–industry interaction in the process of innovation: The importance of boundary-crossing between systems. *Research policy*, *30*(5), 791–804. https://doi.org/https://doi.org/10.1016/S0048-7333(00)00118-9

Kaufmann, H., Krötsch, S., & Winter, S. (2018). *Manual of multistorey timber construction*. Detail.

Keijzer, E., Klerks, S., van Leeuwen, S., Nijman, R., & Fraanje, P. (2020). Een verkenning van het potentieel van co2-opslag bij houtbouw. *TNO report*. 10.13140/RG.2.2.36146.32966

Kibert, C. J. (2016). *Sustainable construction: Green building design and delivery*. John Wiley & Sons.

Kircher, M. (2021). Reducing the emissions scope 1-3 in the chemical industry. *Journal of Business Chemistry*, *18*(1), 2–8. 10.17879/88069570495

Klein Woolthuis, R. J. (2010). Sustainable entrepreneurship in the dutch construction industry. *Sustainability*, *2*(2), 505–523. https://doi.org/https://doi.org/10.3390/su2020505

Klimaatakkoord. (n.d.). Wat is het verschil tussen het klimaatakkoord en de klimaatwet? Retrieved March 16, 2024, from https://www.klimaatakkoord.nl/klimaatakkoord/vraag-en-antwoord/wat-is-het-verschil-tussen-het-klimaatakkoord-en-de-klimaatwet

Kline, S., & Rosenberg, N. (1986). The positive sum strategy: Harnessing technology for economic growth. https://doi.org/https://doi.org/10.17226/612

Knott, E., Rao, A. H., Summers, K., & Teeger, C. (2022). Interviews in the social sciences. *Nature Reviews Methods Primers*, *2*(1), 73. https://doi.org/10.1038/s43586-022-00150-6

Kremer, P., & Simmons, M. (n.d.). Overcoming psychological barriers to widespread acceptance of mass timber construction in australia. 2016.

Kremer, P. D., & Symmons, M. A. (2018). Perceived barriers to the widespread adoption of mass timber construction: An australian construction industry case study. *Mass Timber Construction Journal*, *1*(1), 1–8.

Kremer, P., & Symmons, M. (2015). Mass timber construction as an alternative to concrete and steel in the australia building industry: A pestel evaluation of the potential. *International Wood Products Journal*, *6*(3), 138–147. https://doi.org/https://doi.org/10.1179/2042645315Y.0000000010

Kuitert, L., Volker, L., & Hermans, M. H. (2019). Taking on a wider view: Public value interests of construction clients in a changing construction industry. *Construction management and economics*, *37*(5), 257–277. https://doi.org/https://doi.org/10.1080/01446193.2018.1515496

Kulatunga, U., Amaratunga, D., & Haigh, R. (2009). Critical success factors of construction research and development. *Construction Management and Economics*, *27*(9), 891–900. https://doi.org/https://doi.org/10.1080/01446190903186152

Kvale, S. (1994). Ten standard objections to qualitative research interviews. *Journal of phenomenological psychology*, *25*(2), 147–173.

Langley, D. J., Pals, N., & Ortt, J. R. (2005). Adoption of behaviour: Predicting success for major innovations. *European Journal of Innovation Management*, *8*(1), 56–78. https://doi.org/10.1108/14601060510578574

Lehmann, S. (2012). Sustainable construction for urban infill development using engineered massive wood panel systems. *Sustainability*, *4*(10), 2707–2742. https://doi.org/https://doi.org/10.3390/su4102707

Lehmann, S. (2013). Low carbon construction systems using prefabricated engineered solid wood panels for urban infill to significantly reduce greenhouse gas emissions. *Sustainable Cities and Society*, *6*, 57–67. https://doi.org/https://doi.org/10.1016/j.scs.2012.08.004

Lessing, J., Stehn, L., & Ekholm, A. (2015). Industrialised house-building–development and conceptual orientation of the field. *Construction innovation*, *15*(3), 378–399. https://doi.org/10.1108/CI-06-2014-0032

Levander, E. (2010). *Addressing client uncertainty: A swedish property owners' perspective on industrialised timber framed housing and property* [Doctoral dissertation, Luleå tekniska universitet]. https://ltu.diva-portal.org/smash/get/diva2:999836/FULLTEXT01.pdf

Lindbergh, L. B. (2009). *The relationship between project manager perceived capability, organizational culture, and project outcomes*. Capella University.

Lippke, B., & Perez-Garcia, J. (2008). Will either cap and trade or a carbon emissions tax be effective in monetizing carbon as an ecosystem service. *Forest Ecology and Management*, *256*(12), 2160–2165.

Luijkx, T., Kuindersma, P., Weterings, H., & Willems, M. (2021). Rapportage woningbouw in hout. Retrieved April 17, 2024, from https://www.omgevingsweb.nl/wp-content/uploads/po-assets/567998.pdf

Lundvall, B.-A., et al. (1992). *National systems of innovation: Towards a theory of innovation and interactive learning* (Vol. 242). London Pinter.

Minunno, R., O'Grady, T., Morrison, G. M., & Gruner, R. L. (2021). Investigating the embodied energy and carbon of buildings: A systematic literature review and meta-analysis of life cycle assessments. *Renewable and Sustainable Energy Reviews*, *143*, 110935. https://doi.org/10.1016/j.rser.2021.110935

Miozzo, M., & Dewick, P. (2002). Building competitive advantage: Innovation and corporate governance in european construction. *Research policy*, *31*(6), 989–1008. https://doi.org/https://doi.org/10.1016/S0048-7333(01)00173-1

Moore, T. (2012). *Facilitating a transition to zero emission new housing in australia: Costs, benefits and direction for policy* [Doctoral dissertation, RMIT University]. https://www.researchgate.net/profile/Trivess-Moore/publication/259334480_Facilitating_a_transition_to_zero_emission_

new_housing_in_Australia_Costs_benefits_and_direction_for_policy/links/62759a1b3a23744a726931f8/Facilitating-a-transition-to-zero-emission-new-housing-in-Australia-Costs-benefits-and-direction-for-policy.pdf?_tp=eyJjb250ZXh0Ijp7ImZpcnN0UGFnZSI6InB1YmxpY2F0aW9uIiwicGFnZSI6InB1YmxpY2F0aW9uIn19

Moore, T., & Doyon, A. (2023). *A transition to sustainable housing: Progress and prospects for a low carbon housing future*. Springer Nature.

Motowidlo, S. J., Borman, W. C., & Schmit, M. J. (2014). A theory of individual differences in task and contextual performance. In *Organizational citizenship behavior and contextual performance* (pp. 71–83). Psychology Press.

Murtagh, N., Scott, L., & Fan, J. (2020). Sustainable and resilient construction: Current status and future challenges. *Journal of Cleaner Production*, *268*, 122264. https://doi.org/10.1016/j.jclepro.2020.122264

Nilsson, E., Ménard, S., Bard, D., & Hagberg, K. (2023). Effects of building height on the sound transmission in cross-laminated timber buildings–airborne sound insulation. *Building and Environment*, *229*, 109985. https://doi.org/https://doi.org/10.1016/j.buildenv.2023.109985

North, D. C. (1990). *Institutions, institutional change and economic performance* (Vol. 4). Cambridge university press.

Nuñez-Cacho, P., Górecki, J., Molina-Moreno, V., & Corpas-Iglesias, F. A. (2018). What gets measured, gets done: Development of a circular economy measurement scale for building industry. *Sustainability*, *10*(7), 2340. https://doi.org/https://doi.org/10.3390/su10072340

Nyrud, A. Q., & Bringslimark, T. (2010). Is interior wood use psychologically beneficial? a review of psychological responses toward wood. *Wood and Fiber Science*, 202–218. https://wfs.swst.org/index.php/wfs/article/download/1365/1365/0

Oostindië, H., & van Broekhuizen, R. (2008). The dynamics of novelty production. In *Unfolding webs-the dynamics of regional rural development* (pp. 68–86). Van Gorcum. https://www.researchgate.net/profile/Rudolf-Van-Broekhuizen/publication/37792681_The_Dynamics_of_Novelty_Production/links/55dc3d9008aec156b9b010cc/The-Dynamics-of-Novelty-Production.pdf?_tp=eyJjb250ZXh0Ijp7ImZpcnN0UGFnZSI6InB1YmxpY2F0aW9uIiwicGFnZSI6InB1YmxpY2F0aW9uIn19

Ortt, J. R., & Kamp, L. M. (2022). A technological innovation system framework to formulate niche introduction strategies for companies prior to large-scale diffusion. *Technological Forecasting and Social Change*, *180*, 121671. https://doi.org/10.1016/j.techfore.2022.121671

Paja, E., Dalpiaz, F., & Giorgini, P. (2013). Managing security requirements conflicts in socio-technical systems. *Conceptual Modeling: 32th International Conference, ER 2013, Hong-Kong, China, November 11-13, 2013. Proceedings 32*, 270–283. https://doi.org/10.1007/978-3-642-41924-9_23

Parry-Husbands, H., & Parker, G. (2014). Wood naturally better: Media advertising & consumer research. *Forest & Wood Products Australia*.

Pasmore, W. A. (1988). Designing effective organizations: The sociotechnical systems perspective. *(No Title)*. https://doi.org/10.5465/amr.1989.4279087

Plan Radar. (n.d.). Decarbonising the construction industry: Opportunities and challenges. Retrieved August 19, 2024, from https://www.planradar.com/au/decarbonising-the-construction-industry/

Raven, R., Reynolds, D., Lane, R., Lindsay, J., Kronsell, A., & Arunachalam, D. (2021). Households in sustainability transitions: A systematic review and new research avenues. *Environmental Innovation and Societal Transitions*, *40*, 87–107. https://doi.org/https://doi.org/10.1016/j.eist.2021.06.005

Ribeirinho, M. J., Mischke, J., Strube, G., Sjödin, E., Blanco, J. L., Palter, R., Biörck, J., Rockhill, D., & Andersson, T. (2020). The next normal in construction: How disruption is reshaping the world's largest ecosystem. *McKinsey & Company*. https://www.mckinsey.com/capabilities/operations/our-insights/the-next-normal-in-construction-how-disruption-is-reshaping-the-worlds-largest-ecosystem#/download/%2F~%2Fmedia%2Fmckinsey%2Fbusiness%20functions%2Foperations%2Four%20insights%2Fthe%20next%20normal%20in%20construction%2Fthe-next-normal-in-construction.pdf%3FshouldIndex%3Dfalse

Rijksoverheid. (n.d.-a). Dashboard klimaatbeleid: Beleidstheorie. Retrieved March 16, 2024, from https://dashboardklimaatbeleid.nl/mosaic/mosaic/beleidstheorie-5

Rijksoverheid. (n.d.-b). Voortgang klimaatdoelen. Retrieved February 5, 2024, from https://www.rijksoverheid.nl/onderwerpen/klimaatverandering/voortgang-klimaatdoelen#:~:text=In%202030%20moet%20Nederland%2055,is%20de%20uitstoot%20dus%20nul

Rijksoverheid. (2023). Nationale aanpak biobased bouwen van boerenland tot bouwmateriaal. https://open.overheid.nl/documenten/36800f92-e4bc-4d76-b152-073736609290/file

Robati, M., Oldfield, P., Nezhad, A. A., Carmichael, D. G., & Kuru, A. (2021). Carbon value engineering: A framework for integrating embodied carbon and cost reduction strategies in building design. *Building and environment*, *192*, 107620. https://doi.org/10.1016/j.buildenv.2021.107620

Rogers, E. M., Singhal, A., & Quinlan, M. M. (2014). Diffusion of innovations. In *An integrated approach to communication theory and research* (pp. 432–448). Routledge. https://www.researchgate.net/profile/Rob-Geraedts/publication/281579050_Routekaart_Innovatieakkoord_Bouw_Eindverslag_van_het_Actieteam_Innovatie/links/560176fa08ae42bbd540f863/Routekaart-Innovatieakkoord-Bouw-Eindverslag-van-het-Actieteam-Innovatie.pdf?_tp=eyJjb250ZXh0Ijp7ImZpcnN0UGFnZSI6InB1YmxpY2F0aW9uIiwicGFnZSI6InB1YmxpY2F0aW9uIn19

Rohracher, H. (2001). Managing the technological transition to sustainable construction of buildings: A socio-technical perspective. *Technology Analysis & Strategic Management*, *13*(1), 137–150. https://doi.org/10.1080/09537320120040491

RVO. (2017). Milieuprestatie gebouwen - mpg. Retrieved March 27, 2024, from https://www.rvo.nl/onderwerpen/wetten-en-regels-gebouwen/milieuprestatie-gebouwen-mpg

Sahoo, K., Bergman, R., Alanya-Rosenbaum, S., Gu, H., & Liang, S. (2019). Life cycle assessment of forest-based products: A review. *Sustainability*, *11*(17), 4722. https://doi.org/10.3390/su11174722

Sandanayake, M., Lokuge, W., Zhang, G., Setunge, S., & Thushar, Q. (2018). Greenhouse gas emissions during timber and concrete building construction—a scenario based comparative case study. *Sustainable cities and society*, *38*, 91–97. https://doi.org/https://doi.org/10.1016/j.scs.2017.12.017

Santana-Sosa, A., & Kovacic, I. (2022). Barriers, opportunities and recommendations to enhance the adoption of timber within multi-storey buildings in austria. *Buildings*, *12*(9), 1416. https://doi.org/https://doi.org/10.3390/buildings12091416

Sarkar, J. (1998). Technological diffusion: Alternative theories and historical evidence. *Journal of economic surveys*, *12*(2), 131–176. https://doi.org/https://doi.org/10.1111/1467-6419.00051

Schlamadinger, B., & Marland, G. (1996). The role of forest and bioenergy strategies in the global carbon cycle. *Biomass and Bioenergy*, *10*(5-6), 275–300. https://doi.org/10.1016/0961-9534(95)00113-1

Schraven, D., Bukvić, U., Di Maio, F., & Hertogh, M. (2019). Circular transition: Changes and responsibilities in the dutch stony material supply chain. *Resources, Conservation and Recycling*, *150*, 104359. https://doi.org/https://doi.org/10.1016/j.resconrec.2019.05.035

Shirmohammadi, M., Leggate, W., & Redman, A. (2021). Effects of moisture ingress and egress on the performance and service life of mass timber products in buildings: A review. *Construction and Building Materials*, *290*, 123176. https://doi.org/https://doi.org/10.1016/j.conbuildmat.2021.123176

Smith, A. (2007). Translating sustainabilities between green niches and socio-technical regimes. *Technology analysis & strategic management*, *19*(4), 427–450. https://doi.org/https://doi.org/10.1080/09537320701403334

Soete, L., & Freeman, C. (2012). *The economics of industrial innovation*. routledge.

Spink, A., et al. (2010). *Information behavior: An evolutionary instinct* (Vol. 16). Springer. https://doi.org/https://doi.org/10.1007/978-3-642-11497-7

Syed, T. (2020). Identifying mass timber research priorities, barriers to adoption and engineering, procurement and construction challenges in canada. https://www.academia.edu/download/114118065/TahaSyed_Capstone.pdf

Tidd, J., & Bessant, J. R. (2020). *Managing innovation: Integrating technological, market and organizational change*. John Wiley & Sons.

Tupenaite, L., Zilenaite, V., Kanapeckiene, L., Gecys, T., & Geipele, I. (2021). Sustainability assessment of modern high-rise timber buildings. *Sustainability*, *13*(16), 8719. https://doi.org/https://doi.org/10.3390/su13168719

Tushman, M., & O'Reilly, C. A. (2002). *Winning through innovation: A practical guide to leading organizational change and renewal*. Harvard Business Press.

Tykkä, S., McCluskey, D., Nord, T., Ollonqvist, P., Hugosson, M., Roos, A., Ukrainski, K., Nyrud, A. Q., & Bajric, F. (2010). Development of timber framed firms in the construction sector—is eu policy one source of their innovation? *Forest Policy and Economics*, *12*(3), 199–206. https://doi.org/https://doi.org/10.1016/j.forpol.2009.10.003

UNEP. (2020). Global status report for buildings and construction 2020: Towards a zero-emission, efficient and resilient buildings and construction sector. *Global Alliance for Buildings and Construction*. Retrieved February 5, 2024, from https://wedocs.unep.org/bitstream/handle/20.500.11822/34572/GSR_ES.pdf?sequence=3&isAllowed=y

Van Belzen, T. (2020). 'hout flink benadeeld in overheidseisen duurzaam bouwen'. Retrieved September 19, 2024, from https://www.cobouw.nl/290962/forse-kritiek-op-weglaten-co2-opslag-in-milieuberekening-houten-huis

Van de Ven, A., Polley, D., Garud, R., & Venkataraman, S. (1999). Building an infrastructure for the innovation journey. *The Innovation Journey*, 149–180.

Vermeulen, Marco. (n.d.). Ruimte voor biobased bouwen strategische verkenning. Retrieved August 19, 2024, from https://marcovermeulen.eu/files/pub/0255/RuimtevoorBiobasedBouwen.pdf

Vos, R. O. (2007). Defining sustainability: A conceptual orientation. *Journal of Chemical Technology & Biotechnology: International Research in Process, Environmental & Clean Technology*, *82*(4), 334–339. https://doi.org/10.1002/jctb.1675

Walker, G. H., Stanton, N. A., Salmon, P. M., & Jenkins, D. P. (2008). A review of sociotechnical systems theory: A classic concept for new command and control paradigms. *Theoretical issues in ergonomics science*, *9*(6), 479–499. https://doi.org/10.1080/14639220701635470

Wei, W., Zhang, P., Yao, M., Xue, M., Miao, J., Liu, B., & Wang, F. (2020). Multi-scope electricity-related carbon emissions accounting: A case study of shanghai. *Journal of Cleaner Production*, *252*, 119789. https://doi.org/10.1016/j.jclepro.2019.119789

Wheelwright, S. C., & Clark, K. B. (1992). *Revolutionizing product development: Quantum leaps in speed, efficiency, and quality*. Simon; Schuster.

Winch, G. (1998). Zephyrs of creative destruction: Understanding the management of innovation in construction. *Building research & information*, *26*(5), 268–279. https://doi.org/https://doi.org/10.1080/096132198369751

Winch, G. M. (2001). Governing the project process: A conceptual framework. *Construction management and economics*, *19*(8), 799–808. https://doi.org/https://doi.org/10.1080/01446190110074264

Woolthuis, R. K., Mulder, G., & Brandes, F. (2010). Future of industry: Competitive sustainability in the dutch construction sector. *Future*, *2*, 55. https://publications.tno.nl/publication/105206/xCGFYn/TNO-034-DTM-2010-00027.pdf

Yates, M., Linegar, M., & Dujič, B. (2008). *Design of an 8 storey residential tower from klh cross laminated solid timber panels*.

Yin, R. K. (2013). Validity and generalization in future case study evaluations. *Evaluation*, *19*(3), 321–332. https://doi.org/10.1177/1356389013497081

Zainal, Z. (2007). Case study as a research method. *Jurnal kemanusiaan*, *5*(1). https://jurnalkemanusiaan.utm.my/index.php/kemanusiaan/article/view/165

Zainul Abidin, N., & Pasquire, C. L. (2005). Delivering sustainability through value management: Concept and performance overview. *Engineering, Construction and Architectural Management*, *12*(2), 168–180. https://doi.org/https://doi.org/10.1108/09699980510584502

A

Table principles and scores of 'Het Nieuwe Normaal'

ONDERDEEL	INDICATOR	EENHEID	ONDERGRENS	SCORE-MOGELIJKHEID	SCORE
1.1 percentage (massa)	Stort	% van massa	0%	-	0%
	Verbranding	% van massa	0%	-	0%
	Recycling	% van massa	geen	X	71%
	Hergebruik (andere bouwwerken)	% van massa	geen	X	29%
2.1 milieu-prestatie-gebouwen	MPG-score	€/m^2 BVO/jaar	0,5	X	0,462
2.2 Materiaalgebruik	Primaire grondstoffen (niet-hernieuwbaar)	% van massa	max 50%	X*	53%
	Secundaire grondstoffen / biogrondstoffen	% van massa	min 20%	X*	47%
	Biogrondstoffen	% van volume	60%	X	72%
3.1 Koolstofopslag	Construction Stored Carbon	kg/m^2 (bvo)	350	-	409
3.2 CO_2-verdringing	Verdringing secundair of biobased (kg)	kg/m^2 (bvo)	geen	X*	-1,86 kgCO2/m2/jr; of 21622 kg CO2
4.1 Hergebruikspotentie	Hergebruikspotentie (BCI)	%	geen	X*	41% hergebruik 48% recycling 11% verbrand of gestort
4.2 Losmaakbaarheid	Losmaakbaarheid (BCI)	%	geen	X*	82%
5.1 Toxiciteit	Verhouding tussen wel/geen certificaten	stuks	geen	-	2 stuks
6.1 Energiegebruik NTA8800	BENG-1	kWh/m^2	bouwbesluit	-	45,01
	BENG-2	kWh/m^2	0	-	23,96

	BENG-3	%	100%	X	BENG: 56,5; optie NOM: 100
6.2 EPV-geschikt (huur)	EPV 2.0 publicatie 30-11-2022	n.v.t.	n.v.t.	-*	Ja, indien NOM optie wordt gekozen
7.1 Watergebruik	BREEAM WAT	m^3/persoon/dag	geen	-*	0,080 (80,74 liter pp / per dag)
7.2 Hergebruik water	Aandeel regen- en grijs watergebruik	%	geen	X	0%
8.1 Habitat	Hoogwaardige habitat soorten	st	2	-	4
8.2 Groenoppervlak	Verhouding groenoppervlak en perceel	%	70%	X	120%-145%
9.1 Afwatering en berging	Schade ten gevolge heftige regenval	mm/uur	70 mm	-*	116 mm
9.2 Hittestress	TO-juli zonder installaties (NTA8800)	Dagen/jaar	TO-juli	-	voldoet; TO-juli 1,09

B

Informed consent form interviews

Delft University of Technology
HUMAN RESEARCH ETHICS
INFORMED CONSENT TEMPLATES
(Dutch Version: January 2022)

The following templates have been developed by the Human Research Ethics Committee (HREC) to assist you in the design of your Informed Consent materials for non-medical research involving human Research Subjects. **It is important to adapt this template to the outline and requirements of your particular study, using the notes and suggestions provided.**

For additional information or specific expertise on preparing your Informed Consent materials you can consult the following:

- The TU Delft Research Ethics webpages,
- Your faculty Data Steward, the TU Delft Privacy Team
- Our brief guide on Completing the HREC checklist
- Our Risk-Planning tool, Managing Risk in Human Research

If you have any questions about applying for HREC approval which are not dealt with on the Research Ethics webpages, please contact HREC@tudelft.nl

You can find guidance on Informed Consent together with **English versions** of the Informed Consent templates in the Informed Consent section of the Research Ethics webpages.

Key points to include	Suggested text
1. Level (eg: Masters, PhD, research) purpose, potential outcomes and implications of the study 2. The role of TU Delft and any third parties including funding body 3. Who participants are (eg: children, experts, students in a dependent role to the researcher) 4. What exactly what they are being asked to do 5. What if any Personal Data (Personally Identifiable Information and/or Personally Identifiable Research Data) will be collected, and how it will be used, published and managed. This should include clarity on: o how the data you collect will be used during the research o safeguarding personal information, maintaining confidentiality o de-identifying (pseudo/anonymising) data o controlling access to data, data archiving and reuse o (possible) data publication and dissemination, and o data archiving and the retention period for research data or criteria used to determine that 6. What physical, emotional or reputational risks might arise from participation either during or after the study, and what steps will be used to mitigate these risks 7. Participants' right to refuse to answer/withdraw from the study at any time 8. The right (or otherwise) of participants to request access to and rectify or erase personal data 9. Any remuneration for time/compensation for travel 10. Contact details of the Responsible Researcher and procedure for making complaints. **Note: the TUD Human Research Ethics Committee should not be included as a contact and does not deal with participant complaints.**	U wordt uitgenodigd om deel te nemen aan een afstudeeronderzoek genaamd ''Ontgrendeling van houtbouw potentie in Nederland: een kwalitatief onderzoek naar de key-factoren, drivers en barrières bij ontwikkeling van implementatie en strategieën voor houtbouw projecten in de Nederlandse woningbouw. Dit onderzoek wordt uitgevoerd door Melissa Law van de TU Delft in samenwerking met BAM Wonen. Het doel van dit onderzoek is om de belangrijkste sociaal-technische factoren en essentiële actoren te doorgronden die van invloed zijn op de grootschalige implementatie van nieuwe houtbouw concepten in Nederland. Daarbij richt het onderzoek met name op het verkrijgen van inzichten in de complexe interactie en dynamiek tussen aan de ene kant technische factoren en aan de andere kant de wensen en eisen van opdrachtgevers die essentieel zijn bij innovatieve houtbouw concepten. Door het inzichtelijk krijgen van de kritische sleutelfactoren en mogelijke knelpunten binnen de woningbouw sector, zullen waardevolle inzichten worden verkregen voer hoe deze duurzaamheidsuitdagingen op het gebied van houtbouw effectief aangepakt kunnen worden binnen een beperkte tijdsbestek. Het resultaat van het onderzoek zal worden gepresenteerd door middel van een implementatiestrategie framework, wat inzichtelijk maakt welke sociaal-technische factoren op houtbouw concept, de schaal en timing van de implementatie van de innovatie nodig is om de markt met de essentiële actoren te doordringen. Het interview zal circa 60 minuten in beslag nemen en worden opgenomen ter verwerking van de antwoorden. Het interview wordt gebruikt voor het verkrijgen van inzichten wat betreft de huidige situatie van implementatie van houtbouwconcepten en de gerelateerde drivers maar ook de ondervonden barrières. Dit fenomeen zal vanuit verschillende perspectieven worden belicht en de verzamelde inzichten wordt gebruikt voor het hoofdstuk resultaten in het rapport en ook voor het beantwoorden van de hoofdonderzoeksvraag. Daarnaast zullen de (opgenomen) interviewtranscripten ook in de appendices van het rapport toegevoegd worden, uiteraard geanonimiseerd. Je wordt gevraagd om de gestelde vragen tijdens de interview met eerlijkheid te beantwoorden, hiervoor zullen een aantal vragen alvorens gedeeld worden om je eventueel voor te bereiden.

	Zoals bij elke online activiteit is het risico van een databreuk aanwezig. Wij doen ons best om uw antwoorden vertrouwelijk te houden. We minimaliseren de risico's door de antwoorden in het interview in de vorm van interviewtranscripten te de-identificeren door persoonlijke gegevens en alle informatie die kan leiden tot personificatie uit het transcript te verwijderen. Vertrouwelijkheid van de data wordt gewaarborgd door ze alleen op te slaan op één plek en daarbij zal na verzameling van zowel de data als persoonlijke gegevens van de geïnterviewden maximaal 3 maanden bewaard worden. Deze informatie wordt tevens vernietigd nadat het afstudeeronderzoek is afgerond. Uw deelname aan dit onderzoek is volledig vrijwillig, en u kunt zich elk moment terugtrekken zonder reden op te geven. U bent vrij om vragen niet te beantwoorden. Contactgegevens van de uitvoerende onderzoeker: Naam: Melissa Law

PLEASE TICK THE APPROPRIATE BOXES	Yes	No
A: GENERAL AGREEMENT – RESEARCH GOALS, PARTICPANT TASKS AND VOLUNTARY PARTICIPATION		
1. Ik heb de informatie over het onderzoek gedateerd op 12-2-2024 gelezen en begrepen, of deze is aan mij voorgelezen. Ik heb de mogelijkheid gehad om vragen te stellen over het onderzoek en mijn vragen zijn naar tevredenheid beantwoord.	☐	☐
2. Ik doe vrijwillig mee aan dit onderzoek, en ik begrijp dat ik kan weigeren vragen te beantwoorden en mij op elk moment kan terugtrekken uit de studie, zonder een reden op te hoeven geven.	☐	☐
3. Ik begrijp dat mijn deelname aan het onderzoek de volgende punten betekent: • Het verzamelen van gegevens en data d.m.v. een audio-recorded interview (ofwel via Teams of via voice recording) • De audio-recorded interviews zullen ook worden transcript naar tekst, hierbij wordt het verzamelen van persoonlijke gegevens gelimiteerd en wanneer nodig ook geanonimiseerd. De audio-recorded interviews en transcripts zullen maximaal 3 maanden na het afnemen van de interview bewaard worden.	☐	☐
5. Ik begrijp dat de studie op 30-9-2024, bij het plaatsvinden van de afstudeer verdediging, eindigt.	☐	☐
B: POTENTIAL RISKS OF PARTICIPATING (INCLUDING DATA PROTECTION)		
7. Ik begrijp dat mijn deelname betekent dat er persoonlijke identificeerbare informatie en onderzoeksdata worden verzameld, met het risico dat ik hieruit geïdentificeerd kan worden op basis van de antwoorden en transcripts uit het interview. Omdat het onderzoek ook op de repository van de TU Delft wordt gepubliceerd, inclusief de geanonimiseerde transcripts, wordt er zorg gedragen om de gegevens en data zoveel mogelijk te de-identificeren.	☐	☐
9. Ik begrijp dat de volgende stappen worden ondernomen om het risico van een databreuk te minimaliseren, en dat mijn identiteit op de volgende manieren wordt beschermd in het geval van een databreuk: • Het anonimiseren van persoonlijke gegevens; • Het veilig bewaren van verzamelde data op 1 werk OneDrive, waar beperkte toegang tot is; • Het maken van transcripten van de interview door het de-identificeren van de data	☐	☐
10. Ik begrijp dat de persoonlijke informatie die over mij verzameld wordt en mij kan identificeren, zoals naam, functie, e-mail en telefoonnummer, niet gedeeld worden buiten het studieteam.	☐	☐
11. Ik begrijp dat de persoonlijke data die over mij verzameld wordt, vernietigd wordt op 30-9-2024.	☐	☐

PLEASE TICK THE APPROPRIATE BOXES	Yes	No
C: RESEARCH PUBLICATION, DISSEMINATION AND APPLICATION		
11. Ik begrijp dat na het onderzoek de geanonimiseerde informatie gebruikt zal worden voor: • Het onderzoeksrapport wat gepubliceerd zal worden op de Repository van de TU Delft	☐	☐
13. Ik geef toestemming om mijn antwoorden, ideeën of andere bijdrages anoniem te quoten in resulterende producten.	☐	☐
14. Ik geef toestemming om mijn naam te gebruiken voor quotes in resulterende producten	☐	☐
D: (LONGTERM) DATA STORAGE, ACCESS AND REUSE		
16. Ik geef toestemming om de geanonimiseerde data wat betreft de die over mij verzameld worden gearchiveerd worden in de repository van TU Delft opdat deze gebruikt kunnen worden voor toekomstig onderzoek en onderwijs.	☐	☐
17. Ik begrijp dat de toegang tot deze repository open is.	☐	☐

Signatures

_____	_____	_____
Naam deelnemer	Handtekening	Datum

Ik, **de onderzoeker**, verklaar dat ik de informatie en het instemmingsformulier correct aan de potentiële deelnemer heb voorgelezen en, naar het beste van mijn vermogen, heb verzekerd dat de deelnemer begrijpt waar hij/zij vrijwillig mee instemt.

Melissa Law		20-3-2024
_____	_____	_____
Naam onderzoeker	Handtekening	Datum

Contactgegevens van de onderzoeker voor verdere informatie: Melissa Law,

C

Set of semi-structured interview questions

Nederlandse versie interviewvragen voor de casussen

****Start recording****

"Goeiemorgen/goeiemiddag [Naam], hoe gaat het met je? Fijn dat je even de tijd hebt genomen voor dit gesprek. In dit interview wil ik graag meer inzicht krijgen in de belangrijkste sociaal-technische factoren bij de transitie naar houtbouw en jouw ervaringen hierin. Hierbij ben ik voornamelijk op zoek naar praktijk voorbeelden en specifieke situaties die jij binnen jouw rol in de transitie hebt ervaren. Dit interview zal ik opnemen en is ingestoken als een open gesprek, dus voel je vrij om open en eerlijk te zijn.

A.1 Interviewvragen voor sociaal-technische key-factoren in de transitie naar houtbouw

Introductie en achtergrond: (10 min)

1. Kun je kort iets vertellen over je ervaring en betrokkenheid in de bouwsector, specifiek met betrekking tot [Project casus]?

2. Heb je eerder aan projecten gewerkt die gericht zijn op duurzaamheid en houtbouw?

3. Wat is je beslissingsbevoegdheid binnen de organisatie met betrekking tot [Project casus]?

    - Kan je een situatie benoemen waarin je beslissingen hebt genomen specifiek gericht op houtbouw binnen dit project?

Case study

1. Wat waren de uitgangspunten voor de gebiedsontwikkeling van Leeuwenpoort in Utrecht?
2. Wat was jouw rol als projectmanager hierin?
3. Welke uitdagingen ondervonden jullie in het proces in het denken in hout?
4. Waren er ook keuzes die herijkt moesten worden omdat houtbouw nog onbekend was?
5. Was de opdrachtgever welwillend om mee te denken?

Project prestaties en kwaliteit: (10 min)

1. Hoe zou je de prestaties en kwaliteit van het ontwerp in houtbouw bij [Project casus] beoordelen?

    - Zijn er specifieke kwaliteitsnormen of prestatie-indicatoren die je hebt gehanteerd voor dit project?

2. Heb je ervaringen met kwaliteitsproblemen in houtbouw bij [Project casus]? Zo ja, hoe zijn deze opgelost?

Product prijs: (10 min)

1. Hoe verhoudt de prijs van houtbouw zich tot traditionele bouwmethoden binnen [Project casus]?

    - Wat zijn de grootste kostenfactoren in houtbouw voor dit project?

2. Zijn er financiële voordelen of nadelen die je hebt waargenomen in de context van [Project casus]?

Productiesysteem en industrialisatie: (10 min)

1. Kun je het productieproces van houtbouw binnen [Project casus] beschrijven?

- Zijn er specifieke uitdagingen of voordelen in het productieproces van houtbouw ten opzichte van traditionele bouwmethoden?

2. Hoe wordt binnen [Project casus] gezorgd voor efficiëntie en kwaliteit in het productieproces?

Aanvullende producten en diensten: (10 min)

1. Welke aanvullende producten en diensten zijn cruciaal voor het succes van houtbouw in [Project casus]?

    - Kun je voorbeelden geven van hoe deze producten en diensten zijn geïntegreerd in het project?

2. Zijn er specifieke partnerschappen of leveranciers die een belangrijke rol spelen in [Project casus]?

Netwerkvorming en coördinatie: (10 min)

1. Hoe belangrijk is netwerkvorming en coördinatie voor het succes van houtbouw in [Project casus]?

    - Kun je voorbeelden geven van hoe netwerkvorming heeft bijgedragen aan het project?

2. Welke partijen in het netwerk zijn volgens jou essentieel voor de succesvolle implementatie van houtbouw in [Project casus]?

Institutionele factoren: (10 min)

1. Welke institutionele factoren (bijvoorbeeld regelgeving, subsidies) beïnvloeden houtbouw in [Project casus]?

    - Zijn er specifieke regels of instellingen die een grote impact hebben gehad op het project?

2. Hoe zou je de rol van innovatiegerichte instellingen beoordelen in het succes van houtbouw binnen [Project casus]?

Toekomstvisie: (10 min)

1. Is houtbouw volgens jou op dit moment nog een niche product in de markt, specifiek binnen het kader van [Project casus]?

2. Hoe zie jij de toekomst van houtbouw in de komende jaren tot decennium, specifiek met betrekking tot projecten zoals [Project casus]?

- Heb jij hierin als aanjager persoonlijke doelen om deze ambitie binnen dit project te behalen?

3. Wat denk je dat de belangrijkste factoren zijn die het tempo en de schaal van adoptie van houtbouw in de komende jaren zullen bepalen, specifiek in de context van [Project casus]?

****AFRONDING INTERVIEW****

Super, bedankt voor je tijd en openheid, [Naam]. Ik waardeer echt de ervaringen en ideeën die je in openheid hebt gedeeld. Het geeft me een goed beeld van welke factoren in jouw ervaringen het belangrijkst zijn geweest en waar nog verbeteringen en inhaalslag te maken is met de transitie naar houtbouw. Als er nog iets is waar je later aan denkt, weet je me te vinden. Nogmaals dank en laten we in contact blijven. Fijne dag verder!

****Stop recording****

D

Overview tables categorization and characterization

Instance			Characterization & categorization										
			Leader-ship	Managerial Levers					Business Processies				
Case/ interview	Nr.	Description		Mission, goals & strategy	Structure & systems	Resource allocation	Organizational learning & knowledge	Organizational culture	Initiation & decision-making	Portfolio management	Development & implementation	Project management	Commercialization
DeKwekerij	INST1.1	Shift construction techniques from project-based approach to conceptual (timber) design approach		X							X		
DeKwekerij	INST1.2	Early shift construction techniques incorporating sustainable building practices with timber		X					X		X		
DeKwekerij	INST1.3	Adoption rate of new timber construction methods in a conventional construction sector					X						
DeKwekerij	INST1.4	Lack of robust frameworks for timber project assessment			X								
DeKwekerij	INST1.5	Feasibility vs. Affordability – viable business case										X	
DeKwekerij	INST1.6	Assumptions and uncertainties in financial matrix converted from concrete in wood										X	

Case/ interview	Nr.	Description	Leader-ship	Managerial Levers					Business Processies				
				Mission, goals & strategy	Structure & systems	Resource allocation	Organizational learning & knowledge	Organizational culture	Initiation & decision-making	Portfolio management	Development & implementation	Project management	Commercialization
DeKwekerij	INST1.7	Increase failure costs due to undertaking an overly complex timber construction project for an initial pilot										X	
DeKwekerij	INST1.8	Spin-off strategic decision undertaking timber project serving as a catalyst for future opportunities and building legitimacy							X				X
DeKwekerij	INST1.9	Conducting a detailed risk analysis and assessment with corresponding mitigating measures prior to starting the innovative timber design										X	
DeKwekerij	INST1.10	Mitigating novel high-impact risks through acceptance										X	
DeKwekerij	INST1.11	Coordinating new processes of internal network formation and task transfers			X		X						
DeKwekerij	INST1.12	Network formation with knowledgeable external partners and building strong relationships				X							X

Case/ interview	Nr.	Description	Leader-ship	Managerial Levers					Business Processies				
				Mission, goals & strategy	Structure & systems	Resource allocation	Organizational learning & knowledge	Organizational culture	Initiation & decision-making	Portfolio management	Development & implementation	Project management	Commercialization
Ambachts-laan	INST2.1	Ensuring compliance with Dutch Building Codes									X	X	
Ambachts-laan	INST2.2	Allocation of responsibilities research and piloting on construction technique between contractor and client				X						X	
Ambachts-laan	INST2.3	Converting design from concrete into wood while adhering to traditional design choices									X	X	
Ambachts-laan	INST2.4	Shift towards timber inherently leads to incorporating both standardization and industrialization		X	X		X				X		
Ambachts-laan	INST2.5	Design optimization and adoption upon conducting research with designing in timber									X		
Ambachts-laan	INST2.6	The need to provide extensive documentation and evidence of compliance with local regulations on timber performance and quality			X							X	

Case/ interview	Nr.	Description	Leader-ship	Managerial Levers					Business Processes				
				Mission, goals & strategy	Structure & systems	Resource allocation	Organizational learning & knowledge	Organizational culture	Initiation & decision-making	Portfolio management	Development & implementation	Project management	Commercialization
Ambachts-laan	INST2.7	Perception, acceptance & true believe in timber buildings by stakeholders, internal colleagues as well as external clients & resident users (support base)		X				X					
Ambachts-laan	INST2.8	Willingness and buffer to invest in innovative timber projects with regard to learning costs of pilot project				X			X				
Ambachts-laan	INST2.9	Availability of funding by the client for research and piloting in innovative timber construction projects				X						X	
Ambachts-laan	INST2.10	Continuity of an organization, where the traditional way of building still must remain a part		X						X			
Ambachts-laan	INST2.11	Outweighing higher construction costs by using financial compensation on timber projects				X						X	

Case/ interview	Nr.	Description	Leader-ship	Managerial Levers					Business Processies				
				Mission, goals & strategy	Structure & systems	Resource allocation	Organizational learning & knowledge	Organizational culture	Initiation & decision-making	Portfolio management	Development & implementation	Project management	Commercialization
Ambachts-laan	INST2.12	Involvement client in innovative timber designs preferably in a Bouwteam for demarcating liability										X	
Ambachts-laan	INST2.13	Project management on alignment in work culture with international partners										X	
Ambachts-laan	INST2.14	Securing cross-references and knowledge transfer from the first timber construction projects					X						
Ambachts-laan	INST2.15	Alignment of shared ambitions on sustainability and conveying project goals throughout the construction phase		X								X	
Ambachts-laan	INST2.16	Putting forward driven leaders that truly believe in the transition and the future perspective of timber & enthuse their environment	X										
Ambachts-laan	INST2.17	Finding the sweet spot between the pace of upscaling timber projects and reinventing the timber wheel	X				X				X		

Case/ interview	Nr.	Description	Leader-ship	Managerial Levers					Business Processes				
				Mission, goals & strategy	Structure & systems	Resource allocation	Organizational learning & knowledge	Organizational culture	Initiation & decision-making	Portfolio management	Development & implementation	Project management	Commercialization
Leeuwe-poort	INST3.1	Tender appeal & presence of timber as construction material in urban planning & development											X
Leeuwe-poort	INST3.2	Commitment to advance building methods and sustainability with cutting-edge construction techniques		X					X		X		
Leeuwe-poort	INST3.3	Misalignment between the tender bid and design phase for execution on timber projects										X	X
Leeuwe-poort	INST3.4	Support of (academic) research in making design choices on new timber construction techniques					X	X					
Leeuwe-poort	INST3.5	Misalignment of the design principles of the new timber concept in relation to the tender design and knock-out criteria									X		

Case/ interview	Nr.	Description	Leader-ship	Managerial Levers					Business Processies				
				Mission, goals & strategy	Structure & systems	Resource allocation	Organizational learning & knowledge	Organizational culture	Initiation & decision-making	Portfolio management	Development & implementation	Project management	Commercialization
Leeuwe-poort	INST3.6	Limitations on design alterations when cost overruns in the design phase occur due to project's innovative nature and unfamiliar construction techniques										X	
Leeuwe-poort	INST3.7	Termination of project due to unfeasible business case presented by the contractor							X				
Leeuwe-poort	INST3.8	Inadequate risk identification and diversification at the start for determining a quick-scan on feasibility of timber project										X	
Leeuwe-poort	INST3.9	Effective use of ongoing discussions leading to partnerships between construction companies and (experienced) timber suppliers outside of the Netherlands						X					X

Case/ interview	Nr.	Description	Leader-ship	Managerial Levers					Business Processies				
				Mission, goals & strategy	Structure & systems	Resource allocation	Organizational learning & knowledge	Organizational culture	Initiation & decision-making	Portfolio management	Development & implementation	Project management	Commercialization
Leeuwe-poort	INST3.10	Identification and incorporating of knock-out criteria in tender during an innovation trajectory - e.g. fully understanding the client's needs and wishes										X	X
External interviews	INST4.1	Adaptation of legislation and regulations on timber and acceleration of approval processes for timber projects			X								
External interviews	INST4.2	Creation of market alignment by designing timber concept and products to meet specific technical requirements and constraints while integrating stakeholders needs and preferences									X		X
External interviews	INST4.3	Collective advancement besides individual performance		X				X					

Case/ interview	Nr.	Description	Leader-ship	Managerial Levers					Business Processies				
				Mission, goals & strategy	Structure & systems	Resource allocation	Organizational learning & knowledge	Organizational culture	Initiation & decision-making	Portfolio management	Development & implementation	Project management	Commercialization
External interviews	INST4.4	Clear allocation of shifts in responsibilities as product owner and communication channels in new process			X		X						
External interviews	INST4.5	Cohesive approach from engineering towards production and assembly					X					X	
External interviews	INST4.6	Maintaining organizational alignment as change managers within the industrialization			X			X					
External interviews	INST4.7	Rendition of maturing in processes and timber product over time					X				X		
External interviews	INST4.8	Timely involvement of the commercial organization and initiatives to upskill existing knowledge and workforce					X						X
External interviews	INST4.9	Assessing project affordability to the appropriateness of the chosen timber system									X		

Case/ interview	Nr.	Description	Leader-ship	Managerial Levers					Business Processies				
				Mission, goals & strategy	Structure & systems	Resource allocation	Organizational learning & knowledge	Organizational culture	Initiation & decision-making	Portfolio management	Development & implementation	Project management	Commercialization
External interviews	INST4.10	Identification of potential cost-saving opportunities from the outset									X	X	
External interviews	INST4.11	Incorporation of a new perspective on the respective timer business case		X		X	X						X
TOTAL:			**2**	**9**	**7**	**6**	**11**	**5**	**5**	**1**	**13**	**21**	**9**

E

Overview tables all parameters

Characterization & categorization

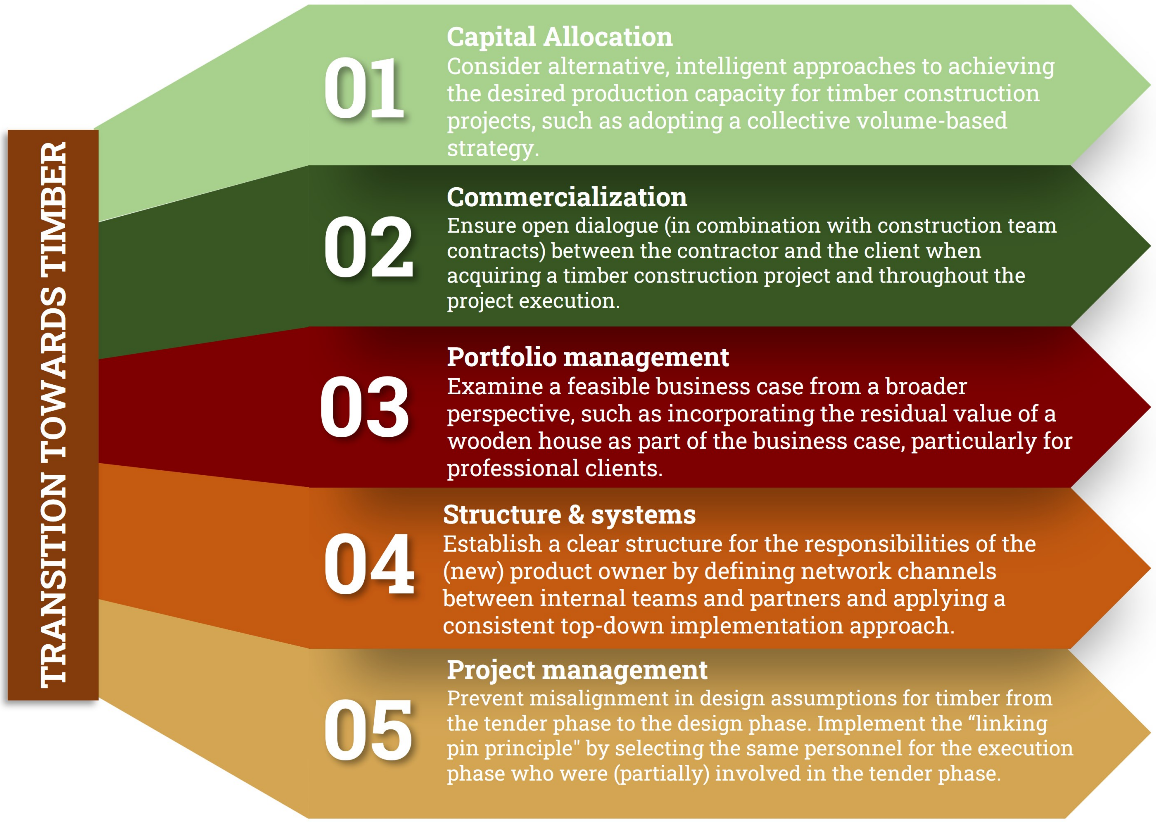
Case/ interview	Nr.	Leader-ship	Managerial Levers					Business Processes				
			Mission, goals & strategy	Structure & systems	Resource allocation	Organizational learning & knowledge	Organizational culture	Initiation & decision-making	Portfolio management	Development & implementation	Project management	Commercialization
Q1 Monitor: Low Control – Low Impact												
Ambachtslaan	INST2.11				x						x	
TOTAL Q1:		-	-	-	1	-	-	-	-	-	1	-
Q2 Manage: Low Control – High Impact												
DeKwekerij	INST1.3					x						
DeKwekerij	INST1.4			x								
DeKwekerij	INST1.8							x				x
DeKwekerij	INST1.10										x	
DeKwekerij	INST1.13							x			x	x
Ambachtslaan	INST2.2				x						x	
Ambachtslaan	INST2.5									x		
Ambachtslaan	INST2.6			x							x	
Ambachtslaan	INST2.9				x						x	
Ambachtslaan	INST2.12										x	
Leeuwepoort	INST3.1											x
Leeuwepoort	INST3.2		x					x		x		
Leeuwepoort	INST3.3										x	x
Leeuwepoort	INST3.5									x		
Leeuwepoort	INST3.6										x	
Leeuwepoort	INST3.7							x				
External interviews	INST4.1			x								
TOTAL Q2:			1	3	2	1	0	3	-	3	8	4

Case/ interview	Nr.	Leader-ship	Managerial Levers					Business Processes				
			Mission, goals & strategy	Structure & systems	Resource allocation	Organizational learning & knowledge	Organizational culture	Initiation & decision-making	Portfolio management	Development & implementation	Project management	Commercialization
Q3 Optimize: High control – Low impact												
DeKwekerij	INST1.9										x	
Ambachtslaan	INST2.1									x	x	
Ambachtslaan	INST2.3									x	x	
Ambachtslaan	INST2.16	x										
Leeuwepoort	INST3.4					x	x					
Leeuwepoort	INST3.9						x					x
External interviews	INST4.4			x		x						
External interviews	INST4.5					x					x	
External interviews	INST4.6			x			x					
External interviews	INST4.8					x						x
TOTAL Q3:		**1**	**-**	**2**	**-**	**4**	**3**	**-**	**-**	**2**	**4**	**2**
Q4 Focus: High control – High impact												
DeKwekerij	INST1.1		x							x		
DeKwekerij	INST1.2		x					x		x		
DeKwekerij	INST1.5										x	
DeKwekerij	INST1.6										x	
DeKwekerij	INST1.7										x	
DeKwekerij	INST1.11			x		x						
DeKwekerij	INST1.12				x							x
Ambachtslaan	INST2.4		x	x		x				x		
Ambachtslaan	INST2.7		x				x					
Ambachtslaan	INST2.8				x			x				
Ambachtslaan	INST2.10		x						x			

Ambachtslaan	INST2.13										x	
Ambachtslaan	INST2.14					x						
Ambachtslaan	INST2.15		x								x	
Ambachtslaan	INST2.17	x				x				x		
Leeuwepoort	INST3.8										x	
Leeuwepoort	INST3.10										x	x
External interviews	INST4.2									x		x
External interviews	INST4.3		x				x					
External interviews	INST4.7					x				x		
External interviews	INST4.9									x		
External interviews	INST4.10									x	x	
External interviews	INST4.11		x		x	x						x
TOTAL Q4:		**1**	**8**	**2**	**3**	**6**	**2**	**2**	**1**	**8**	**8**	**4**

F

5-step-strategy framework transition towards timber



G

NL versie: 5-stappen-strategie transitie naar houtbouw

H

Relationship between socio-technical factors and enabling processes