Driving Factors for Large-Scale Mass Timber Construction: An Analysis of the German and U.S. Markets

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ABSTRACT

The issue of climate change and humanity's contribution through greenhouse gas emissions has been a frequent topic of discussion among politicians and the public. The obligation to reduce the carbon footprint affects a wide range of business sectors, demanding new approaches to established practices in various markets. The real estate industry resembles a crucial area that demands attention, as it is responsible for approximately 40% of global CO2 emissions. The introduction of mass timber construction into the real estate market, therefore, represents a significant milestone in achieving the goal of carbon neutrality as it holds the potential to enhance sustainability throughout the construction process. Being more energy efficient than common construction techniques and capable of extracting carbon from the atmosphere by sequestering it in a building in the form of embodied carbon, mass timber construction is emerging as a promising solution for advancing sustainability in the real estate sector. However, the construction industry has historically been slow to adapt to new trends. This study, therefore, analyzes the underlying forces that propel the transformation process by identifying eight driving factors that influence the speed of adaptation to mass timber construction in a market. The analysis specifically focuses on the real estate industries in Germany and the United States, based on the insights provided by experts who are actively engaged in large-scale mass timber projects. The research goes beyond merely acknowledging sustainability aspects as a reason for the increasing popularity of mass timber in high-volume construction projects. Instead, it reveals that several underlying drivers impact the speed of market adoption of this construction technique. The findings advance the existing literature by identifying these factors and further assessing their interdependencies based on local differences and the stage of market development.

1. INTRODUCTION

As we work towards a more sustainable and environmentally friendly future, changes are required in nearly every aspect of our daily lives. This transformation has an impact on many different branches, from transportation and energy consumption to the way we live. Being responsible for around 40% of global CO2 emissions, the real estate industry is one of the main contributors to global warming and, therefore, essential to be discussed when talking about climate change (Scott, 2023; O'Roarty, 2022). It is also an industry that is known to be slow to adapt to new trends and transform itself. This gives mass timber as a new building technique the potential of becoming an interesting renewal of a long-established industry. According to experts, mass timber construction is a promising alternative and can provide a solution to many of the industry's current problems. It is not the mere use of wood, which has a long-standing history as a building material, that excites the real estate sector. Instead, it is rather the advancements in mass timber products such as cross-laminated timber (CLT), glue-laminated timber (Glulam), dowel-laminated timber (DLT), and nail-laminated timber (NLT) that have captured the attention. These innovative products enable wood as a construction material to surpass the limitations of being considered suitable only for small structures. They now present a competitive alternative to common construction materials, such as concrete and steel, in terms of technical feasibility. This opens up a whole new market for wood as a sustainable and renewable resource for large-scale construction projects all over the world (Cover, 2020; WoodWorks & Think Wood, 2022).

This building technique is not to be seen as a competitive approach to the reuse and renovation of existing buildings but rather as a sustainable alternative for new, ground-up construction. To understand the environmental benefits of mass timber, it is vital to consider the whole life cycle of this construction material. The production cycle of mass timber construction begins with the tree, which extracts carbon dioxide from the atmosphere during its growth. This CO2 remains stored in the wood even after it is harvested, processed, and used for construction. While some of the stored CO2 may be released back into the atmosphere after the deconstruction of the building, the overall storage of carbon in the construction components for a period of time is described to have a mitigating effect on climate change. The utilization of trees is closely tied to the health and regeneration of forests to ensure a consistent supply of timber. Another important aspect is the lower amount of required energy. This can be attributed to timber's lighter weight compared to common construction materials such as concrete, brick, or steel. As

a result, the transportation, production, and construction of a mass timber building is less energy intensive (Cover, 2020; Harte, 2017).

The existing research and literature predominantly focus on the sustainability aspects of mass timber products and the technical requirements for this type of construction as part of the ongoing debate about climate change and the reduction of CO2 emissions. Building on this, the study accepts mass timber construction's environmental benefits, as discussed by Cover (2020), as a foundation. These findings are supported by multiple life cycle analysis studies, which demonstrate the positive environmental impact of mass timber construction (Durlinger, Crossin, & Wong, 2013; Harte, 2017; Robertson, Lam, & Cole, 2012). Therefore, the research examines the various influences and market characteristics surrounding the mass timber construction industry. It investigates how these factors either incentivize or limit the adoption of mass timber as an established building technique in both Germany and the United States of America. This thesis aims to provide a comprehensive overview of the current influences on the mass timber market. It categorizes these factors into distinct subjects and describes and compares them to understand their impact on the industry and on each other. The thesis further offers recommendations for future analysis of these driving factors.

This study seeks to answer the following research question: *How do the key drivers of mass timber construction affect its adoption as a sustainable alternative to common construction practices?* In order to provide an answer to this question, I conducted semi-structured interviews with 11 professionals who, at the time of the interview, were actively engaged in large-scale mass timber projects. The interviewees were selected based on their expertise in their respective fields and their extensive background in the construction industry. The participants resemble a selection of occupations representing different industry sectors, such as finance, construction, and architecture. The guideline for the semi-structured interviews is based on existing literature, prior conversations, and the interviewees' individual focus on particular topics within their fields of expertise.

The results can be classified into eight significant driving factors influencing the adoption of large-scale mass timber projects across the German and U.S. markets. These driving factors can be further categorized into three overarching categories relating to *4.1 Innovation and Supply of Mass Timber Products*, *4.2 Market Conditions for the Mass Timber Construction Industry*, and *4.3 Mass Timber Construction as an Investment Case*.

This study advances the existing literature by analyzing the underlying forces of the adoption process of mass timber as a common construction practice. It identifies and organizes these fundamentals into groups influenced by different market actors and discusses their stage of development under the current conditions. Additionally, this study sheds light on the effectiveness of diverse efforts aimed at supporting the mass timber industry based on the perceptions of industry experts. It considers both effective drivers that promote, as well as limiting forces that prohibit a faster adoption process. Further, this thesis aims to explain how these driving factors interact, as specialized subject areas are typically examined in isolation.

Following this brief introduction, the remainder of this study is structured into four chapters. The following part provides some background information about mass timber and the general state of the German and U.S. real estate markets where this analysis occurs. After that, the research process will be described in more detail, including the method and framework used for conducting the interviews and the data analysis process. Subsequently, the findings will be presented based on the information provided by the interviewees, organized into eight topics, which resemble the driving factors that influence the adoption of large-scale mass timber construction. In the final chapter, these results will be discussed and interpreted in the context of existing literature.

2. THEORETICAL BACKGROUND

The following chapter provides an overview of the existing framework within the real estate industry in which the research is being conducted.

2.1 Historical Evolution of Timber Construction

Until the early modern age (1450 - 1500), wood remained the most important building material in Northern and Central Europe. Despite being known since ancient times, it was not until the 12th century that various types of timber framing began to be widely used north of the Alps, gradually developing into the most commonly employed construction method. Unlike the earlier block and skeleton construction, this new method tremendously increased the building's lifespan by decoupling the wooden construction elements from the ground, protecting them from moisture and water. The invention of timber framing also strongly impacted the European production industry by introducing prefabrication of individual components and faster assembly on the construction site.

In the 19th century, brick reemerged as the dominant construction material, surpassing timber as the primary choice. Especially in major cities, traditional timber buildings were progressively replaced with masonry construction due to the growing availability of steel, concrete, and brick, as they became mass-produced materials during the Industrial Revolution. Nevertheless, due to its accessibility and directional load-bearing capacities, wood continued to be utilized for the construction of roofs, ceilings, and interior elements such as staircases. Besides that, this new development resulted in the vanishing of wood from the list of modern building materials for most buildings in Central Europe during that period in time. Despite its loss in appreciation, the research and development into new timber products continued, which led to the invention of laminated wooden components made-up of multiple slates glued together and bonded irreversibly. This laid the groundwork for the development of laminated timber products as we know them today and therefore engineered mass timber construction components. Due to a lack of resources during the First and Second World Wars, wood gained a short-lived spike in popularity during the 1920s and 30s. During this time, the first patent for wood-concrete composite slabs was granted in Germany. Since the 1970s, new materials and construction methods have been used in the construction industry in growing numbers. Consequently, this resulted in a recurring increase in popularity after the 1980s by using the complementary

properties of wood and concrete in composite products. Imported materials such as oriented standard board (OSB) panels from the United States and practices like post-and-beam building were adopted and further developed into panel or frame construction. Laminated timber decks and walls, which have been known since the 1920s, were optimized into high-performance, prefabricated load-bearing components. (Deplazes, 2000; Kaufmann, Krötsch, & Winter, 2022; Krötsch, 2023).

With the growing interest in environmental issues around the turn of the 21st century, wood experienced another increase in appreciation, this time not just for its technical capacities but especially for its sustainable characteristics as an environmentally friendly and renewable resource. In the 1990s, research and development efforts in Austria and first test projects in Bavaria further propelled the interest in this material by demonstrating that it can be used beyond the construction of single-family homes. A fundamental change happened with the introduction of cross-laminated timber (CLT) and glue-laminated timber (glulam). Both can be used as the main load-bearing structural elements in a building after their approval for construction in Germany and Austria in 1998.

CLT and glulam still play a significant role in timber construction up to this day. This blooming interest led to the development of an increasing number of mass-timber products, especially in combination with other materials, such as concrete or steel, in the form of hybrid construction projects. In recent years the most noteworthy development happened in multi-story building construction. A renewal of the building code in most Central European countries at the beginning of the century lifted the height limitation, which until then allowed for rarely more than three stories. As a result, the first urban multi-story wood structures started showing up. By growing in size and height, these projects keep pushing the boundaries of timber construction. The development can be observed by contemplating the increased attention received by these new buildings. In 2007 the E3 residential and commercial building by Kaden Klingbeil Architects, a seven-story timber building, caused a sensation (Kaufmann, et al., 2022). Twelve years later, with the completion of the 85,4m/280,2ft high, 18-story Mjøstårnet in Brumunddal/Norway, the height limit of what was technically possible was increased by 11 stories. To this day, this high-rise building holds the record as the tallest timber construction in the world, with the restriction that all load-bearing structural elements are entirely composed of wood. Including wood-hybrid structures into that ranking, currently the tallest timber building is the Ascent Tower in Milwaukee/USA, which surpasses the Mjøstårnet by seven stories and

1,2m/3,9ft (Gerst, 2021; Safarik, Elbrecht, & Miranda, 2022; Appendix 4). This height limit will be exceeded again soon, as several new projects are in the planning stages. The upcoming buildings that are expected to surpass the Ascent Tower's height of 86,6m/284,4ft include the WoHo in Berlin/Germany, with 29 stories and a height of 98m/321,5ft (Treusch, 2021), the Rocket in Winterthur/Switzerland, with 32 stories and a height of 100m/328,1ft (Orie, 2022), the Atlassian headquarter in Sydney, Australia with 40 stories and a height of 180m/590,6ft, and the C6 in Perth/Australia with 50 stories and a height of 186,5m/612,6ft (Gerst, 2021).

2.2. Mass Timber Products

As a result of its recent success and growing popularity, several innovative mass timber building products are currently available on the market. Precisely defined mass timber construction is a technique that involves the usage of large solid wood panels to construct walls, floors, and roofs. Following the International Building Code (IBC) definition, mass timber is more broadly used as an umbrella term that also includes heavy timber materials such as glue-laminated columns and beams based on their size and weight (Cover, 2020). In accordance with this interpretation, cross-laminated timber (CLT), glue-laminated timber (Glulam), dowel-laminated timber (DLT), and nail-laminated timber (NLT) are among the most popular products (Ahmed & Aroch, 2020).

- **CLT** – is one of the most widely used products in mass timber construction. It comprises layers of dimension lumber bonded vertically to create solid and rigid structural panels. The characteristics these panels are renowned for are their dimensional stability and strength. Typically, they consist of three, five, or seven layers of timber plies, varying in thickness to tailor the product's load-bearing characteristics to their exact requirements. They are glued together using polyurethane, melamine, or phenolic-based adhesives. Founded on this quality, CLT panels are often the preferred choice for structural elements such as walls, roofs, and floor slabs.
- **Glulam** – is another popular type of mass timber product and is commonly used for columns and beams. Like CLT, glulam consists of dimensional lumber selected for its structural performance and bonded together using durable and moisture-protected adhesives. Glulam gains its remarkable directional strength through the parallel layering of wood during the gluing process, making it a preferred choice for structural elements experiencing concentrated load transfer, such as beams or columns.

- **NLT** – is a classic mass timber product that has recently gained revived attention, especially for its applicability in elevator shafts and staircases in mid-rise timber buildings. It is also commonly utilized for floors, decks, and roofs. NLT is created by stacking individual dimension lumbers on edge and fastening them with nails or screws to produce a larger structural component. This grants it a distinct advantage in roofing structures over other mass timber products since its panels are made up of individual boards spanning in a single direction (Ahmed & Aroch, 2020).
- **DLT** – is an engineered wood product (EWP) that uses timber lamellas assembled with hardwood dowels. Its composition happens similarly to NLT, with the difference of it being an all-wood product, by employing wooden dowels to join laminations instead of nails or screws. Traditional construction techniques of DLT have been combined with advanced research on highly densified wood materials to manufacture adhesive-free EWPs, by improving their physical and mechanical properties (Sotayo, Bradley, & Bather, 2020). Based on its characteristics, it is well suited for horizontal spans, as in flooring and roofing applications, or sheer walls. DLT is commonly used in Europe and also gaining popularity in the U.S. due to its all-wood composition and compatibility with computer-controlled machinery, which makes it easy to work with (WoodWorks & Think Wood, 2022).

2.3. Building Classifications

As implied in the title, the purpose of this study is to analyze the factors that drive the adoption of large-scale mass timber construction. Since the term 'large-scale' does not provide a specific design definition, the following paragraph outlines the characteristics of building classes that serve as the minimum threshold for the structures included in the subsequent analysis.

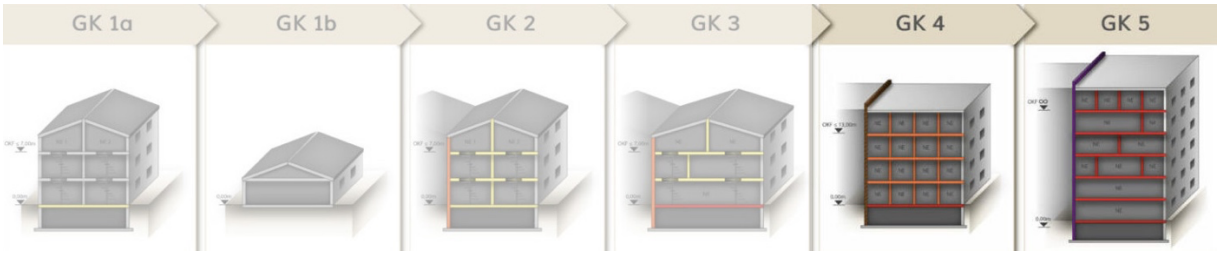

Figure 1. Overview of Building Classes in Germany
Source: Halbach (2021, online)

The German ‘Gebäudeklasse 4’ (GK 4) is defined based on the size and height of a building, independent of the construction material used. The basic requirements for this category include a height of > 7m/23ft and ≤ 13m/42,7ft and a maximum area of ≤ 400m²/4.305,5sqft per individual unit. There is, however, no limit on the number of individual units that can be integrated within a building. Any structure that exceeds these dimensions falls under ‘GK 5’ and naturally qualifies for inclusion (Musterbauordnung, 2022).

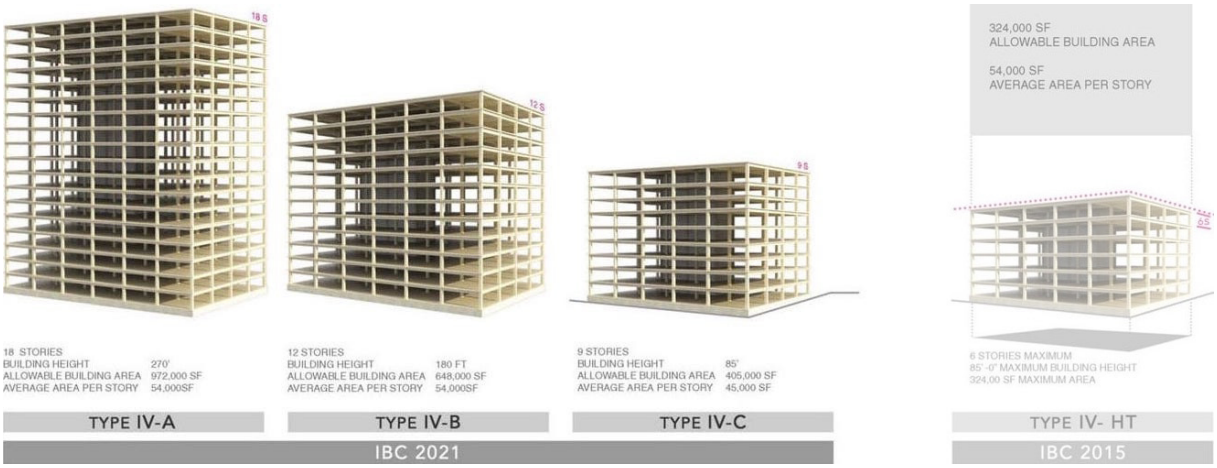

Figure 2. Overview of Building Classes in the U.S.
Source: WoodWorks & Think Wood (2022, p. 21)

In the U.S. the type of construction is commonly chosen based on the material (WoodWorks, 2023a). *Section 602.4 of the 2021 IBC building code* addresses the use of structural load-bearing elements made of engineered wood products, including mass timber. The smallest category within this section is ‘Type IV-C’, which is defined by an upper limit of nine stories or roughly 30m/98,4ft. This classification’s maximum allowable building area is 37.625m²/ 405,000sqft. Mass timber structures that exceed these limits fall under ‘Type IV-B’ for buildings up to 12 stories or ‘Type IV-A’ for buildings up to 18 stories. The analysis also considers these categories (ICC, 2021). ‘Type IV-C’ is commonly used in large-scale mass timber construction projects in the United States. However, other building classifications, beyond 'Type IV', also permit the utilization of mass timber under specific limitations, as demonstrated in *Tables 3 and 4* of *Appendix 4*. (WoodWorks, 2023a). Therefore, the additional requirement of a minimum of three stories or a height > 7m/23ft becomes a qualifying criterion for the consideration of other construction classifications in the analysis, to ensure comparability with the German 'GK 4'. Furthermore, a minimum of 4.645m²/50.000sqft is assumed for inclusion in this study for buildings in both markets.

2.4 The current State of the German Real Estate Market

The European real estate market faces challenges from the aftermath of the COVID-19 pandemic, the outbreak of war in Ukraine, supply chain issues, and rising interest rates. Despite the ongoing importance of environmental, social, and governance (ESG) issues, the focus has been partly overshadowed by macroeconomic concerns and inflated construction costs. Industry leaders are increasingly concerned as Europe faces a potential recession with rising interest rates and soaring inflation. As a result, private equity firms face pricing limitations due to higher debt costs. Attention is being paid to investment deals completed in 2018 and 2019, which were record-high transaction years in Europe, as many of them were funded with five-year loans that are coming due in 2023 and 2024, coinciding with a period of quantitative tightening (PwC & ULI, 2022a).

After a record year in 2021 with a total transaction volume of €111 billion, Germany's investment market saw a reduction in activity with a total transaction volume of €66 billion by the end of 2022. This poses a decrease of about 41% compared to the previous year. Nevertheless, it is important to mention that this number is only 8% below the 10-year average and was strongly impacted by the extreme difference in Q4. In 2021, the last quarter accounted for a total transaction volume of more than €50 billion alone. In contrast, the final quarter of 2022, with a total amount of only €13 billion, missed the traditional year-end rally, making it the weakest final quarter of the past 10 years. Reasons for this sharp decline in investment activity are rising interest rates due to the European Central Bank's recent increases in key interest rates to combat inflation. As a result, the yield gap between German government bonds and real estate has narrowed to levels comparable to those last seen in 2008, diverting the interest of institutional investors (JLL, 2023a). Reinforced by slowing demand due to the rise in financing costs and the overall cost of living, the fourth quarter of 2022 witnessed a decrease in prices for residential real estate of 3.6% compared to the previous year, marking the first decline since the end of 2010 (Destatis, 2023a). The availability of equity and debt is not the only factor slowing down the real estate market in Germany. Another aspect that has a significant influence on the industry is the aforementioned cost increase in almost every profession related to the construction industry, as well as material prices (Destatis, 2023b). According to the German Federal Statistical Office (Destatis), the prices for newly constructed conventional manufactured residential buildings in Germany increased by 16.9% in November 2022 compared to November 2021. The price surge for the construction of new office buildings

(17,8%) and for commercial and industrial buildings (17.6%) even exceeds this number (Destatis, 2023c). Regardless of the recent slowdown in the German real estate industry over the past year, 19% of investors believe that prices for residential properties in prime locations will continue to rise. About 40% of the respondents expect prices to remain stable for the year (Statista, 2023b). This expectation is supported by ULI & PwC's European City ranking for 2023, which consistently ranks Berlin, Munich, Frankfurt, and Hamburg among the top 10 European cities in various categories such as investment, development, rent, and capital values (PwC & ULI, 2022a). The German government's initiative to build 400.000 affordable and climate-neutral residential units per year, including 100.000 units designated for social housing, underscores the anticipated future necessity for additional housing (Bundesregierung, 2022). This goal was not achieved in 2022 and is unlikely to be met in 2023. Despite the challenges and setbacks, the government intends to continue working towards achieving the target of 400.000 residential units per year (Radomsky, 2023). In 2022, a total of 304.600 apartments were approved for construction in Germany, representing a decrease of 7.3% or 23,900 apartments compared to the previous year. This number can also be interpreted as an early indicator for future demand (Destatis, 2023d). The percentage of permits granted in Germany for residential buildings using wood as the primary construction material, on the other hand, has increased from 12.2% in 2003 to 21.3% in 2021 (Statista, 2023a). This number includes all building classes.

2.5. The current State of the U.S. Real Estate Market

The U.S. real estate industry is battling similar obstacles going into 2023, such as increasing construction costs, high inflation, and the consequential increase in interest rates by the Federal Reserve (Barkham, 2022; JLL, 2023b). Despite job growth and low unemployment claims, concerns about declining consumer confidence and slowing economic growth could impact tenant demand. Additionally, while there has been strong demand for various types of real estate, except for central business district (CBD) offices and regional malls, some investors have moved to other asset classes like equities and bonds. Rising interest rates have also increased debt costs for property acquisition and development, reducing leveraged returns. Major product types with strong demand fundamentals, such as industrial and multifamily housing, are considered safer sectors with compelling market fundamentals. As investors become more selective, there is a potential for slower rent growth and price appreciation rates (PwC & ULI, 2022b).

After a year with only $450 billion in commercial real estate transactions in 2020, the total volume jumped to $875 billion in 2021 as a result of the pandemic and the pent-up demand as the economy reopened (Statista, 2023c). A significant part of the total transaction volume in 2021 was achieved during the year-end rally in Q4, which accounted for approximately 43%. During the third quarter of 2022, the post-pandemic surge has slowed down. The total volume was down 21% in comparison to the previous year. Especially the 33% decrease in office space had a major impact on the development, whereas apartments maintained a steady performance (PwC, 2023). 2022 can be seen as a transitional year for the North American real estate market, necessitating adjustments in investment strategies. Some capital has been sidelined, and the money invested focuses on top-quality assets or sectors with strong demographic support and favorable demand fundamentals. (PwC & ULI, 2022b). One of these asset classes is residential multifamily apartments. A study commissioned by the National Apartment Association (NAA) and the National Multifamily Housing Council (NMHC) predicts a demand of 4.3 million new apartments by 2035 (NMHC, 2022). This increase of 331,000 apartments per year would expand the existing apartment rental stock by more than 20% over the next 12 years (PwC & ULI, 2022b). The number of permits issued for multifamily units in 2022 registered an increase of 9.9% compared to the previous year, while permits for single-family units decreased by 12.5%. The majority (54.3%) of permits were issued in the Southern region of the United States (NAHB, 2023). This aligns with the findings of the Emerging Trends in Real Estate 2023 survey, which ranked Nashville, Dallas/Fort Worth, Atlanta, and Austin as the top four cities to watch in the U.S. market (PwC & ULI, 2022b).

Similar to other markets, conversations about ESG and society's call for reducing the industry's carbon footprint are also starting to play a more prominent role in the U.S. (PwC, 2023; PwC & ULI, 2022b). One governmental program addressing this issue is the 'Inflation Reduction Act of 2022', aiming for a 40% reduction of greenhouse emissions by 2030 (The White House, 2023). This infrastructure law does not exclusively focus on the real estate sector but rather on a broad number of topics, including health care, clean energy, and taxes (The White House, 2022). The incentives included in the bill, which are directly aimed at the real estate sector, focus on encouraging the construction of high-performing and cost-effective buildings, as well as improving the energy efficiency and sustainability of existing structures, in line with LEED standards, by granting tax credits and tax deductions to builders and developers, that meet certain sustainability criteria (USGBC, 2022).

3. RESEARCH METHOD

Focusing on the current market situation in Germany and the United States, this study aims to answer the research question: *How do the key drivers of mass timber construction affect its adoption as a sustainable alternative to common construction practices?* This paper intends to identify the most significant characteristics of both markets and analyze their effect on establishing mass timber as a competitive construction technique. The study seeks to provide a better comprehensive and organizational understanding of a market undergoing rapid transformation. Therefore, the analysis relies on an interview-based qualitative research process to identify the effects certain characteristics have on the current situation and the role they might play in the future. Based on its evolving nature and the lack of available data, qualitative research provides the tools to explore this topic further and to develop a theory based on information gathered through a semi-structured interview process. When studying this trend, the focus lies on how individuals in the industry derive and interpret their experiences rather than the quantity or frequency of measurable events (Eisenhardt & Graebner, 2007; Gioia, Corley, & Hamilton, 2012).

3.1 Research Context

With its potential to move the construction industry into a more sustainable direction, the widespread adoption of mass timber offers several opportunities (Cover, 2020; Harte, 2017). Consequently, it is crucial to investigate the driving forces behind this emerging trend, as well as the effects of specific market characteristics and their influence on its further evolvement. A wide range of studies has been conducted on the technical aspects surrounding mass timber construction, especially relating to fire testing, construction techniques, loadbearing capacities, and sustainability aspects (Durlinger, et al., 2013; Harte, 2017; Robertson, et al., 2012). These studies, as well as built examples, are proof of the technical possibility of building sustainable, large-scale mass timber structures. What they fail to explain are the circumstances that contribute to the growing popularity of this trend or hinder its faster adoption within the real estate sector. With a continuing population growth and predictions indicating that 68% of the world population will be living in urban areas by 2050, along with the increasingly visible effects of climate change, the demand for sustainable urbanization will play a significant role in the future (United Nations, 2018).

3.2 Sample Selection

My thesis utilizes interviews as the primary source of information based on their effectiveness in collecting detailed and valuable empirical data when studying infrequent and episodic phenomena with limited preexisting information. By using multiple experienced individuals with diverse perspectives, including different organizational hierarchies, functional areas, and geographies, from a variety of organizations, the data collected is enriched and reflects the current market situation from different perspectives (Eisenhardt & Graebner, 2007). The interviewees were chosen based on several different selection criteria: 1) An active involvement in an ongoing large-scale mass timber project in the German or U.S. market, 2) their role and background in the real estate industry, 3) their position in the company, and 4) the educational background in their respective field. To reflect the latest state of information in a constantly changing environment, it was imperative that the interviewees already had substantial industry experience while at the same time being involved in the planning or construction phase of an ongoing mass timber project in order to contextualize the matter and put the current situation into perspective (Merriam & Tisdell, 2009). Additionally, using retrospective and real-time cases through interviews and observations allows for efficiently building up the thesis while reducing the risk of 'retrospective sensemaking' and impression management (Eisenhardt & Graebner, 2007).

For the first round of interviews, I selected a group of people I had previously known through my personal and professional background. Using the insights obtained from these conversations, their recommendations, and professional connections, I employed 'snowball sampling' to reach out to additional experts for the second round of interviews. Although most of the interview data was collected through this method, I contacted a few specific individuals based on their expertise and reputation in the industry without any prior personal connections. Therefore, 'unique sampling' was also used as an approach. This way, I got access to a distinguished group of experts that was able to give informed opinions based on the most recent developments and market conditions (Merriam & Tisdell, 2009). The gathered data reflects the opinions of a total of 11 interview partners. Six of them are involved with mass timber projects in the German market, four of them in the United States, and one person is engaged in both markets. The results represent a comprehensive evaluation of the construction cycle of a mass timber building by combining the assessments of developers, planners, suppliers, and contractors engaged in the process. By including various project stages, such as material

sourcing, designing, manufacturing, as well as financing, and operating, this study offers a holistic representation of the current mass timber market. With all the participants having a substantial education and professional background in the real estate industry and being actively involved in a large-scale mass timber project at the time of the interview, it is worth noting that they differ in orientation. While some have dedicated their entire careers to mass timber, others consider it a crucial component of their portfolio rather than their sole focus. Their distinct orientations and stage of adoption are accounted for in the research findings, as they impact their assessment of the current situation (Eisenhardt & Graebner, 2007; Suddaby, 2006). *Table 1* displays the interviewee's occupation, market location, and involvement in the industry.

Nr.	Position	Area of Responsibility	Market
I	Managing Director	Planning / Project Management	Germany
II	Marketing Manager	Project Development / Acquisition	Germany
III	Managing Director / Professor / Architect	Product Development / Education / Architecture	Germany
IV	Architect	Architecture	Germany
V	Partner	Architecture	Germany
VI	Project Development	Project Development / Timber Product Supplier	Germany
VII	Sales Manager	Timber Product Supplier	Germany / USA
VIII	Development Associate	Project Development	USA
IX	Project Manager	Project Management / Engineering	USA
X	Regional Director / Wood Product Council	Consultant on Timber Construction	USA
XI	Senior Vice President, Development	Project Development / Acquisition	USA

Table 1. Sample Overview
Source: Own illustration

3.3 Data Collection

The research was conducted following Eisenhardt and Graebner's (2007) approach to qualitative research by conducting semi-structured interviews, which were recorded and later transcribed in order to be further analyzed and appended to this research paper (Appendix 3). At the beginning of each interview, the participants were asked for their consent to be recorded and assured anonymity to allow them to speak openly without any conflict of interest. All interviews were conducted online via 'Zoom' except for one. The remaining interview was carried out in person. One participant also objected to having the conversation recorded. Instead, the interviewee agreed to a discussion summary based on my notes taken during the conversation and provided consent after review.

The conversations were guided by a predetermined list of questions covering nine different topics. Each interview lasted for 30 - 45 minutes. The guideline was developed based on existing literature, while additional questions were added to the catalog throughout the research process. The topics discussed throughout the interviews remained consistent and included 1) General Decision-Making Process, 2) Market Development, 3) Legal and Political Conditions, 4) Research and Education, 5) Suppliers and Know-How, 6) Public Perception and Demand, 7) Funding Programs and Subsidies, 8) Financing and Investment, and 9) Forestation and Resource Availability. The participants were asked open-ended questions at the beginning of each interview so that they could steer the conversation in a direction they perceived as being of particular importance. Later in the interview, the questions became more structured to ensure that the required topics were covered if they were not naturally addressed before. As a result, the questions were frequently answered, without strict adherence to a predetermined sequence, during the course of the conversation (Merriam & Tisdell, 2009). This approach allowed me to adjust the discussion to the level of importance placed on each topic by the interviewee. Since the participants' backgrounds and professions differ, some of the prepared questions vary between the interviews, depending on the participant's field of expertise, following Gioia, et al.'s (2012) approach to qualitative research. The framework developed from the initial interviews also served as a guide for the subsequent conversations and played a role in shaping them, leading to slight adjustments in the interview guidelines. The research process also involved collecting data from various sources relating to the conversations, such as books, articles, and websites.

3.4 Data Analysis and Coding

An inductive coding strategy was chosen to analyze the data and bring structure to the collected information (Merriam & Tisdell, 2009). After conducting the initial round of interviews, which involved speaking with three individuals from the U.S. market and three from the German market, I transcribed the conversations using 'condens.io'. Afterwards, I evaluated the information carefully and identified numerous topics discussed by the participants. This analysis resulted in a large number of topics that encompassed both markets. The process was repeated after every subsequent interview (Gioia, et al., 2012). For this step, 'taguette.org' was used to code the conversations. The first round of interviews already provided a rough framework for the analysis, which was further advanced and specified throughout the following process.

It is crucial to adhere closely to the data and avoid any biases, such as 'going native' during this stage of the research, to ensure the accuracy of the results (Gioia, et al., 2012). At the same time, it is essential to consider the various perspectives and intentions of the interviewees during the analysis process. Since there are different professions involved in the data collection, their points of view and their incentives differ in certain aspects. To avoid the 'fact of fiction' as discussed by van Maanen (1979), it is necessary to keep the interviewee's role in mind. For the development of the data structure, I relied on the information collected during the interview process to paint a holistic picture of the current situation described by the experts. Therefore, my personal interpretations and existing literature were not taken into consideration during this initial stage of the analysis, and I solely relied on the collected information to derive the overall structure (Gioia, et al., 2012).

In order to become closely familiar with the different cases and avoid biases in the analysis relating to the time of the interview, each case was revised again after the interview process was completed. This close familiarity with the collected data also accelerated the cross-case comparison while searching for patterns between the different interviews (Eisenhardt, 1989). Building on the results of the initial round of coding, which generated 16 'first-order codes', I identified eight 'second-order themes' that are of significant influence in both markets but differ in their level of development and, therefore, their impact under the current stage of adoption. These eight 'second-order themes', which can be assigned to three 'aggregate dimensions', are the driving factors I intend to explore closer in this study. For a clearer understanding, *Figure 3* illustrates the different steps of the analysis process (Eisenhardt & Graebner, 2007).

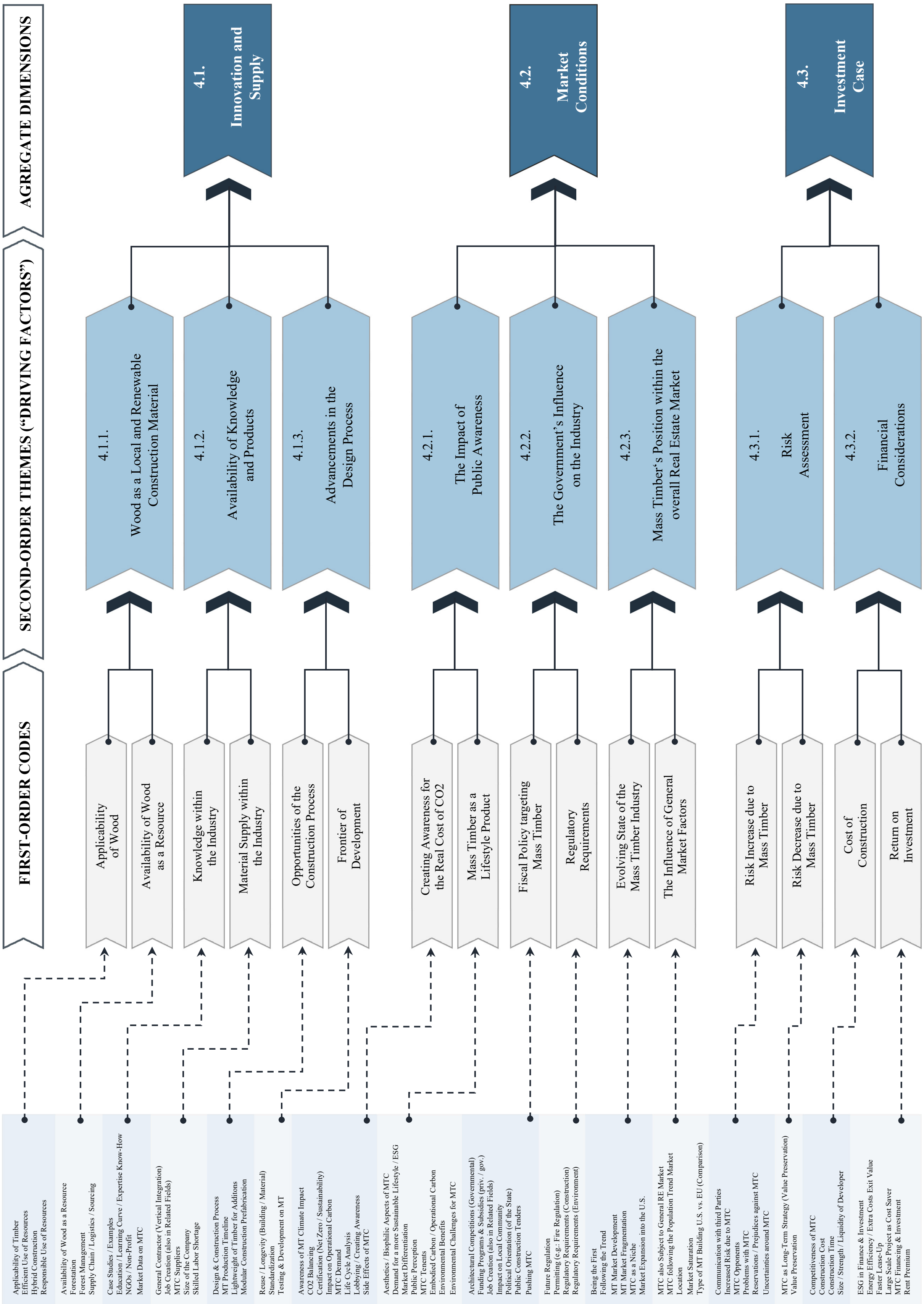

Figure 3. Organizational Framework of the Analysis
Source: Own illustration

4. RESULTS

In order to answer the research question, this chapter analyzes the eight distinct driving factors for mass timber construction that were derived from the interview process. It further outlines their general effect on the industry, particularly their impact on the German and the U.S. mass timber market, based on the current economic environment. The identified factors can be classified into three broader categories relating to the supply side, the government's influence, and the demand side. The results described in the following chapter are derived holistically from the information provided by the interviewees and represent their perceptions of the current developments. Additionally, existing literature was used to verify and support claims made by the participants, to guarantee the validity of the statements when necessary. Direct quotes that have been translated from German to English are denoted by an asterisk (*), and all interviews can be found in *Appendix 3* of this thesis. The individual interviewees are represented by the roman numerals 'I - XI' in the following chapters.

4.1. Innovation and Supply of Mass Timber Products

The first topic explores the impact that arises from the characteristic qualities of wood as a construction material, the availability of suppliers and general market knowledge, as well as innovations in the design process.

4.1.1. Wood as a Local and Renewable Construction Material

The general availability of wood as a renewable resource sets the baseline for the entire mass timber construction industry. This chapter summarizes the findings related to the necessity of sustainable forest management, local availability, overall efficient and responsible resource consumption, and timber's applicability for different construction tasks.

- Germany -

The total forest area in Germany amounts to approximately 27.4 million acres, with 43.6% of it being privately owned by individuals and 3.7% allocated for restitution. Therefore, a total of 47.3% is being held by private owners. The remaining 52.7% is publicly owned, with 3.7% owned by the federal government, 29.6% owned by state governments, and 19.5% owned by

public bodies at the local level (Koch & Maier, 2015). Out of these woodlands, the vast majority of timber harvested and used for construction in Germany comes from spruce trees (V). Its light-specific dry weight (VI) varies depending on age, size, and location-specific factors, with an average of approximately 436 - 447 kg/m³ (Schwappach, 1898). When greater durability of timber is needed, such as for creating longer spans or stronger connections, construction lumber made from beech wood is a popular domestically grown alternative. With approximately 840 kg/m³ it weighs almost twice as much (VI).

In both cases, local supply is important to various industry parties, although the reasons for this vary depending on their respective objectives (III; V; VI). At the initial stage of the production process, German forestry is characterized by ecologically sustainable practices. A thorough forest management system has consistently been monitoring the inventory by collecting data and overseeing harvesting and reforestation (I; VII). This has resulted in a comprehensive raw material supply currently being available (II; IV; VI). Manufacturers of engineered timber products in Germany have the opportunity to partner with local sawmills and timber suppliers, which allows for close and lasting relationships (VI) and helps keep transportation costs to a minimum (I). If the prices of raw materials do not differ significantly between locations, there is no real incentive for clients to source their materials from further away (V). This agrees with architects and developers, who like to focus on the sustainability aspects of local production (III; VI), as well as certification that allows for sustainable building subsidies (VI). Even though the objective of local material supply is supported by various parties involved in the construction process, it becomes more complicated to achieve and verify the bigger the project gets, and the more steps are involved in the process (I). Especially with government contracts, which must be tendered product-neutral (III) and throughout Europe (IV), the usage of local materials can be a deciding factor among other sustainability aspirations and therefore have some influence on the result, but cannot be guaranteed (V). The situation is similar from the perspective of the supplier. For smaller producers of engineered timber products, it is not a constraint and logical to use locally available sources (III). However, for internationally operating manufacturers, locality becomes less of an issue. The extent of vertical integration of work steps within a firm is a crucial determinant of that (I; VII). If a company's production involves all steps from harvesting to manufacturing the final construction elements, the process can be designed more efficiently and with a stronger local focus (VII). A larger engineering firm that sources its materials externally may find it more difficult, if not impossible, to track the origin of the raw materials (I).

For the time being, the domestic timber supply is considered to be sufficient and provides room for further growth of the German mass timber market (II; IV; VI). In the long run, the assessments are more skeptical, regarding whether the domestic forest industry will be able to sustainably provide the necessary resources (I; III; V). Various factors, such as increasing temperatures and alternations in ecosystems as a result of climate change, the rise in bark beetle infestations (II), and the growing demand from other industries (III), are important considerations. Especially for producers of engineered timber products, the sufficient supply of raw material is of fundamental significance. Globally operating suppliers have already started to expand their material sourcing into other markets, in order to be prepared for changes in availability (VII).

Since the market is aware of potential future sourcing difficulties, efficiently utilizing resources during the design process plays a crucial role. This means staying close to the material's qualities and saving resources by not overcomplicating the design (III) but also evaluating the general applicability of timber for a particular design solution (I; II; IV; V). While the use of timber as a construction material is widely acknowledged to be more sustainable and environmentally friendly than conventional building practices (III; Cover, 2020; Durlinger, et al., 2013; Harte, 2017; Robertson, et al., 2012) and is versatile enough to be used for various construction tasks, it may not always be the optimal choice. Planners like to point out that no one-size-fits-all solution exists, especially with custom-designed buildings. A material's strengths and weaknesses must be considered to use resources as efficiently as possible (I; III; IV). This is of particular importance in Germany, where the general market practice is to build very solid and durable structures that require substantial material input (VII). As the mass timber industry is currently pushing its boundaries, resulting in ever taller timber buildings, it is necessary to note that not all stakeholders see this development as the most appropriate use of material (III). As a result, many timber buildings rely to a varying degree on using other materials in the form of hybrid construction (I). Common construction techniques are often still used for elements such as staircases and elevator shafts to provide a stiffening core, as well as for basements and underground parking garages in many timber building designs (II; IV).

- United States -

Out of 823 million acres of forests and woodlands in the U.S. (Oswald, 2019a), 58% are owned by private entities, including 38% owned by families, individuals, trusts, and estates, and 20%

owned by corporations. These privately held timberlands constitute about 80% of the domestic raw material supply, most of which are located in the eastern parts of the country (X; Tidwell, 2016). The remaining 42% of forested land is publicly owned, with 31% owned by the federal government, 9% by the states, and 2% by local public institutions. (X; USDA, 2023; Oswald, Smith & Miles, 2019). While a significant amount of forested land exists, it is important to differentiate between the availability of wood as a resource and the usability of the available raw material in supplying the domestic mass timber market (VII). Construction companies and developers of large-scale mass timber structures often rely on imported construction materials from Europe and Canada for structural elements (IX; VIII; XI). This is strongly related to a lack of development of suppliers and a shortage of available testing of local timber species (VII), which will be analyzed further in chapter *4.1.2. Availability of Knowledge and Products*. The raw material for the small amount of domestic production of engineered mass timber construction elements is largely obtained from areas along the northern U.S. border. Specifically, Douglas Fir and Spruce Pine Fir from Canada and parts of the Pacific Northwest reaching into the United States are the most attractive types of lumber for mass timber producers in North America (VIII). South Yellow Pine, a less commonly favored tree species, is also finding application in the southeastern regions of the country. Despite its widespread availability, this particular tree species presents considerable difficulties during the processing stage. The problems become apparent in the form of less efficient outcomes, stemming from increased material consumption and the necessity for intricate manufacturing methods (VII).

However, there is observable growth in the market, especially for the production of CLT (Shahabandeh, 2023). This change addresses the deficits in sustainable forest management practices and the implementation of a sufficient domestic supply chain. Currently, factories that plan to use local wood for manufacturing are being built. They are expected to open within the next five years (VIII). Additionally, paper mills are being converted into sawmills as a result of decreasing demand in a declining industry. The conversion of mostly non-metropolitan production facilities also entails the opportunity to make use of the available labor force in rural areas due to the shift in employment from industries such as paper or coal (IX; X). This movement is being supported by the U.S. Forest Service by helping to create demand and thereby increasing economic incentives. *"There is a saying that a force that pays is a force that stays. And that's kind of a simplification, but it really does illustrate a very simple truth, that a forest's survival, especially nowadays, depends in most cases on its value to the local community"* (X, p. 143). Since most of the harvested timber comes from privately owned land,

the strategy is based on highlighting the need for sustainable forest management practices by incentivizing the use of wood for private landowners as a long-term business model (X). A significant key to further establishing mass timber as a competitive construction technique is the availability of local suppliers. This helps to address risk-related issues, affecting the supply chain, and the overall costs (XI). Further elaboration on this topic will be provided in chapter *4.3.1 Risk Assessment*, and chapter *4.3.2 Financial Considerations*.

While there is certainly room for improvement and additional research in forest management practices and timber usability, it is important to note that the U.S. already has a solid foundation to build upon. There are working institutions in place observing the state of the woodlands, showing stable, even slightly increasing land areas for forestry over the last 100 years. Only recently, the growing demand for mass timber construction has been met by an increasing focus on sustainable forest management practices and the efficient utilization of the available inventory for engineered wood products. One example where this change in perspective can be observed is the development of the U.S. Forest Service's rating system to evaluate sustainability aspects through a life cycle assessment (LCA) of forest-based products. This rating system considers factors such as local sourcing of materials, waste mitigation, and recycling, which reflects the shift in priorities toward sustainable practices (X; Sahoo, Bergman, & Alanya-Rosenbaum, 2019). Industry professionals and experts express confidence in the forests' capacity to effectively address the increasing demand over the long term by making the large amount of available timber usable for construction and improving sustainable forest management practices (X).

Also, in order to suggest relatively small impacts on forest stock at aggregate national and regional levels, it has to be pointed out that this cannot be assessed without observing global economic and environmental developments (Nepal, Johnston, & Ganguly, 2021). Increasing aridity in the West, particularly in Colorado and the Rocky Mountains, resulting from changing temperatures due to climate change, has already led to a rise in the number of wildfires (IX). California, Oregon, and Washington are also ready to incentivize the use of local wood for the fabrication of timber products. A large number of trees in these areas are becoming drought-stricken, weakening their defense system and making them more susceptible to beetle borers, which are killing the trees. Incentive-driven forest management practices aimed at improving these situations are influencing the mass timber market by promoting the use of locally sourced wood (X).

4.1.2. Availability of Knowledge and Products

Considering the German and the U.S. mass timber market, characteristic with a substantial impact on the market adoption are the availability of the construction materials, as well as the level of know-how and familiarity of local planners, craftsmen, investors, and developers with the building technique.

- Germany -

Vorarlberg, a region located in western Austria, bordering Germany and Switzerland, has emerged as an innovative hub for the development of mass timber construction techniques since its inception in the 1990s (II; Kaufmann, et al., 2022). The local proximity has resulted in a quick spread of information across the border into Germany, resulting in the adoption of the first test projects in Bavaria early on (Kaufmann, et al., 2022). This has led to a head start for the tri-border area that lasts to this day (II). While the potential of using engineered timber elements for construction may not yet be widely known among the general public, there is a high level of awareness within the industry. This has produced a significant number of qualified companies involved in various aspects of the timber construction industry, including the supply, construction, and planning sector (III; IV; V; VII), allowing for a timber construction ratio of more than 20% across all building classes (III; Statista, 2023a). If problems arise during the construction process, it is often not due to a lack of specialized expertise but rather due to insufficient coordination between the different trades (I; VI; VII). Difficulties often still occur with subcontractors, such as electrical installation or water supply, due to a lack of experience in mass timber construction. This is particularly true for smaller, local firms that are less familiar with the subject (VII).

Mass timber construction has gained popularity in Germany, especially among architects, whose job often involves advising and educating their clients on building techniques (I; VII). Particularly with the younger generation, who tends to be more familiar with concepts such as recycling and reuse in the form of sustainable and innovative construction methods, it is often already part of their education. However, also for professionals with a longer history in the industry, there are various opportunities to advance their training, such as post-graduation university courses (III), journals, online portals, or professional development courses offered by the different chambers of architects (IV). The sophisticated level of expertise in the planning

and execution of timber trades is one factor contributing to the popularity of timber construction in Germany. Since clients, especially when it comes to private developers, are often still less experienced with this type of construction technique, in many cases, it is the consulting architect on the project that introduces the possibility of mass timber construction into the conversation (I; VII). What helps to reduce skepticism is the comparatively large number of successful precedents in the market, verifying the possibility of using mass timber construction not just for small or mid-sized projects but also for large structures (III; IV; VI; VII).

Another essential supply criterion is not only the availability of the necessary knowledge in the market but also the accessibility of the construction materials themselves, as well as the labor force. In most cases, products can be obtained locally from a variety of suppliers, spanning from small, specialized companies (III; IV) to large firms operating on an international level (VII), with holistic vertical integration of the design, production (VI) and the construction process (VII). Despite the presence of numerous participants in the market, the construction industry has witnessed full capacity utilization in recent years. Even though there is an anticipated decrease in overall construction demand due to prevailing market conditions of high inflation and high-interest rates (V; PwC & ULI, 2022a), a noticeable trend is emerging whereby construction companies are showing a growing interest towards establishing strategic partnerships and gaining expertise by collaborating with timber construction firms (IV). This trend appears to delay and mitigate the decrease in demand for the mass timber industry (V). In recent years, the major bottleneck in Germany has not been related to material supply or availability of expertise but rather the shortage of skilled labor (II; V; VI), which has impacted almost all sectors of the economy (VII). This phenomenon is expected to worsen as the number of people entering retirement significantly exceeds the birth rates of subsequent generations (II; VI). Mass timber construction offers three significant improvements that help address this issue, which partially explain the growing popularity. Firstly, a major obstacle for companies in recruiting new workforce are the lengthy construction times on site, which can result in long commutes or absence from home during the week, depending on the project (II). Mass timber products exhibit a significantly higher degree of prefabrication, enabling a large portion of the construction process to be manufactured in a location-independent manner. This results in shorter on-site construction times (V). Secondly, building upon the previous point, the off-site fabrication in a production hall enhances the working environment by avoiding exposure to adverse weather conditions and extreme temperatures. It also enables the use of specialized machinery to support workers. The combination of these characteristics significantly increases

a company's chances of attracting skilled workers (VI). Lastly, due to the resolution of most technical challenges during the planning and prefabrication stages, the on-site construction process becomes accelerated and requires less specialized expertise. This allows for a broader market of available workforce, including less experienced individuals, to participate in the on-site construction process. As one interviewee portrayed it, the assembly of a timber building can be described as "*Lego for grownups*" (VII p. 127)*.

- United States -

In comparison, the U.S. market appears to be less advanced in terms of available knowledge and the number of domestic suppliers. Despite the long-standing use of wood in construction, there remains a relatively limited pool of expertise, in the field of mass timber, especially for large-scale projects. This observation seems to apply to all areas of this construction technique but is particularly evident in the design and production phase of specific mass timber construction components (VII). Skilled on-site construction companies for mass timber projects can already be found, as the actual construction process is relatively straightforward once the design phase is completed. Alternatively, companies are willing to take on these projects with an increased safety margin to prepare for unexpected challenges or time increases due to the learning process. A comparable situation can be observed in the architectural planning industry, where the challenge is not finding architects willing to take on the job, some of whom already have experience designing large-scale mass timber projects. The main difficulties arise in the engineering aspect of the planning phase (VIII). As a result, developers and companies resort to a number of measures to cope with this knowledge gap. In some cases, seeking inspiration, planning support, and material supply from outside the country is a viable option (VI). Since the level of interest in mass timber construction is growing in the United States, globally operating companies on the supply side also tailor their product specifically to the needs of different markets. One major industry supplier from the tri-state area of Vorarlberg describes the situation as follows: *"In Germany, for example, the know-how is already very high, so we only act as a pure producer, but in Scandinavia or North America, there are still few skilled workers, few engineers, few structural engineering companies. They need the whole package, from the delivery of the elements with planning to structural engineering, design, and everything that goes with it. Sometimes even supervising or installation."* (VII, p. 121)*.

Additional support, especially at the beginning of a project, is offered by Non-Governmental Organizations (NGOs) and other nonprofit organizations that provide advisory services to interested companies. Furthermore, they assist in establishing contacts with qualified firms in order to lower the entry barrier for newcomers (IX; VIII; X), offer project support for professionals such as structural engineers, architects, general contractors, and developers (X), and assist in engaging in discussions with code officials. In addition, they offer educational programs that are accredited by the American Institute for Architects (AIA) to assist architects in enhancing their training (VIII; X; American Wood Council, 2023; WoodWorks, 2023b).

Difficulties and delays especially occur when it is the first large-scale mass timber project in a city or region. Developers and investors tend to be more cautious when there are no successful precedents in a particular market yet, as their usual investment analysis is not applicable in these situations, and their predictions have to be based on several difficult-to-assess variables (VIII; XI), such as setbacks during the planning process and negotiations with code officials (IX; VIII). Over time, the holdups tend to decrease as experience has shown that the introduction of the first large-scale mass timber project into a new market already results in a more streamlined process, a learning curve, and a reduction of obstacles due to unfamiliarity with the topic, in areas like fire testing and permitting (IX; X; XI). These pioneering projects also provide a foundation for case studies (The Wood Products Council, 2022), which increase developers' confidence by presenting them with tangible numbers to use as a point of reference (VIII).

Concerning the actual supply of materials, local sourcing is often not yet feasible, despite the notable growth in the solid wood or cross-laminated timber (CLT) sector on the supply side (VII). U.S. developers often still compare international offers since manufacturing is restricted predominantly to the Pacific Northwest and Canada, except for two sawmills in the Southeast (VII; X). This places less emphasis on the location of production, as domestic supply does not always ensure the most efficient logistical process at this stage of market adaptation. In some instances, shipping from Europe is easier than road freight transportation across the country (VIII). The limited number of domestic production companies is not due to a scarcity of resources but rather the insufficient research and testing conducted on local species of trees. The type of wood found in Canada and the northern parts of the United States is comparable to some of the species found in Europe and can therefore be used more efficiently for manufacturing, given the available knowledge (VII).

As the demand for mass timber construction rises, the current situation is expected to change in the long run. The number of domestic (VIII; X; XI) and international producers seeking to further expand into the U.S. market is increasing (VII), which stands to reduce the supply-demand imbalance (XI). Furthermore, this growth is expected to create job opportunities in rural areas, where the demand for employment is an ongoing issue and the required labor force is available. While the number of jobs has generally increased in metropolitan areas from 2009 to 2021, job growth in rural areas has been slow, with numbers consistently remaining below the pre-Great Recession levels of 2007. The COVID-19 pandemic particularly impacted the 2020 non-metropolitan employment rate (USDA, 2022).

4.1.3. Advancements in the Design Process

In comparison to common construction practices, some considerations and different approaches need to be taken into account when designing a mass timber building. This chapter analyzes what they are and how they affect the planning process. Given the Austrian, German, and Swiss tri-state area's significant influence on the general state of innovation in the industry, this chapter focuses predominantly on the developments currently influencing the German mass timber market.

- Germany -

Since mass timber construction is a relatively new construction technique, there is still room for optimization in the planning stages of a timber building. In many cases, aspirations for testing and development are focused on reducing construction times by standardizing and prefabricating specific structural components to save costs (III; VI; VII). More precisely, refining the detailing, designing versatile and applicable connections, and expanding the data set of building physics characteristics could lead to a more streamlined design process (VII). When planning a mass timber structure, architects often start from scratch and treat every new design as a prototype (III; VI). A standardized framework for orientation in Germany functions as a design guideline for timber buildings. The so-called 'Muster-Holzbaurichtlinie' (MHolzBauRL) provides legal security and undergoes constant updating (VII), as it currently still leaves room for improvement, particularly in relation to large-scale timber structures. (V; VII). Innovations such as organic adhesives (II), all-timber staircases, elevator shafts, and recently even basements made of timber (VI) require time for implementation (V). While this

design guideline serves as a reliable foundation for exploring various approaches towards standardization in mass timber buildings, the reality is that many structures still require the inclusion of hybrid elements, such as combining wood with steel or concrete, to meet fire safety regulations or structural requirements (I; IV).

At the moment, the level of standardization manifests itself in varying degrees and is often restricted to small market areas. There is no generally accepted solution for a multitude of specific design questions. Therefore architects, engineers, and product suppliers try to implement their own standards (III). As a result, developers often try to rely on existing business relationships to leverage the knowledge gained from past experiences rather than starting over again (II), given the significant variations that still exist between companies (VII). It is, however, not just business relationships industry actors like to rely upon but also specific products they have used successfully in past projects. An architect can simplify the design process by using familiar materials. Mass timber walls, for example, can be prefabricated in a standardized two-dimensional manner since they can be adjusted for openings and specific measurements with relatively low energy input. This leaves room for creativity as long as the material's known qualities and limitations are taken into consideration (III).

The next advancement beyond company internal standardization and prefabrication of individual construction elements is a greater level of industrialization in the form of modular construction. This quality is not exclusive to the mass timber industry but lends itself very well to it. By respecting certain limitations, like maximum width for transportation and flexibility of usage, systemized modules can be prefabricated even before a specific project has been defined. By uniformizing this three-dimensional space, design agility gets restricted, compensating for the savings in fabrication time since serial production only unfolds its advantages when used in large numbers. Therefore, it is primarily suitable for construction tasks that do not have strict site-specific dimensions, such as building on an open space, as opposed to densification in urban areas (VI). Once again, this trend remains predominantly supplier bound since every manufacturer relies on their own standards by implementing an industrialized process based on their individual design. Despite these various methods to address the currently fragmented market situation, established mass timber suppliers (VII) and newcomers in the market are both setting up and expanding production facilities for modular mass timber units (VI), sharing a common desire for standardization.

Relating to new developments in the design and pre-construction processes, another factor that was described is a building's longevity, in the form of repurposing (II; IV), as well as a partial, or in the case of modular construction, even complete de-constructability (VI) and recycling of the materials (VII). The approach of creating a flexible floor plan with a discrete load-bearing structure to give lasting value to a large-scale building is a common architectural aspiration, independent of the construction material. This approach allows for versatile spaces that can be utilized for different purposes and easily be adapted to specific needs by adding non-load-bearing walls as partition elements. As stated, this is not a distinctive quality of mass timber construction. However, the fact that nowadays, modern mass timber construction practices are capable of producing structures like these is noteworthy since this eliminates the restriction to common construction materials like concrete or steel. It is not so much a selling argument but rather a constraint that has been overcome. Therefore, mass timber structures are not only able to blend in visually with their surroundings but also adapt to their purpose, supporting sustainable and long-lasting urban planning (IV; VI).

Another question that planners aim to address during the design phase is what will happen to the building once it has reached the end of its intended lifespan. For individually planned structures, the 'Cradle-to-Cradle' approach, meaning the selective deconstruction and repurposing of construction materials, has started to affect the design process. At the moment, the goal of constructing individually designed buildings in a way that allows for complete material repurposing is still unattainable. However, it may play a more significant role in the future (V). This objective is already more achievable considering modular mass timber buildings since individual units can be designed for disassembly and reuse in other buildings. Production in an enclosed environment ensures high quality (I; IV; VI), which can serve as a basis for repairing or renovating the modules before repurposing them in another building, thereby saving time and resources (VI). Using form-fitting connections instead of composite construction materials also simplifies the recycling and reassembly process (VII).

Mass timber construction places far more emphasis on the design phase than common building practices. Numerous objectives must be defined before the production of the construction materials can start, to take advantage of the described benefits, such as a simple and fast assembly on the building site (I). A lot of questions that can be answered with simple adjustments on the construction site, such as installing a new socket by cutting a slot for new electrical lines when building with brick or concrete tend to be more complicated in mass timber

buildings. This is often the result of challenges in areas such as load-bearing capacity and fire safety, which leads to over-planning, especially in modular construction units intended for flexible use, to avoid retrofitting later on (VI). It is, therefore, crucial to define a project's objectives in detail as early as possible and to consider advantages and disadvantages from the start (I). Once these goals are defined, the planning process is supported by sophisticated digital applications, like 3D modeling and 'BIM' (III). Given the increased complexity of mass timber construction, the planner is responsible for providing comprehensive consultation to the client to ensure an efficient process and optimal use of resources (I). As the construction process becomes increasingly complicated, suppliers prefer to offer a comprehensive approach that includes consultation, execution planning, and material production. Dividing this process among multiple subcontractors can result in a loss of efficiency in construction time and a reduction in the quality of the final product. (I; VII).

- United States -

Keeping in mind that the U.S. is still less advanced than Germany from a supply-side perspective, there are many recurring topics to consider when planning a mass timber building. The benefits of prefabrication in an enclosed environment, high-quality production, and faster on-site assembly times, which are characteristics of mass timber, also influence the decision-making process in the United States (XI). In cases where materials are imported, for example, from Europe or Canada, additional factors must be considered depending on the location (VII; VIII). These aspects primarily relate to an increase in risk, which will be further examined in detail in chapter *4.3.1 Risk Assessment*. One aspect that needs to be considered here is the additional lead time required due to transportation time (XI). Additionally, mass timber has to be chosen early on as a construction technique, as it requires a high upfront investment and detailed planning before production can start (IX). The suppliers who operate internationally try to meet the needs of their clients by offering various services based on the demands of the specific market. For international delivery, additional time for shipping and trucking must be accounted for in the planning process (XI). To minimize these time increases, some suppliers offer additional monitoring and coordination services specifically targeting their international clients, which may not be necessary for their home market (VII). The general approach for many structures built in the U.S. market is a traditional 'design-bid-build-model'. The building is fully designed, permitted, and ready for construction before being sent to multiple contractors to receive bids to compare and choose from. This approach contradicts the ideal planning

process for a mass timber building, which heavily relies on efficient coordination between the various parties involved in the design, from concept to construction. This necessitates a modification of the process to a 'design-build-model', which includes involving the manufacturer as early as possible in the design process to ensure that the necessary timber products can be secured by a predetermined date (VIII).

Since this is a fundamental change in the way the planning phase is approached, it still leaves room for design optimizations in order to create the most effective strategy (X). Similar to the German market, aspirations for standardization can also be observed on a company level in the United States. Developers commonly prefer to use design solutions they have previously employed as a baseline for new projects. Examples of this include reusing specific detailing (VIII), grid systems, and floor plans to speed up planning and fabrication. Due to the growing demand, domestic suppliers are also emphasizing prefabrication to handle increasing backlogs. In addition, design strategies such as providing flexible floor plans for various uses and enabling de-constructability for reuse are starting to be included in discussions aimed at prolonging a building's lifespan (X).

4.2. Market Conditions for the Mass Timber Construction Industry

After exploring different aspects impacting the supply of construction materials in the German and U.S. mass timber market, our focus shifts to the properties that impact demand. This section addresses the overall market environment the mass timber industry finds itself in by distinguishing the role of public awareness in material selection and how the government influences industry development through targeted incentives and regulatory requirements. We will then look at mass timber construction's role in the overall real estate market.

4.2.1. The Impact of Public Awareness

Within the real estate industry, mass timber construction is accepted to be a sustainable alternative to common construction practices (Cover, 2020; Durlinger, et al., 2013; Harte, 2017; Robertson, et al., 2012). This chapter examines the translation of awareness to the general public, explores methods to visually represent the environmental benefits, and investigates how public perception influences the demand for mass timber construction and market adoption.

- Germany -

Environmental consciousness is widely prevalent in German society and is increasingly influencing the real estate sector as it continues to grow in popularity. Mass timber construction is commonly marketed as a sustainable and environmentally friendly building technique, as a selling proposition supporting its adoption. While the majority of people acknowledge the credibility of calculations involving the extraction of CO2 from the atmosphere through embodied carbon, there are still skeptics who question its validity. Despite some differing opinions on the calculation of the carbon sequestration, wood "i*s a natural material that can be returned to the cycle of nature, leaving no hazardous waste. So, even if there were no such calculations, wood would still be a preferable building material*" (III, p. 95)*. Further, building with mass timber requires less energy than common construction practices. Especially for large-scale projects which are intended to be long-lasting, these factors, in combination with resource efficiency, have become fundamental considerations of a project's planning phase (VI). In most cases, these large-scale projects are linked to professional real estate developers or corporations with a long-term perspective. These factors, therefore, significantly influence today's decision-making on an institutional level (II).

After its market introduction in the 1990s, mass timber construction had to battle several prejudices and concerns, often relating to quality aspects (V), load-bearing capacities, longevity, and fire resistance, some of which last until today (II). However, the level of public awareness and sophistication is continuously increasing. According to the interviewees, pioneer projects that set an example and often receive extensive media coverage are seen as an important tool to reduce prejudices and promote the general openness and trend towards environmental sustainability in the form of mass timber (I; III; V; VII). This has helped this building technique to reshape its image and be recognized as an equal and modern construction material by industry professionals, with a positive connotation (V). In contrast to other markets like Italy, the average German tenant also seems to appreciate the atmosphere and aesthetic qualities of wood in their built environment as a visible design feature (II). Initially, due to the prevailing solid and robust building practices in Germany (VII), mass timber construction had to focus more on convincing and pushing the boundaries instead of being solely used for positive market differentiation and highlighting its beneficial qualities (III; V; VI). Now that mass timber construction has become a more established construction technique, accounting for more than 20% of new construction in Germany, skepticism has been reduced (III; Statista,

2023a). Therefore, apart from pioneer projects pushing new limits, mass timber construction has also partially lost its power as a distinguishing factor by solely relying on wood as a construction material (III). Among individuals less familiar with the real estate industry, there remains an element of surprise when encountering large-scale mass timber construction projects (VII). In line with showcasing built examples that demonstrate technical feasibility (III; VII), it is also important to visually represent and validate the environmental impact in a comprehensible manner. This task is accomplished through an array of different certification schemes that evaluate various steps of the construction process. These programs verify the legal and sustainable procurement of raw materials, assess resource management, and waste production, and examine energy consumption during construction and transportation. The evaluations not only serve as a marketing tool to attract potential clients or tenants who value sustainability by making the subject matter tangible, but also provide a basis for governmental subsidy programs by enabling the comparison of different projects (I). *"However, the range of certification options is diverse. Each certification body focuses on different criteria. Some prioritize sustainability, while others prioritize process quality. There is little uniformity. The idea behind certification is the same, but there are still no standards in place"* (VII, p. 122)*. Among the quoted third-party certification programs were:

- **PEFC** (**P**rogram for the **E**ndorsement of **F**orest **C**ertification Schemes) – was founded by a group of international forest owners. This program evaluates forests based on ecological, economic, social, and sustainability aspects of the management practices. It is implemented globally, often on a large scale, using a simplified approach. According to their numbers, this program certified nearly two-thirds of Germany's woodlands, about 17.3 million acres (II; PEFC Deutschland, 2023; von Willert, 2023).
- **FSC** (**F**orest **S**tewardship **C**ouncil) – is established by environmental organizations, business enterprises, and labor unions. This certification focuses on sustainable forest management in a more detailed approach with the goal of globally consistent standards. The organization states that they account for approximately 14% of Germany's forest area, about 3.6 million acres (II; FSC Deutschland, 2023; von Willert, 2023).
- **DGNB** (**D**eutsche **G**esellschaft für **N**achhaltiges **B**auen) System – is applied by the German Sustainable Building Council. It evaluates a project's overall performance through a holistic life cycle assessment (LCA) of all steps in the construction process. The certification process also distinguishes between different building tasks (I; DGNB, 2023).

- **QNG** (**Q**ualitätssiegel **N**achhaltiges **G**ebäude) – is issued by the Federal Ministry of the Interior, Building, and Community. The program supports a common understanding of sustainability and provides a legal basis for the allocation of funding, tax incentives, and subsidies by the government (I; VII; BMWSB, 2023).

A point of criticism from people involved in the mass timber industry is that, currently, none of these certification programs account for embodied carbon. They consider the use of renewable resources in an environmentally friendly way and also put a strong emphasis on the operational carbon emitted over a building's lifetime. The actual amount of CO2 extracted from the atmosphere during the growth process of the trees, which is then encapsulated in the construction parts, is not yet being accounted for in the evaluation of buildings for financial incentives (II; III). Regulatory changes are underway on multiple levels to address this issue, as stated by one interviewee: *"I believe what would be important is that the true costs that go into a building are reflected in the price, so to speak. It has to be CO2-balanced, and then timber construction becomes immediately highly competitive. […] That urgently needs to be addressed. […] There are efforts being made on many levels to put it into law. It won't take long, I believe, maybe one or two years, then it should be implemented"* (III, p. 97)*.

For industry organizations, lobbying serves as a necessary tool to raise awareness among the public and specifically among politicians. This is done to affect and accelerate the legislative process, to keep up with the constantly evolving state of mass timber construction (VII). Even though the level of sophistication regarding timber construction varies with public officials, depending on their experience with the subject matter, building in wood seems to have a positive connotation, thanks to its sustainability implications. It is therefore well received by politicians in most cases (VI). Several municipalities even actively support local mass timber projects to showcase their city as a paragon of innovation and sustainability (VII). It is important to acknowledge that while this building technique has numerous positive implications that can be showcased through certification programs and utilized as a marketing tool to demonstrate awareness and moral virtue, its direct impact on financial aspects is an influential factor closely linked to certification. These programs provide a basis for the allocation of government funding programs, tax incentives, and subsidies, which will be further explored in chapter, *4.2.2 The Government's Influence on the Industry* (II; III).

- United States -

Issues related to sustainability are receiving increasing attention, driven by programs such as the ‘Inflation Reduction Act’ and news coverage highlighting actions like the re-entry into the ‘Paris Agreement’. Taking a closer look at the real estate industry, programs like the ‘AIA 2023 Commitment’ place importance on sustainable development and send strong signals in support of mass timber construction (X). As previously determined, the level of familiarity with this building technique in the U.S. is not as advanced as in other markets (VII; XI). Therefore, mass timber is still met with a higher degree of skepticism and reservations since the number of built examples is significantly lower and therefore offers fewer points of contact for the general public. Concerns about issues that may seem counterintuitive at first, such as air quality and fire safety, as well as how cutting down trees can lead to increasing sustainability, are still more prevalent (IX; X). According to the U.S. Green Building Council, wood is among the most highly incentivized strategies, providing a reason for more people to get familiar with it in the future. To support mass timber’s claim for sustainability and create awareness, the United States already has several rating and certification systems in place. Since new construction products are continuously being introduced to the industry, green building rating systems must keep evolving. Similar to the German market, there is no one-size-fits-all approach, and therefore, various certification schemes are in place to evaluate different types of structures by assigning varying degrees of importance to different criteria. In addition to the already mentioned FSC, the following programs are popular voluntary third-party evaluation systems in the United States (X):

- **Green Globes** – is offered by the Green Building Initiative (GBI), an international nonprofit organization accredited by the American National Standards Institute (ANSI). It is one of two rating systems approved by the U.S. government and, therefore, often used for smaller federal projects. The three-in-one building rating system evaluates new construction, existing buildings, and sustainable interiors based on environmental sustainability, health and wellness, and resilience (X; GBI, 2023).
- **LEED** (**L**eadership in **E**nergy and **E**nvironmental **D**esign) – is an evaluation system issued by the U.S. Green Building Council. It evaluates buildings based on awarded points for different criteria, classifying them into four categories: Certified, Silver, Gold, and Platinum (worst to best). It is approved by the U.S. government and commonly used for larger federal projects (VII; X; XI; USGBC, 2023).

- **LBC** (**L**iving **B**uilding **C**hallenge) – is established by the International Living Future Institute. This program is based on actual, rather than modeled or anticipated, performance. A building must be operational for at least 12 consecutive months prior to the audit. This evaluation is applicable for new buildings, existing buildings, interior, and landscape or infrastructure projects (X; ILFI, 2023).

In addition, 'BREEAM' and 'EarthCraft' were also mentioned during the interview process (VII; X). The characteristics being evaluated in these rating systems, relevant to mass timber construction, include material efficiency, recycling, use of salvaged materials, energy efficiency, local sourcing, waste mitigation and minimization, and indoor air quality. A criticism is that these evaluation systems strongly emphasize the distance of supply for mass timber products but fail to consider the mode of transportation (X). This is particularly relevant given that, in many cases, the United States still relies on foreign sources for these products (VII). Also, the predominant focus on a building's energy performance, while neglecting the embodied carbon, was mentioned on multiple occasions as a major deficit. The possible implications for the competitiveness of mass timber are expected to be significant if carbon sequestration were included in evaluations for incentive programs (VIII; X; XI). While efforts are being made to address the issue, the likelihood of embodied carbon being considered in the short term is questionable. One interviewee indicated: "*I very much see that changing in the next 10 to 15 years. A lot of cities like D.C. have put out pretty lofty goals of becoming carbon neutral by a certain date the only way to do that is to start regulating embodied carbon as well as operational"* (VIII, p. 132).

However, certification currently serves as a driver for mass timber construction in the U.S. real estate market, as it allows for product differentiation. Due to a lower supply, it is still relatively easy to distinguish the product in the short term by utilizing mass timber as a sustainable construction technique. The scarcity of alternatives, combined with the available knowledge from more established markets, provides a valuable marketing tool by demonstrating a high degree of environmental awareness and responsibility (VII; X; XI). Besides its environmental sustainability, another characteristic that seems to be appreciated by the market is the aesthetic appeal of visible wood elements. This construction technique is also a way to set the project apart from the competition visually. People seem to appreciate the connection to nature resulting from using wood as a construction material for interior spaces (VIII; X). Studies also suggest that wood's biophilic qualities translate positively to stress reduction, cognitive

performance, productivity, concentration, creativity, and well-being, which has a strong influence on attracting various tenants. In large-scale projects, the combination of these qualities – the biophilic characteristics and sustainable image – particularly appeals to office tenants, such as large corporations and tech companies. Especially millennials and 'Gen Zs' place great value on a healthy workplace environment. As a result, businesses are paying increasing attention to workplace quality in the form of ESG goals in order to attract and retain young talent. This phenomenon is not only acknowledged by large corporations but also by smaller institutions, ranging from 'K-12' schools to higher education facilities. Universities, often serving as the point of origin of sustainability knowledge, embrace mass timber in their building projects, encompassing libraries, student centers, classrooms, and laboratories. This aligns with the principles of biophilic design, as supported by their research (X). Besides the workplace and education sectors, these design characteristics are also appreciated in the residential market, particularly in large-scale projects in the form of multifamily buildings. Individuals seem to value a home that differentiates itself from the 'cookie-cutter' design that currently dominates the industry (X; XI). Especially in highly competitive real estate markets, where tens of thousands of housing units are delivered every year, buildings tend to look very similar, making it difficult for developers to distinguish their products. Market differentiation currently plays a significant role in advocating for mass timber construction in all those areas.

It is, however, expected to be a temporary feature since it depends on a lack of comparable alternatives. In the long run, this driving factor could turn into downside protection for developers. If mass timber becomes more established in the market, it could be perceived less as a mark of quality than as a prerequisite to attract high-quality tenants (XI). Since end-users value these attributes, mass timber construction is often portrayed as a sustainable alternative with a strong connection to nature. From a developer's perspective, the decision is generally more heavily driven by demand than by environmental considerations and, therefore, it tends to follow market logic rather than community logic. (VIII; X; York, Vedula, & Lenox, 2018). Especially on an institutional investment level, mass timber's qualities are often promoted based on a limited number of domestic case studies (VIII). In the current market situation, these examples suggest that mass timber construction is expected to generate higher quality tenants, long-term value, and profit incentives (XI), which will be explored further in chapters *4.3.1 Risk Assessment* and chapter *4.3.2 Financial Considerations.*

4.2.2. The Government's Influence on the Industry

There are several approaches that governments can take to promote desired behavior in a market environment. This chapter will focus on the two major scenarios in which the administration can influence the mass timber construction industry by either incentivizing or regulating. One meaningful way of promoting preferred behavior is through fiscal policy in the form of subsidies and taxation to modify price signals (Koirala, 2019). Therefore, this approach aims to influence market logic in voluntary decision-making scenarios for self-benefit. Another way to apply pressure is through regulation and regulatory threats by passing new laws (Harrison & Antweiler, 2003). Grant (1997) found that policies granting individuals the right to sue are among the most significant factors influencing industry change concerning environmental pollution.

- Germany -

Sustainability issues have become a major political topic in the construction industry, over the last years (I). Several interviewees described an apparent politically driven push for sustainable construction (II; V; VII) in order to reduce carbon emissions and reach Germany's goal of CO2 neutrality by 2045 (BMWK, 2023). The overarching environmental policies are determined on the EU and national levels. The actual implementation and funding of environmentally friendly initiatives, however, are primarily handled at the state level (II). In some cases, these initiatives are even further promoted and implemented at the city or municipality level (VI). A broad spectrum of financial incentives is available across the country (II). As described in the previous chapter, these stimulus programs rely on third-party certification to evaluate qualification criteria. In particular, the 'QNG' certification, in combination with KfW funding programs, was mentioned as an influential financial incentive (I). The KfW Development Bank operates under the supervision of the German Federal Ministry of Finance. It is commissioned by the federal and state governments to improve economic, social, and ecological living conditions. Therefore, it commonly provides financial incentives for desired behavior through a variety of subsidized loans, which are granted based on third-party certification (KfW, 2023). The incentives described are usually not explicitly aimed at mass timber construction but rather at environmentally friendly construction in general. Due to its sustainable qualities, it tends to score high in these evaluation systems, making it eligible for incentives (I).

In this instance, the omission of embodied carbon in the evaluation system is a point of criticism from recipients since they feel that part of their efforts are not being valued (II; III). In a pioneering attempt to address this issue, the state of Bavaria implemented an incentive program called 'Bayerisches Holzbauförderprogramm' (BayFHolz) in mid-2021, directly targeting large-scale mass timber construction projects. Multifamily buildings exceeding 'GK 3', as well as those used for public and administrative purposes, may be eligible for the program, provided they meet certain other criteria (Bayrische Staatskanzlei, 2022). The exact funding amount is determined by receiving €500 per ton of sequestered carbon, up to €200,000 for each construction project, and can be calculated with the 'CO2-Tool_Wood' (BMWSB, 2023; Hafner, & Piayda, 2022). This incentive program is a frontrunner and recently got extended (BStMB, 2023). Planners advocating for CO2 balancing, however, take issue with the way the use of wood is encouraged in this approach. Their concern is that promoting the use of as much wood as possible without evaluating the specific construction task at hand in more detail could contradict the efficient use of resources. They fear that this could lead to instances where timber might not be the most applicable choice but is used regardless to trigger a quota for additional subsidies (II; III).

Besides these voluntary incentives, governments can also enforce change through new regulations and by indicating future regulatory changes (Harrison & Antweiler, 2003). After the modernization of the procurement law in 2016, public construction tenders for government projects became a very straightforward way for the governing body to influence the choice of construction material in Germany. While product neutrality must be respected in these architectural competitions, and the bidding process must be done on a European basis, it is still possible to predefine the type of construction material (II; IV; VI; Faßnacht, Götz, & Hafner, 2022). Therefore, mass timber can be specified as a prerequisite. This plays an important role, especially on a local level. Cities and municipalities like to set themselves apart by demonstrating a leading role in environmental awareness and responsibility (II; VI; VII). Another way to incentivize sustainable construction is by strengthening existing laws. This has recently been done in Germany, where a building's energy consumption is being targeted, independent of the construction material. Specific benchmarks are set by the lawmaker, in the form of the 'EEG' (Erneuerbare-Energien-Gesetz) and 'GEG' (Gebäudeenergiegesetz), as a prerequisite for eligibility for subsidization (I; V; BMWSB, 2023).

More prominently noted was the adaptation and renewal of the existing building code, particularly the implementation of an official timber construction guideline (Muster-Holzbaurichtline) for buildings exceeding 'GK 3'. This was mentioned as an essential step in providing clarity, a basis for orientation, and especially legal certainty (V; VII). In contrast to a building's energy consumption, where laws often impose limits, the revision of the building code aims to reduce restrictions by updating it to include new construction practices. This step towards clarification seems to be widely appreciated. However, according to suggestions from the interviewees, there is still room for improvement in terms of updating speed, a more precise differentiation of construction techniques, and a higher degree of flexibility (IV; V; VII). Currently, even minor deviations from the norm trigger an excessive amount of additional work, especially when related to obtaining permits for fire safety. While these measures have made it easier to plan and build with timber, experience and familiarity with the subject matter are still differentiating factors among planners, especially in technical aspects such as fire safety. *"It has improved, but I would not say it's easy yet. It definitely helps to have relevant prior knowledge"* (V, p. 108)*.

The uniform direction towards sustainable development in the construction industry, from the EU level down to small municipalities, implies future regulations to achieve CO2 neutrality (II; III). The current policies and social climate indicate that this trend will continue to grow. Most government initiatives that directly target construction materials tend to focus on fiscal policy rather than setting regulatory boundaries. However, planners, investors, and developers already have to consider possible future changes in regulations (II).

- United States -

The trend towards sustainable construction is also emerging in the United States, independent of party politics or a state's political orientation. The reasoning for political support may differ, with the Democratic Party placing more importance on environmental aspects, while Republicans tend to argue for economic freedom. However, this has resulted in genuine support for mass timber construction, with politicians across the aisle particularly rallying behind the argument of new rural jobs that could be created by the emergence of a more substantial mass timber market. This trend can be observed especially well with federal, state, and municipal agencies in the Washington D.C. area (IX; X). Overall, the U.S. takes a more holistic approach by incentivizing the use of low-carbon materials and equipment, which are not commonly

directed at a particular construction technique (XI). The '2022 Inflation Reduction Act' is an example of efforts to support sustainable building practices by providing additional funding, tax incentives, grants, and government loans (VIII; The White House, 2023a). However, these initiatives are currently predominantly focused on reducing operational carbon emissions. The specific form and implementation of incentive programs depends on the state and local government. Mass timber construction is generally known to be energy efficient and often scores high in categories that determine the applicability of incentives. However, the issue of valuing sequestered carbon in construction materials becomes relevant once again when applying for these programs. The lack of consideration for embodied carbon in the sustainability evaluations has also led to unanimous criticism from various stakeholders in the U.S. construction industry, who seem to be less optimistic about any imminent changes, with some estimates suggesting that it could take anywhere from 5 to 15 years to see any significant progress (IX; VIII; X; XI).

Government organizations such as the U.S. General Service Administration, the Environmental Protection Agency, the Department of Housing, and the Department of Health and Human Services took an early lead in incorporating green building guidelines in the design, construction, and renovation of federal facilities (X). This is part of the administration's goal to achieve a 30% reduction in direct greenhouse gas emissions from federal buildings by 2030 (The White House, 2023a). While leading by example is a meaningful step in promoting industry transition (III), implementing a support system of market intermediaries is beneficial to reduce the entry barrier for newcomers (VIII). Particularly in an environment defined by market logic, intermediaries substantially affect the implementation of green building practices by *"easing adoption and fostering legitimacy"* (York, et al., 2018, p. 8). The U.S. government supports this through institutions such as the United States Department of Agriculture (USDA) Forest Service, which provides funding to intermediaries acting as independent third-party consultants. These intermediaries are well-connected within the industry and encourage the adoption of mass timber construction through counseling, research, project support, and education (X). Especially early in the decision-making process, this is an effective tool, directly promoting the use of mass timber by reducing entry barriers. These intermediaries not only help to identify potential incentives but also provide crucial assistance to developers and planners in navigating a complex landscape of regulatory requirements in an ever-changing legal environment. This extends to providing assistance in negotiating with local permitting authorities regarding fire safety (VIII; IX).

In order to stay up to date with the latest technical advancements, the '2021 International Building Code' (IBC) will be replaced by the '2024 IBC', which will bring about substantial regulatory changes for mass timber construction (X; McLain, 2022). The most significant adjustments in the past were often related to fire safety, exposure of load-bearing timber elements, and building height. Currently, 90% of large-scale mass timber projects built, under construction, or in design are 12 stories or less, presumably mainly due to limitations on timber exposure (McLain, 2022). After having had positive experiences in the past, the city of Washington, D.C., among others, has gone so far as to already adopt the '2024 IBC' code in advance (X). Changes in the updated version permit 100% timber exposure for buildings up to eight stories and 25,9m/85ft (Type IV-C). The changes for buildings up to 54,9m/180ft, including 12 stories of timber, build over a possible multi-story podium (Type IV-B), allow for 100% exposure of timber ceilings, in addition to partial exposure of the load-bearing structure and walls. Only structures up to 18 stories and 82,3m/270ft (Type IV-A) are not permitted to expose any timber (McLain, 2022). Based on verified test results, these constant adaptations are essential in promoting the use of mass timber as a more established construction practice, making it a suitable choice for an even broader range of large-scale building tasks (VIII).

4.2.3. Mass Timber's Position within the overall Real Estate Market

This chapter explores how large-scale mass timber construction is influenced by the overall real estate market. The interviewees' perspectives offer insights into the relationship between mass timber construction, the economy, local markets, and regional adoption. While this thesis primarily concentrates on factors directly related to large-scale mass timber construction, it is essential to acknowledge that this industry is also subject to broader macroeconomic forces. During the interviews, conducted in the aftermath of the COVID-19 pandemic, the implications of Russia's invasion of Ukraine, high inflation, and rising interest rates were additional significant factors that need to be considered (IV).

- Germany -

Price fluctuations in construction materials particularly shook up the German market. This phenomenon was not exclusive to mass timber. It affected all types of construction practices, including the production of bricks, for example, which was postponed due to high gas prices. During the COVID-19 pandemic, insulation also saw extreme fluctuations, with prices as much

as tripling at certain points in time (IV). Despite its widespread domestic production, the availability of wood as a raw material posed a problem for the timber construction industry, as several suppliers preferred to ship their materials to the U.S. and Canada. This provided an opportunity for some established German mass timber producers to leverage their long-standing supplier relationships or rely on their internally owned raw material supply (VI; VII). However, industry experts do not attribute these uncertainties specifically to the mass timber construction sector. They are rather perceived as a cross-industry phenomenon that has occurred irrespective of the material due to external circumstances (IV). "*This cannot be considered a precedent for future, similar developments in timber construction, since construction in general, as well as material procurement are commonly subject to risks"* (V, p. 107)*.

Over the course of the interview process, the situation stabilized to a more predictable level in the beginning of 2023 (IV; VI). Stakeholders remain optimistic about mass timber construction, especially in the large-volume sector, where the mass timber construction industry is expected to continue gaining market share (II; IV; V; VII). *"In general, we see growth in the timber construction industry and are very positive about it. Even though the construction industry may be cooling down at the moment, we see a very positive development in the timber construction sector"* (II, p. 93)*, showing *"potential to build even more in wood and significantly increase its market segment"* (II, p. 90)*. Additionally, the government's commitment to sustainability and its target of constructing 400.000 new residential units each year generate optimism among manufacturers employing modular series production. They anticipate a continuous rise in demand as a result (VI). The interviewees expressed a shared expectation of an increasing emphasis on prefabrication and modular construction (II; V; VI; VII) *"as the conventional construction process still leaves substantial room for optimization"* (V, p. 109)*.

Despite this remaining potential to reduce market fragmentation through standardization in the industry, mass timber construction has successfully transitioned from being a niche market to becoming a more widely recognized construction practice (V). This does not imply that it has already reached the same level of acknowledgment as conventional construction practices, which still represent the majority of new construction (III). However, it has gained enough traction that a growing number of clients specifically seek it out for its distinct qualities. Some even started following this trend more blindly due to its increasing popularity and the growing number of successful examples in the market (III; IV). "*Compared to 10 to 15 years ago, the domestic timber industry is booming since it is being supported on multiple levels"* (I, p. 85)*.

It is not just architects anymore advocating for this type of construction. Clients from the private and public sectors are also proactively requesting it (V; VI). This development is based on the very favorable framework conditions that Germany offers. The mass timber industry has, therefore, managed to establish a market for itself, where nowadays, the *"main competitor usually isn't the traditional construction industry, but rather another timber construction company"* (II, p. 88)*****.

- United States -

In the U.S. mass timber finds itself in a market environment where a building can still easily differentiate itself from other large-scale projects based on the construction material used. With only a few available examples to learn from, the market can be considered a niche. Since market differentiation is still an influential factor, mass timber is predominantly employed in highly competitive markets. For that reason, the aforementioned adverse market influences over the last two years have shown less of an impact on mass timber construction (XI).

In many cases, the number of comparable alternatives in local markets is low to nonexistent. This phenomenon is particularly evident in the office segment, which according to current estimates, is projected to continue its downward trend over the next year (X). A Baltimore-based project manager offered the following description: *"As soon as the timber started going up, there was a lot of interest. We were having tours weekly. […] People were all over it",* while at the same time, there were *"hundreds of open office tenders in Baltimore"* (IX, p. 136). This effect is not exclusive to the office sector but can be observed throughout the industry. Most large-scale mass timber buildings under design or construction are situated in densely populated urban areas, with a notable concentration along the East and West Coast (IX). In prime locations, an extremely high density is *"required to recoup the land costs"* (VIII, p. 129). This may entail the construction of very tall timber buildings, leading to a more complicated and costly design process (VIII). Due to the current developments in population density, a generally high demand for residential buildings in these urban areas exists (X). As a result, mass timber construction is also gaining popularity in the mid-rise multifamily building segment in secondary cities, allowing for smaller project sizes. The structures in this particular category are often constructed as 'Type IV-B', which, under 'IBC 2021' regulations, permits timber exposure (VIII; X). Since this is currently not possible with buildings classified as 'Type IV-A', it further increases market differentiation in the form of aesthetic and biophilic qualities (X;

McLain, 2022). The general growth in urban areas due to an increasing population is expected to continue in the coming decades (X). The extent, however, will be subject to specific developments in local markets. While the existing case studies and a small number of built examples provide useful guidance, they only describe isolated segments of a fragmented market that varies across the country (VIII; The Wood Products Council, 2022). Mass timber is subject to the general real estate market, as *"it follows the population, follows the money"* (IX, p. 139). On a more local scale, however, it manages to differentiate itself and create its own niche based on its unique qualities, popularity, and scarce supply (XI).

The mass timber market in the United States is still in the early stages of development among all categories, including research, production, and construction. The implementation of a reliable domestic supply chain is described as a central factor in creating a more established market (VII; X). The industry is expected to undergo a *"gradual transition"* (X, p. 138) as the number of large-scale mass timber buildings increases while the amount of obstacles declines. Over time, market differentiation is expected to play a lesser role and take a subordinate position. One interviewee suggested that *"this process will likely take a long time to happen organically. […] Without such policy changes, I think it is unlikely that the widespread adoption of mass timber construction will happen quickly"* (XI, p. 163). Companies' current focus is to gain a competitive edge by acquiring knowledge early on and avoiding obsoletion in the future, thus trying to *"get ahead of that market"* (VIII, p. 132).

4.3. Mass Timber Construction as an Investment Case

The third and final chapter analyzes the financial aspects of mass timber construction, based on its qualities and deficits described earlier. By exploring how risk assessment impacts the decision-making process, this section outlines driving factors relating to mass timber construction as a business case.

4.3.1. Risk Assessment

This section of the thesis examines the risk related factors identified during the interview process. The respondents described multiple ways in which the choice of construction material can impact the risk assessment of a project in both strategic short-term and long-term considerations.

- Germany -

A shared concern among the interviewees is time increase due to a variety of factors. Since one of mass timber construction's distinct qualities is a fast on-site construction process, delays might cancel out this advantage. Mass timber's production scheduling enhances these concerns, as funds typically get tied up early on for the production of the individually designed construction components. Especially in the early stages of a project, a significant emphasis is placed on planning. The design process for large-scale mass timber buildings necessitates an early commitment to the construction material, as the planning process differs from typical construction practices. The commitment to the material must be made at a point in time when not all design questions have been resolved yet (I; IV). The lack of standardization in planning and detailing, discussed in chapter *4.1.3 Advancements in the Design Process*, is a mutual apprehension among the participants (I; VI; VII). Despite a high level of available knowledge in the German mass timber market, deviating from the norm (MHolzBauRL) can still lead to challenges and cause permitting procedures to become time-consuming (IV). Although legal codes are constantly being updated and lobbying efforts are underway to create awareness among politicians and the general public, developers have been cautious in the past. Specifically, with multi-story residential buildings, the lack of standardization compared to conventional construction practices has been perceived as a potential increase in risk (VII).

The possibility for delays can also arise from interface issues between different trades with varying degrees of experience and precision in execution (I). In Germany mechanical, electrical, and plumbing (MEP) contractors are typically small local companies, which often lack experience with mass timber construction. They are, therefore, not used to the lower level of flexibility for installation in later stages of the construction process (VII). Also, in large-volume projects, where hybrid construction is used in the form of reinforced concrete or brick as a podium, elevator shafts, or staircases, the varying degrees of precision tend to become a problem *"because the mason works in the precision range of centimeters, and timber construction is in the millimeter range, which can often be challenging"* (II, p. 91)*.

The decision-making process and assessment of project goals in the predesign phase are also affected by the general reservations of stakeholders involved in the construction process, as well as the prejudices of potential tenants. Although there has been a noticeable increase in awareness, even among non-experts, prejudices still exist in the market. Most preconceptions

are related to quality, longevity, pricing, and fire safety and can still lead to problems in individual cases. Stakeholders place particular emphasis on the construction cost of mass timber when deciding on the material. While mass timber is commonly expected to be more expensive than conventional construction practices in terms of material (II; III; V), suppliers of modular construction units have suggested that it can already be cost-competitive (VI; VII).

Despite these aspects, mass timber does not just affect risk in a negative way compared to common construction techniques. The overall acceptance among tenants has generally been high for mass timber (VI). To a certain extent, the choice of construction material could still be considered a differentiating factor in large-scale projects, despite an adoption rate of more than 20% across all building classes (III; VII; Statista, 2023a). Therefore, buildings achieve market rents under the current circumstances (VI). Based on present government policies, market developments, and the sentiment in society, experts believe the sustainable building industry to keep growing in significance. *"That will definitely become a more prominent topic. If there isn't a radical shift in public opinion, it will become more and more of a topic. So, the trend is definitely moving in that direction"* (V, p. 107)*. Its qualities are anticipated to significantly impact the long-term value preservation of buildings. *"We are building with wood, because if I have a building in 15 years that has not been constructed according to sustainable criteria, the market value will dramatically decrease"* (II, p. 88)*. Developers, therefore, need to weigh short-term risk increases against possible long-term benefits.

- United States -

As the U.S. market is still in the early stages of adaptation, concerns about risk increases are an important consideration. Starting with the procurement of financial resources, the choice of mass timber for large-scale projects is currently limited to a small number of equity-strong developers, governmental institutions, and corporations. Due to the limited amount of existing market data, lenders are more cautious when extending loans for mass timber buildings. As a result of the higher perceived risk involved, the borrower's liquidity becomes more important. This narrows down the number of companies that can take on such projects. Consequently, the first step to creating these precedents lies with financially strong investors (IX).

It is observable that a growing number of successful examples in the market generally leads to a reduction in risk assumptions. This mitigation of concerns also applies to delays that can occur

during the permitting process. *"The first conversations might slow down permitting, but after that, it will get more streamlined"* (X, p. 140). Also, the fact that *"codes and regulations for mass timber construction are not yet fully developed in the United States, […] could make some developers uncomfortable with the new building method"* (XI, p. 162). Misconceptions on an individual level, particularly regarding fire safety, can lead to prejudices against mass timber construction (IX). Through educational programs, third-party market intermediaries such as nonprofits and NGOs are addressing reservations about mass timber construction, including concerns about its burning behavior, environmental impact, and indoor air quality. These efforts aim to reduce the perceived risk associated with inexperience (VIII; X). The stage of adoption and the level of awareness in the local market are, therefore, important factors for assessing the risk of a specific project. Reservations and inexperience among individual stakeholders involved in the financing, planning, permitting, production, and construction process can lead to longer time and higher cost estimations in the form of safety margins to secure the individual party's own interest (IX; X; XI). Especially concerning the procurement and on-site assembly of mass timber construction components, parties involved often apply a safety margin to their bids to reduce personal risk. When acquiring the engineered construction elements, it can also be necessary to consider issues that may increase the risk on an international scale, as many U.S. companies still rely on imported materials. *"We're global in our sourcing for these mass timber products and so even the currency exchange rate affects our decision, from where we're going to purchase these mass timber products. We do see that inflation and cost escalation has also impacted the timber market*" (VIII, p. 133). Regarding the long-distance procurement of mass timber components, the potential for shipping delays presents a competitive disadvantage compared to common construction practices where materials can be obtained locally. The combination of all these factors can increase the risk of a project being discontinued sooner than it would have in other scenarios.

Despite this, a significant factor currently driving the market adoption of mass timber construction and justifying the added risk is the potential for market differentiation as a risk-decreasing component. As described, the limited number of successful examples in the market increases the risk by providing less reliable market data. However, it also produces an opportunity to differentiate oneself from the competition and is a goal for developers to pursue in the short run. This was often stated as reason during the interview process, and while its impact will most likely decrease with a growing number of built examples, it is still a significant factor in the short term. As a result of choosing mass timber construction, developers expect

higher rent premiums, faster lease-ups, and high-quality tenants to make up for taking on that added risk (VIII; X; XI). Financial details will be discussed further in chapter *4.3.2 Financial Considerations*. Based on the existing case studies, it can be inferred that tenants are willing to pay more for mass timber buildings, which supports the expectation of rent premiums (The Wood Products Council, 2022; XI). The high level of interest further implies quick lease-up times resulting from the supply-demand imbalance (IX). As there is "*latent demand for unique products in the market, […] mass timber construction could provide downside protection for developers, particularly in the case of a financial impact such as rising interest rates or an exogenous effect."* This "*might help to maintain demand for mass timber construction buildings even during difficult economic conditions"* (XI, p. 162). This situation, however, is expected to be temporary since it is based on a pioneering role.

In addition to short-term benefits, mass timber is described to be particularly well-suited for long-term strategies in the real estate sector. The United States is anticipated to see a continued increase in the trend toward sustainable building practices (X; XI). Developers and investors assume that there will be a future 'green premium' associated with energy efficiency and low embodied carbon while simultaneously avoiding a 'brown discount'. *"We see anything that's not being built to that level of environmental rigor is going to become obsolete, in our opinion, in the next 10 to 15 years"* (VIII, p. 132). These qualities are believed to let developers and investors exit at a premium in the long run (XI). It should be noted that all of these assumptions are based on the limited number of existing case studies and must be reevaluated on an individual level for specific local market conditions.

4.3.2. Financial Considerations

Large-scale construction projects generally involve the participation of developers, large corporations, government institutions, and other sizable entities such as universities. While motivations among different parties may vary, to a certain degree, the realization of a project ultimately depends on its overall cost (II; IX; X). Particularly in a business environment, the cost of construction and the expected return on investment (ROI) play a fundamental role in determining the feasibility of a project (VIII; XI). Building upon the risk assessment in relation to mass timber in the previous chapter, we will now examine the key factors that drive the business case for mass timber. At this point, many of the previously described factors interconnect.

- Germany -

It is commonly accepted that choosing mass timber is accompanied by an increase in construction material costs (I; III; V; VI; VII). Some interviewees suggest that price neutrality can already be archived in specific cases through serial production, modular construction, or extensive planning efforts (VI; VII). *"But generally, timber construction tends to be slightly more expensive, and that is the main reservation"* (V, p. 107)* compared to conventional construction practices. The interviewees attribute several reasons to this phenomenon. Firstly, there is a lack of supply due to a shortage of skilled labor to meet the high demand. This supply-demand imbalance is described to have a more substantial impact on mass timber than on other construction practices (V). Secondly, there is remaining potential for optimization during the production process, particularly in terms of standardization. Thirdly, price fluctuations have significantly affected mass timber construction over the past three years (VII).

To understand what drives mass timber's growing popularity, it is crucial to consider costs beyond the tangible figures associated with the production and procurement of materials, as well as the isolated costs of construction. *"That is also always a matter of benchmarking. It is always important to draw the right cost conclusions. Of course, you can compare the building's overall afterwards. On a component level, however, I would caution against doing so, to a certain extent"* (I, p. 85-86)*. Government incentives as analyzed in chapter *4.2.2. The Government's Influence on the Industry, also* contribute to the overall cost performance. Securing financial resources is an essential step in the early stages of the planning process. Therefore, professionals in the real estate industry include tax incentives and subsidized loans for sustainable construction in their overall project cost estimates. These programs support environmentally friendly construction by incorporating ESG goals as a requirement rather than basing their assessment solely on a project's risk evaluation and loan duration. The benefits have started to attract developers to mass timber and have sparked interest among investors, who are often not yet fully aware of the available options. In such cases, the responsibility for providing assistance often lies with the consulting architect, as these incentives vary depending on the state. Even though most of these programs are not directly tied to mass timber, they strongly align with its qualities as an environmentally friendly construction method. As a result, they also provide a financial incentive that can help recoup the higher construction costs (I; III).

Furthermore, according to the interviewees' assertions, some additional characteristics need to be considered for a proper comparison. One aspect that influences the overall cost calculation is the construction time. In combination with timely and efficient material procurement, mass timber excels at fast on-site construction due to prefabrication (II; IV; VI). Faster project completion can lead to earlier commissioning and, consequently, an earlier revenue stream. This accelerated assembly process, leading to a faster lease-up, is of particular importance in build-for-rent projects. Especially with high-volume projects, this earlier entry into the return curve can help offset the increase in construction costs (I; VII). Additionally, the high perceived value resulting from wood's aesthetic, biophilic, and sustainable qualities can potentially justify rents above the market rate and thereby positively impact the overall financial returns (IV; V).

However, the primary reason warranting the cost increase is a project's long-term perspective. As discovered in chapter *4.3.1. Risk Assessment*, sustainability has significant implications for the presumed long-term risk. In anticipation of potential future regulations, investors are now strategically choosing an environmentally friendly construction technique to preserve their long-term interests and avoid value depreciation. Therefore, despite higher short-term costs, mass timber is being perceived as a competitive construction technique for large-scale projects by real estate developers in the German market. This perception is based on the project's goals and a comprehensive long-term value approach (II). *"In its entirety, it is definitely efficient and economical"* (I, p. 86)*. Especially if the *"true cost"* of construction, in the form of CO2 balancing, were to be enforced industry-wide in the future, "*timber construction becomes super competitive right away"* (III, p. 97)*.

- United States -

As the level of familiarity differs more strongly in the United States, expectations regarding project costs vary significantly among industry professionals. One interviewee with extensive industry knowledge suggested a 5% cost increase for the overall project assessment as an achievable number (X). At the same time, a developer new to the market described a 10% to 15% increase compared to traditional construction practices as a realistic goal (XI). Naturally, these estimates depend on the specific project and rely on various factors and the defined scope of the assessment. However, they demonstrate a significant range of variation in cost expectations for several reasons. Firstly, there is a learning curve associated with the use of mass timber. Consequently, projects experience an indirect cost increase due to higher

associated soft costs. "*We've actually seen a few, both on the construction contracting and the architectural and engineering design side, they just put some premium onto their designer contracting costs. Just because they think, this is going to take a little bit more of a learning curve to figure this out. So, they tack on a little bit of an extra fee"* (VIII, p. 129). Secondly, the *"supply constraint of mass timber materials and the relatively small number of manufacturers"* (XI, p. 161) pose an additional financial risk to mass timber construction. Long transportation distances within or to the United States can impact a project's overall costs, resulting from time and shipping expenses. Thirdly, the choice of construction material also affects the direct costs involved. Compared to traditional construction practices, the high degree of complexity, especially in large-scale mass timber projects, leads to a significant increase in the price of the load-bearing structure (IX; Scouse, et al. 2020).

As highlighted in the previous chapter, the increased risk and higher cost make mass timber predominantly sought after by equity-strong developers and large institutions in the United States, "*who prioritize ESG goals as part of their company philosophy".* Therefore, *"currently, only a small amount of investment money is available for such projects"* (XI, p. 164). In order to secure a loan for a mass timber building, borrowers need to demonstrate financial strength to the lender through higher equity contributions or capital reserves (IX). The difference in the financing structure is not the only factor that sets these types of projects apart. The developers' usual approach of analysis based on comparisons also proves ineffective due to the lack of existing precedents in the market. Estimates must be made based on a small amount of existing data, including case studies and market-specific assumptions, depending on the location. Especially in 'build-for-rent' projects, precise predictions regarding rental income are of utmost importance for the assessment of a project's feasibility. A real estate developer operating in a U.S. metropolis explained that they are constrained in making precise predictions due to the absence of conclusive evidence. Instead, an upper limit based on personal expectations and a lower limit based on the average market rent is established. *"Worst case scenario, we are building a nice building, so we'll at least get the average rent for that area"* (VIII, p. 134).

Investors anticipate a rent premium based on choosing mass timber as a construction material. The limited number of case studies generally supports the idea that there is a rent premium attached to mass timber, as it currently functions as a decisive differentiating factor in the U.S. market (VIII; X; XI; The Wood Products Council, 2022). These examples are also used as a selling proposition to investors since *"only a very small percentage of investment money truly*

cares about the sustainable aspects of it. They're more focused on the business, what's driving the return, and if those metrics look good" (VIII, p. 133). In the analyzed cases, tenants were willing to pay a higher price for a mass timber building. The notion is based on wood's aesthetic, biophilic, sustainable, and renewable qualities (X; The Wood Products Council, 2022). This can help to offset the initially higher construction costs in the short term, as this unique selling argument is expected to diminish in significance with increasing competition in local markets (IX).

Additionally, the current lack of comparable alternatives affects the overall economics of a project by facilitating faster lease-up and earlier revenue generation. Firstly, as already described for the German market, mass timber construction excels in fast and efficient construction processes. While this factor also plays a role in the U.S. market, its effects may be mitigated by long transportation distances for product procurement and less established construction procedures (XI). Faster lease-up is, therefore, not only achieved through fast on-site assembly but also by high occupancy shortly after completion, resulting from the high demand. This increase in leasing velocity protects investors from vacancy in the short term, as new tenants can easily be found under the current market conditions (IX; X). Mass timber is therefore expected to also *"provide downside protection for developers, particularly in the case of a financial impact such as rising interest rates or an exogenous effect. This is because there is latent demand for unique products in the market, which might help to maintain demand for mass timber construction buildings even during difficult economic conditions"* (XI, p. 162). The high demand also provides the chance to select high-quality tenants (X).

In addition to all these short-term benefits, government incentives specific to each state support sustainability in the real estate industry in a broader sense through tax incentives or loans (IX). As discovered in chapter *4.2.2. The Government's Influence on the Industry*, these programs primarily address a building's operational carbon. As a result, mass timber is indirectly promoted as a sustainable construction technique, given its tendency to also score high in terms of energy efficiency. The combination of certification for environmentally friendly construction and the sustainability aspects of mass timber are also expected to protect the value of buildings in the long run. Market differentiation as a short-term incentive is projected to lose significance as the market becomes more saturated. This long-term value approach to real estate, which provides downside protection, on the other hand, is anticipated to become more meaningful in the future (XI).

5. DISCUSSION

This final chapter will contextualize the results within the existing literature, considering my interpretation of the findings derived from the interview process. The insights provided by the participants are further supported by relevant research, which serves to strengthen or challenge the analysis. *Figure 4* illustrates how the driving factors interact.

5.1 Interdependencies between the Driving Factors

As already indicated through reoccurring themes among the different driving factors in the previous chapters, the aspects currently affecting mass timber's development as a more established construction practice in the German and U.S. market depend on a combination of different influences. These factors were examined in isolation in chapter *4. Results*, for the purpose of their theoretical assessment. Given that they are part of a dynamically changing market environment, their interdependencies and their practical implications are summarized in the following paragraphs. *Figure 4* illustrates the way the driving factors interact.

Our focus returns to the supply side. The procurement of materials for large-scale mass timber construction is influenced by a multitude of factors. The process begins with the initial harvesting of raw materials. The proximity of sourcing directly impacts the availability of materials within a specific market. Long transportation distances tend to increase uncertainty and limit flexibility. In order to draw on a sufficient local source, acquiring know-how through testing the specific type of available wood is an essential prerequisite for its use in mid- and high-rise buildings (Harte, 2017). The sole availability of raw material in the form of extensive forestlands does not support its use without the necessary research and development to ensure the suitability of the specific species for construction. The impression gained from the interviews that an increase in demand can positively support sustainable forest management is partially substantiated by Pasternack, Wishnie, & Clarke (2022). However, it is also acknowledged that forest health depends on a variety of additional factors, including wildfires, insect infestations, disease, and the effects of climate change.

The availability of a high level of information influences the adaptation of local markets by reducing concerns and entry barriers. Having a knowledge advantage over the competition also enables suppliers and planners to expand their reach beyond the local market and reap

commercial benefits based on intellectual property. This provides small and medium-sized companies (SMEs) with the chance to drive eco-innovation by *"tapping into these green niches"* (Koirala, 2019, p. 15). For less developed markets, it will take time to close this knowledge gap and establish a reliable supply chain (Scouse, Kelley, & Liang, 2020). However, it is not only the construction of necessary facilities and testing of available raw materials that are required but also the development of a local workforce and education systems. To address this relatively new construction technique, educational efforts, and retraining programs are essential to establish a foundation for adaptation, particularly within the planning sectors (Purkus, Lüdtke, & Jochem, 2020). The high degree of complexity and prefabrication make detailed and efficient planning indispensable for a smooth construction process. In less established markets, independent third-party market intermediaries, such as nonprofit organizations and NGOs, can support the adoption of sustainable construction practices (York, et al., 2018). Reducing entry barriers for newcomers and providing assistance in multiple project stages can help achieve this goal. Suppliers simultaneously customize their services to the specific needs of local markets, considering the level of available expertise and the required assistance.

While not affecting the supply side directly, governmental efforts establish the framework for the development of a more mature mass timber market. The overall direction toward sustainability in the construction industry is determined at a national or even international level. The extent and manner in which it supports the development of local markets, however, is particularly influenced by policy decisions at the state and municipal levels. The administration can support faster adoption through regulatory changes and incentive programs (Purkus, et al., 2020). In Germany and the United States, legislative efforts are currently less focused on prohibiting environmentally problematic construction practices than they are on influencing energy consumption by regulating aspects that impact a building's operational carbon (OECD, 2022). The revision of the building code to keep up with the latest technical developments appears to have a more substantial impact on the adoption of mass timber construction. Especially in the categories of timber exposure, fire safety, and building height, frequent revisions appear to be relevant and significantly affect its popularity, per the findings presented by Cover (2020). Providing legal security through clear and up-to-date legislation helps reduce uncertainties and reservations among investors and developers by facilitating a streamlined planning and permitting process. Incentive programs, such as government loans or subsidies, currently prioritize a building's environmentally friendly operation over its lifetime rather than

including the sequestration of carbon and energy consumption during the construction process as an additional factor. Government programs that explicitly address the use of mass timber and directly support its implementation are still rare. Therefore, governmental support for mass timber construction is primarily indirect, as its product-specific characteristics, combined with growing awareness of environmental issues, often align with goals such as Net Zero, passive house, and energy efficiency.

The implementation of an independent third-party certification system ensures accountability and serves as the foundation for evaluating eligibility in these incentive programs. The focus on targeting energy performance rather than embodied carbon reductions by Green Building Rating Systems (GBRs) is described to be a worldwide phenomenon (OECD, 2022). While industry experts widely acknowledge the sustainability implications of mass timber, they often express the feeling that the sequestered carbon is not adequately represented in these evaluations. Widespread awareness is essential for ensuring lasting governmental support on this issue. The large-scale mass timber construction trend is expected to continue gaining popularity (Harte, 2017), supported by the growing environmental movement addressing climate change (Graf, 2020). Expanding green mortgage-backed-security (MBS) markets in Germany and particularly in the U.S. over the last five years also reflect this trajectory (OECD, 2022). The findings of this study indicate that a government's influence on market adaptation significantly affects the speed at which the change occurs. The study conducted by (Koirala, 2019) on SMEs supports this conclusion since it states that possible future environmental regulations have an assertive impact on eco-entrepreneurs and the speed of market adoption, even before implementation.

On the client's side, the resulting construction costs are determined by a combination of the operating framework defined by the government and location-specific factors such as material procurement and labor costs. Since large-scale construction projects are primarily undertaken by developers, corporations, or governmental institutions, costs serve as the basis for discussions among stakeholders and investors, regardless of the construction material. Mass timber is still commonly associated with a cost increase (Graf, 2020). Higher complexity, a shortage of skilled labor, and a lack of standardization are still prevalent forces even in further developed markets (Purkus, et al., 2020). In addition, the learning curve associated with a lack of experience, increased risk due to long transportation distances for product procurement, and longer shipping times contributes to higher direct and indirect costs in less established markets.

The claim that these cost increases are particularly significant for the load-bearing construction frame is substantiated by the findings of Scouse, et al. (2020).

These cost and risk increases find their justification in the material-specific qualities of wood. The underlying driver for its growing popularity is its sustainable characteristic. Since this study is not intended to analyze or verify mass timber's environmental performance, sustainability is assumed based on existing literature (Cover, 2020; Durlinger, et al., 2013; Harte, 2017; Robertson, et al., 2012), governmental efforts in promoting it, and a consensus among the interviewees. The understanding, however, that it is an environmentally friendly way of construction is a vital selling proposition, differentiating it from traditional construction practices such as concrete, steel, or brick. The findings suggest that growing awareness in the market and increased familiarity with the material led to a shift in focus. It appears that instead of solely promoting the use of mass timber over traditional construction practices, increasing emphasis is being paid to evaluating its specific qualities and determining its applicability for different tasks. Furthermore, wood's aesthetic and biophilic qualities add to its growing popularity (Cover, 2020; Scouse, et al., 2020). In certain markets like Italy, wood as a visible design element may be less valued. However, occupants in Germany and the United States seem to appreciate the architectural connection to nature. Therefore, in these markets, mass timber is also promoted for its aesthetics, as well as its positive effects on health and productivity, in addition to sustainability.

In markets where large-scale construction using mass timber is not yet prevalent, visibility becomes crucial for market differentiation and significantly influences strategic decisions. The research suggests that sustainability considerations impact decisions at the administrative level, such as legislation or fiscal policy. An investors' decision-making process, on the other hand, is predominantly influenced by financial considerations. In emerging markets, where mass timber is still a unique selling proposition, stakeholders expect to gain a competitive advantage in the short run based on their choice of construction material. Investors anticipate a faster lease-up, high-quality tenants, and rent premiums attached to mass timber (Cover, 2020). In the U.S. market, potential tenants or buyers are expected to pay a higher price based on that type of building. This factor, however, is expected to lose its significance as the market matures and the number of available alternatives increases. In more established markets, differentiating oneself from the competition becomes more challenging. It can primarily be achieved by pushing the boundaries of mass timber construction through ever larger projects and increased

building heights. This approach cannot be expected to have a lasting effect in the long run. The strategic long-term implications of mass timber, however, are also compelling considerations for stakeholders. The long-term investment approach to real estate seems to be less influenced by the stage of market adaptation to mass timber. The real estate sector is already a well-established asset class for institutional investors and commercial banks that follow a long-term approach (OECD, 2022). In this regard, the strategic assumptions are not necessarily based on achieving a premium due to its unique selling proposition. Instead, they are expected to serve as downside protection in the long run. Based on the current social climate and governmental stance on climate change, it can be expected that sustainability will continue to grow in importance in the building industry. Mass timber construction is therefore viewed as an opportunity to gain a competitive advantage in the market. By anticipating stricter regulations, mass timber is expected to help preserve long-term value and achieve high exit values in the future. The results further imply that as a market becomes more established, mass timber construction increasingly becomes subject to the general real estate market and the overall economy. As the market matures, the significance of market differentiation diminishes and the focus shifts towards comprehensive long-term observation of demand characteristics.

The accurate assessment of the applicable market stage is, therefore, of particular importance to institutional investors and developers. In addition to the private sector, government projects also impact the demand side. Leading by example and showcasing successful projects in the market help to reduce prejudices and concerns among all market participants and newcomers (Purkus, et al., 2020). Institutions at various levels of government seek to establish a precedent for sustainable construction. Even though governmental projects in Germany must go through a product-neutral, European-wide public bidding process, mass timber construction can still be specified as a criterion. Similarly, in the United States, sustainability is gaining importance in construction and retrofitting projects across various branches of government. Additionally, job growth in rural areas provides an incentive for local governments to support this trend toward domestic production in the U.S. (Cover, 2020). The findings also support the assumption that local sourcing of *"wood products in green building projects creates additional earnings and wages through ripple effects"* (Scouse, et al., 2020, p. 6). Koirala's (2019) study on green and inclusive growth among SMEs further elaborates on effects relating to employment substitution, elimination of certain jobs, transformation, and job migration.

In both markets, the increasing interest has led to a supply-demand imbalance. In the German market predominantly, the lack of standardization and the shortage of skilled labor prohibit higher construction numbers. Even though efforts for global standardization are underway, the competitiveness of mass timber will to a certain degree, depend on the successful implementation of these standards (Kurzinski, Crovella, & Kremer, 2022). Moreover, in the United States, the absence of a dependable and well-established supply chain seems to impede a faster adaptation to mass timber construction. These factors are presumed to decelerate the progress of adoption, as they negatively impact construction costs. This cost increase also affects risk assessment and the expected returns, thereby impacting the overall feasibility of a project. In certain instances, the evaluation of a project's value for governments, businesses, or educational institutions goes beyond solely considering financial profits. It encompasses factors such as creating a positive image, fostering a good work environment to attract and retain young talent, and promoting well-being and productivity (Cover, 2020). For institutional investors and developers, return expectations are typically defined by tangible numbers, as the feasibility of a project is evaluated based on its bottom line. The overall assessment of a specific project, therefore, depends on the objectives defined by the respective party.

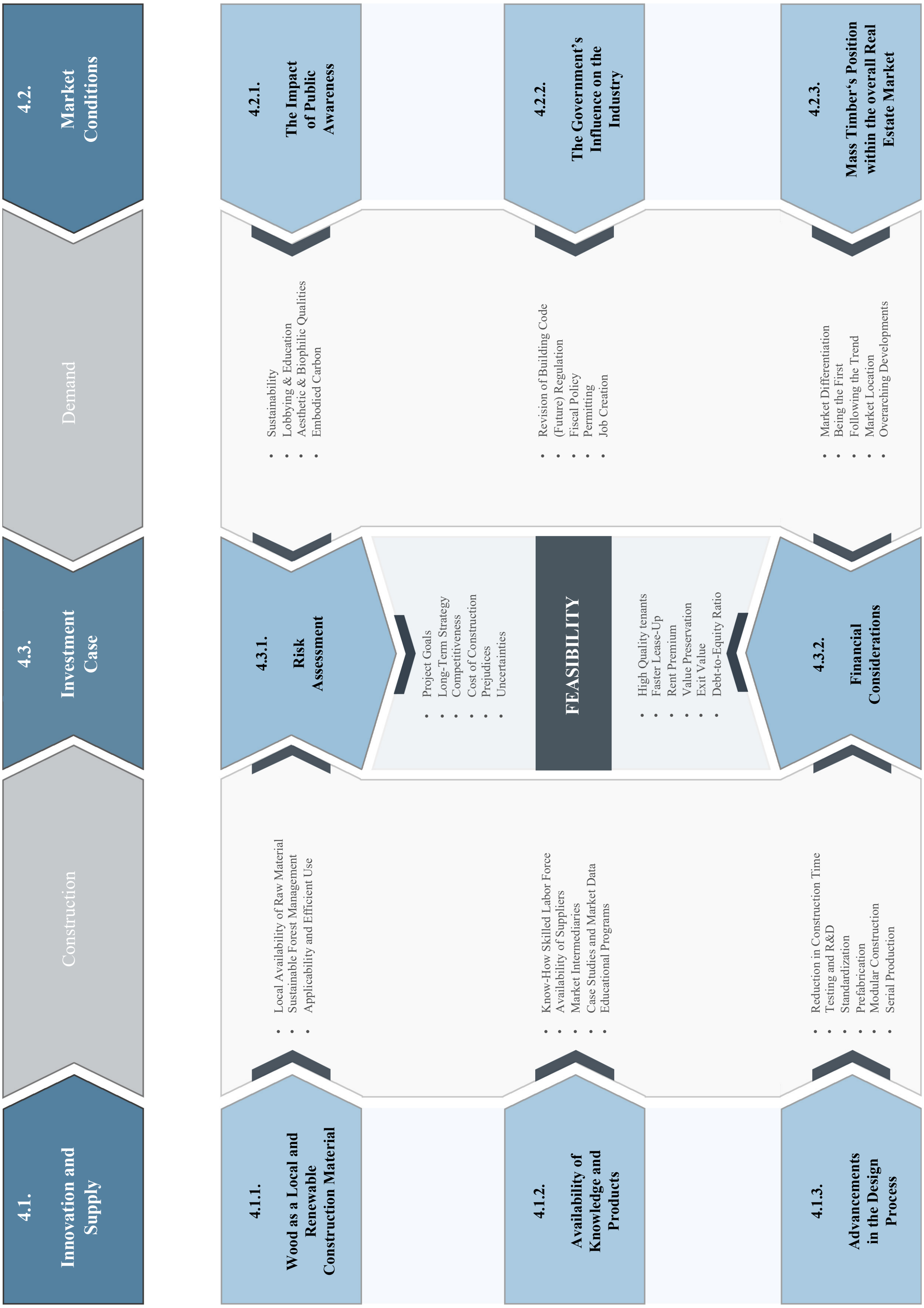

Figure 4. Interdependencies between the Driving Factors
Source: Own illustration

5.2 Current Stage of Market Adoption

The results from the interview process suggest that Germany and the United States are at different stages of market adoption of mass timber. However, it is important to note that when comparing these two markets, both countries already have a strong economy and well-established real estate market structures. Europe, followed by North America, comprises the majority of large-scale mass timber structures worldwide. The global distribution of high-rise mass timber projects (exceeding eight stories) that are completed or currently under construction consists of 65% residential buildings, 19% office buildings, 14% mixed-use buildings, and 2% institutional buildings, as of February 2022 (Safarik, et al., 2022).

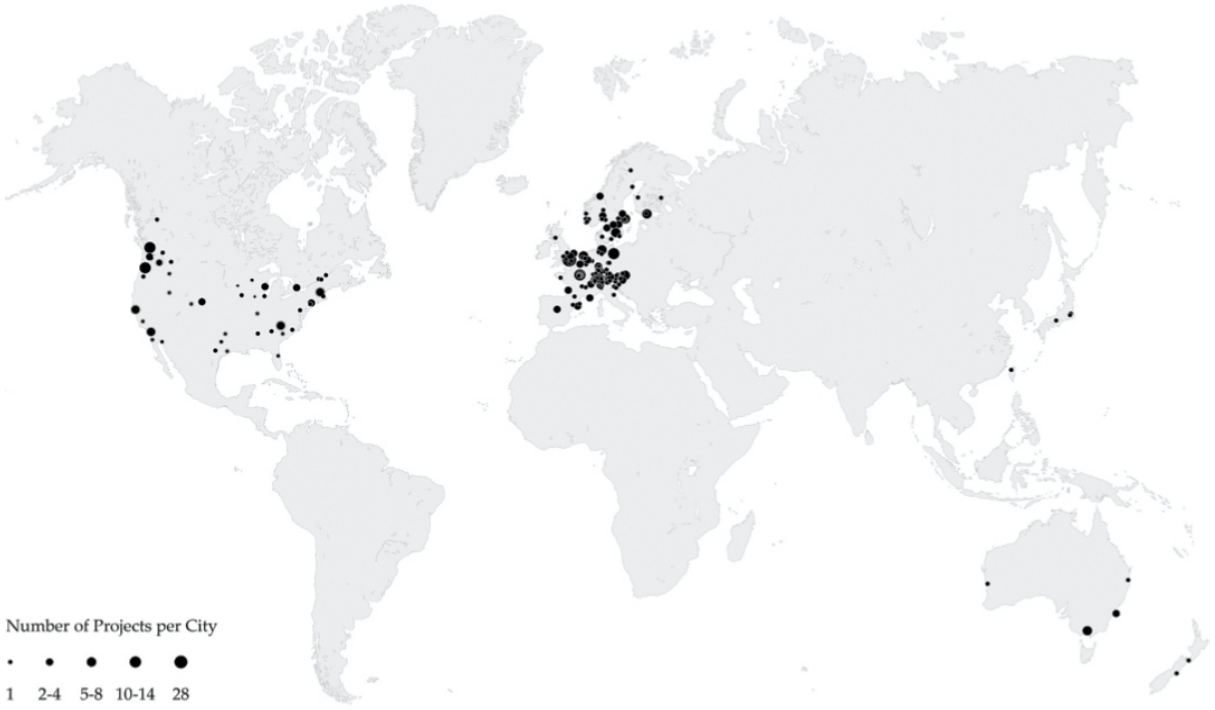

Figure 5. Global Distribution of Large-Scale Mass Timber Projects
Source: Own illustration modified from Svatoš-Ražnjevic´, Orozco, & Menges (2022, p. 5)

The OECD (2022) report on real estate finance and climate transition highlights Europe's prominent role based on its assessment of global green debt issuance for 2021. More than 50% of total green debt issued was accounted for in Europe, followed by China (19%) and the U.S. (16%). Furthermore, the overall trajectory of the real estate market's share of these green debt issuances has increased from 22% in 2014 to almost 30% in 2021, supporting the assumption of a growing sustainable building market. The following analysis examines the stages of market adoption for the German and U.S. markets based on the concept of the 'product life cycle' assessment (Levitt, 1965; Vernon, 1966; Appendix 4).

- Germany -

The German mass timber market is perceived to be at the forefront of development according to domestic and international industry experts. This is partially attributed to the enduring spillover effects of the early development stages of mass timber products from the tri-state area of Vorarlberg. This led to the initiation of the first mass timber projects in the southern part of Germany early on (Kaufmann, et al., 2022). The area has maintained its status as an innovative hub to this day, which has encouraged the emergence of several local suppliers. In addition to this knowledge advantage, locally available high-quality wood as a raw material, coupled with sustainable forest management, have resulted in a diverse range of available products.

Despite being placed among the most established mass timber markets in terms of the supply chain and stage of adaptation, the German market still faces challenges and obstacles in this regard. To some extent, the industry remains fragmented due to the diverse and individual approaches adopted by smaller local firms. This is evident as numerous suppliers and planners try to establish their own design approaches. The lack of standardization continues to produce difficulties among different trades (PwC & ULI, 2022b). While Kurzinski, et al. (2022) describe how existing European standards endorse a 'manufacturing-to-market' approach rather than a 'design-to-construction' perspective, my research suggests that this has not had a significant impact on producers so far. Grounded in Germany's long-standing history in the mass timber industry, developers of large-scale projects often rely on previous relationships and experiences to navigate the market. Therefore, standardization is primarily achieved on an interpersonal level between developers, planners, suppliers, and construction companies rather than on a technical level. The speed of market adaptation is also limited by the lack of skilled labor due to demographic developments towards an aging society, which has broader implications for the German economy. This poses a challenge for large-scale structures as the construction process becomes increasingly complex with additional building height. Traditionally grown, small and medium-sized companies often lack the resources necessary to undertake such projects. Developers of high-volume projects are, therefore, limited to larger construction firms (Purkus, et al., 2020).

Despite a relatively high degree of development, mass timber construction is still not perceived as competitive solely based on construction costs. Government policies supporting sustainable building practices remain relevant in promoting environmentally friendly construction, even

though mass timber is only indirectly addressed through fiscal policies in most states (Koirala, 2019). The revision of building codes, on the other hand, is a significant government action that appears to strongly influence the utilization of mass timber in large-scale construction projects by lifting regulatory barriers. While the interviewees suggest that certain aspects still need updating and clearer detailing to reduce complications, the legislative framework already provides a substantial level of legal certainty for the industry. Especially the introduction of the timber construction guideline (MHolzBauRL) helped to reduce the risk by providing guidance and orientation. Furthermore, the potential for stricter future environmental regulations, in line with the current political climate, incentivizes developers and institutional investors to proactively adapt and incorporate sustainable practices (Harrison & Antweiler, 2003).

It is noteworthy that none of the interviewees from Germany indicated any exceptional challenges in obtaining financing for large-scale mass timber projects. Even though mass timber is still associated with slight cost increases, significant prejudices among market actors appear to have been overcome, especially among those who have prior experience with this type of construction. Concerns are still more prevalent among parts of the general public. Large-scale mass timber projects continue to provoke a sense of amazement. Based on the information gathered from the interviews, placed in the context of the cited literature, the level of adoption in the German real estate market for large-scale mass timber construction can be categorized as being in the ‘growth stage’ of the ‘product life cycle’ (Levitt, 1965; Appendix 4). This is evident as the industry is experiencing a significant ‘boom’, with more market participants entering the scene, and planners and suppliers initiating expansion efforts into international markets. (Vernon, 1966).

- United States -

While less established, the U.S. mass timber market is also picking up speed. According to data from WoodWorks (2022), as of December 2022, construction on mass timber projects has begun in every state in the United States, encompassing all scales of building size. The total number of mass timber projects in the design phase (910) exceeds the number of projects built or under construction (767). While these numbers showcase the increasing popularity of mass timber construction, it is essential to acknowledge that these figures include projects that extend beyond the scope defined for the analysis in this thesis. Therefore, they can only be considered as supporting evidence for the suggested underlying trend. However, considering the smaller

number of buildings that meet the defined criteria for this study, their distribution aligns with the trend described by the interviewees. A majority of the completed large-scale mass timber projects are located in urban and metropolitan areas along the East and West Coasts (WoodWorks, 2023c). This allocation supports the influence of the discovered driving factor relating to the availability of material supply. The East Coast enjoys a geographic advantage over other parts of the country in terms of importing products from Europe.

Furthermore, the production of engineered mass timber components using local resources has begun in the Southeast, leading to a more regionalized supply for this part of the country. The Pacific Northwest also benefits from the local availability of high-quality raw materials. This allows urban areas around Portland and Seattle to supplement their supply through imports from Canada. In addition to these generally popular coastal locations, the increasing numbers in Texas further validate the assertion that mass timber is, to a certain extent, influenced by underlying developments in the general real estate market. Cities such as Dallas/Fort Worth, San Antonio, and Houston are among the U.S. market's 14 'Overall Real Estate Prospects'. Simultaneously, they are witnessing a rise in the number of completed and particularly noteworthy upcoming large-scale mass timber projects (PwC & ULI, 2022b; WoodWorks, 2022).

Even though the number of mass timber projects is expected to grow throughout the country, they currently represent only a fraction of the overall real estate industry. As a result, market differentiation still poses an important selling proposition. The lack of a reliable and efficient domestic supply chain is described to have a slowing effect on market adoption, as international material procurement and long shipping distances increase costs and risk. This effect appears to be amplified by the prevalent inexperience of most professionals in the real estate industry regarding this subject matter. Given that the success of large-scale construction projects is often assessed based on their financial performance, third-party market intermediaries attempt to mitigate decelerating ramifications through assistance and education, particularly in the early stages of the design process and permitting negotiations. This observation builds upon York, et al.'s (2018) research relating to the influence of market intermediaries on the voluntary adoption of sustainable building practices.

The government's impact on market adaptation in the United States primarily occurs through the revision of building codes and the adoption of new standards, thereby lifting regulatory

restrictions based on community and interest group pressure. The financial benefits for developers and investors arising from mass timber's current status as a unique choice for tenants and buyers are not expected to have a lasting effect as the number of alternatives increases in local markets. By staying ahead of the market and proactively avoiding potential future environmental regulations, the goal is to preserve the value of a building in the long run (Grant, 1997; Harrison & Antweiler, 2003). Based on the limited number of available examples in the market, the overall incorporation and sophistication across various trades in the planning, material production, and construction process, reliance on international markets for material procurement and expertise, high equity requirements for financing, and the general level of uncertainty, the rate of adoption by the U.S. real estate industry to this trend can be categorized as being in the 'introduction stage' leaning towards the 'growth stage' (Levitt, 1965; Vernon, 1966; Appendix 4).

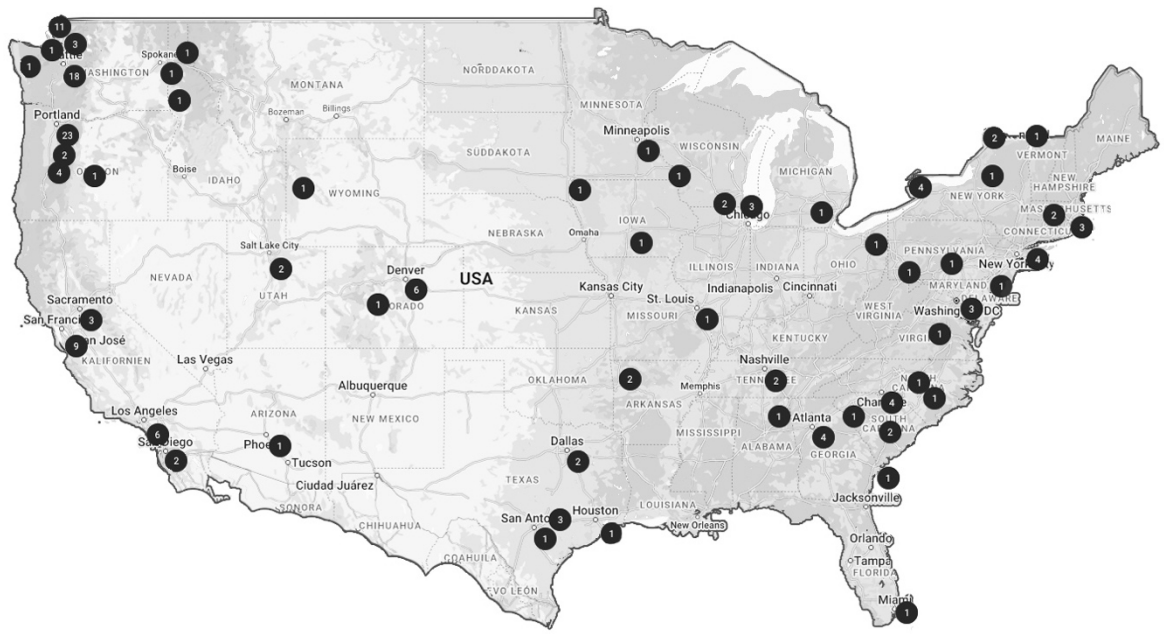

Figure 6. Large-Scale Mass Timber Projects in the U.S.
Source: Own illustration modified from WoodWorks (2023b, online)

5.3. Limitations and Suggestions for Future Research

As this study takes a comprehensive approach to analyze the underlying forces that influence the adoption process to large-scale mass timber construction in the current real estate markets of Germany and the United States, it aims to identify the driving factors that affect this change. Its research is centered around identifying the general structure and understanding the

interdependencies (Gioia, et al., 2012). Future research can therefore be suggested to explore the eight identified driving factors in more detail and precisely measure their impact on the industry over time. The emergence of more upcoming examples in the market will provide a broader basis of information for future case studies and enable a quantitative approach to analysis (Eisenhardt, 1989). As stated earlier, this thesis is built upon the understanding that sustainability, particularly in relation to climate change, will continue to gain importance in the real estate industry and acknowledges the notion that mass timber construction provides a sustainable alternative to common construction practices (Cover, 2020; Durlinger, et al., 2013; Harte, 2017; Robertson, et al., 2012).

Based on the information provided by the interviewees, I suggest focusing future research efforts on addressing market-specific needs by considering the local stage of adoption and the dominant forces at play. The intention should be to enhance the overall competitiveness of mass timber construction compared to conventional construction practices by reducing costs and mitigating associated risk. I, therefore, recommend further directing research efforts toward standardization, prefabrication, and modular construction for the German market. Additionally, as this trend is significantly influenced by government actions, future developments in fiscal policy and environmental regulations represent important areas for further analysis. Based on the current stage of adoption in the U.S. market, I suggest future research to focus on analyzing strategies for the rapid establishment of a reliable and efficient domestic supply chain, as well as the development of educational structures among various industry trades specifically targeted at mass timber construction.

5.4 Conclusion

This study suggests that the adoption rate of mass timber construction in a market is primarily influenced by the eight identified driving factors. It further implies that their specific significance varies based on local factors and their interrelationships. The findings demonstrate an interplay between factors associated with innovation and the supply of engineered mass timber products on the one hand and the demand side and existing industry conditions on the other hand. These driving factors can either serve as a value proposition or act as obstacles in large-scale mass timber construction. This duality is particularly evident in the assessment of risk-related aspects and financial expectations, as it can lead to both positive and negative implications for a project's feasibility.

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APPENDIX

Appendix 1: Interview Guideline (German)

HB = Holzbau *MHB = Massivholzbau*

Einführung

- Erläuterung des Interviewprozesses und Ziele der Thesis
- Erlaubnis zur Aufzeichnung erfragen und Anonymität zusichern
- Vorstellung des Interviewpartners und des Unternehmens

Themen

Allgemeine Entscheidungsfindung

- Was ist der Hauptanreiz der für eine nachhaltige Bauwirtschaft/für den HB spricht?
- Was sind die wichtigsten Anreize/gesetzlichen Richtlinien, welche die Nachhaltigkeit im Baugewerbe vorantreiben?
- Was sind momentan die größten Hindernisse in Bezug auf MHB?
- Wurde eine ganzheitliche Lebenszyklus-Analyse durchgeführt?

Rechtliche und politische Rahmenbedingungen

- Existieren beim HB immer noch Einstiegsbarrieren/zusätzlicher Regulierungsaufwand für den Grünen-Wandel des Baugewerbes?
- Stellte die Möglichkeit einer zukünftigen CO2-Steuer (für Primärenergie beim Bau) einen Anreiz für den HB da?
- Gibt es eine Offenlegungspflicht über CO2-Emissionen?
- Gibt es Unterschiede Im Genehmigungsprozess von Holzgebäuden im Gegensatz zu herkömmlichen Bauweisen?
- Treten Anpassungen im Baurecht eher als Reaktion auf die Steigende Bedeutung des HBs auf oder sind sie eher Anreizfaktor für Innovation?
- Spielen Vorgaben zur Nachhaltigkeit in öffentlich ausgeschriebenen Wettbewerben bereits eine Rolle?
- Spiegeln die rechtlichen Rahmenbedingungen den aktuellen Stand der Forschung im Holzbau wieder?
- Kam es zu Problemen bei der Genehmigung/Kommunikation mit Behörden, Planern, Handwerkern auf Grund mangelnder Vertrautheit mit dem Baustoff Holz?

Forschung & Bildung

- Haben Sie/Ihre Angestellten/Mittarbeiter in irgendeiner Form ein zusätzliches Training im Bereich ESG oder CO2-Neutralität erfahren?
- Wie verbreitet sind etablierte, unabhängige Ansprechpartner/Kommunikationsnetzwerke im Markt und wurde auf diese bereits zurückgegriffen?
- Gibt es gute Möglichkeiten sich als Berufstätiger in Richtung HB weiterzubilden?

Produzenten & Know-How

- Gibt es noch Wissensdefizite im Bereich des Massivholzbaus?
- Haben Sie Zugang zu den erforderlichen Fähigkeiten, Produkten und Know-how auf lokaler oder internationaler Ebene?
- Kann der Massivholzbau, aufgrund des hohen Grads an Vorfertigung und Automatisierung, eine Lösung für den Fachkräftemangel sein?
- Spielt „Re-use“ bei der Planung bereits eine Rolle?
- Zeichnet sich ein Trend zur Standardisierung im Bereich Holzbau ab/sind Bemühungen erkennbar?

Öffentliche Wahrnehmung & Nachfrage

- War die Produktunterscheidung ein Entscheidungsfaktor, der für die Verwendung von Massivholzbau gesprochen hat?
- Wie stark hat die öffentliche Wahrnehmung/Marknachfrage Ihre Entscheidung beeinflusst?
- Wie wird der MHB von der Öffentlichkeit wahrgenommen und welche Vorurteile existieren?
- Gibt es Unterschiede bei den Leerstands-/Vermietungsraten von Massivholzgebäuden im Vergleich zu anderen Gebäudetypen?
- Hat die lokale Baugeschichte der Region/Vertrautheit mit Holz als Baustoff einen Einfluss auf die Materialwahl?
- Gibt es bei der breiten Öffentlichkeit ein Bewusstsein für die Klimawirkung von unterschiedlichen Bauaktivitäten und den Einfluss der Materialwahl?

Förderprogramme & Subventionen

- Gibt es private oder öffentliche Programme, die den MHB unterstützen und subventionieren?
- Welche Erfahrungen haben Sie bei der Zusammenarbeit mit (nicht-) staatlichen Behörden und Organisationen im Bereich des Massivholzbaus gemacht?
- Gibt es staatliche Subventionen, die sich ausschließlich auf den Massivholzbau konzentrieren?

Finanzstrukturen & Investments

- In welchen Bereichen sehen Sie noch Optimierungspotenzial/Möglichkeiten zur Kostenoptimierung durch höhere Effektivität?
- Ist es immer noch schwierig Investoren für grüne Geschäftsmodelle zu finden?
- Gibt es spürbaren Druck von Seiten der Investoren zu detailliertem ESG-Reporting?
- Ist eine nachhaltige Bauweise ein Mittel, um den langfristigen Wert eines Gebäudes zu sichern/zu erhöhen?
- Ist der MHB ein Absicherungsmaßnahme, um möglichen zukünftigen Regulierungen zuvorzukommen?
- Unterscheiden sich die Quadratmeterpreise in MHB von vergleichbaren, herkömmlichen Bauweisen?
- Kann der nachweißlich stake ESG beim Holzbau einen Vorteil darstellen, um Investoren anzuziehen?
- Sind Ihnen signifikante Unterschiede bei den Kosten/der Kostenallokation im Vergleich zu herkömmlichen Bauweisen aufgefallen?

- Wirken sich Unsicherheiten anders auf den Massivholzbau als auf die allgemeine Bauwirtschaft aus?
- Wie verhält sich er MHB bei den Nebenkosten im Betrieb?

Branchen- & Marktentwicklung

- Was sind Hindernisse, die einer schnelleren Markteinführung im Weg stehen?
- Welche Rolle spielt Lobbyarbeit?
- Sind Auswirkungen auf den Arbeitsmarkt durch den Holzbau bereits spürbar?
- Was ist die Rolle/der Einfluss von großen Konzernen auf das Angebot und die Nachfrage von Holzbauprodukten?
- Hat Unsicherheit bezüglich der Materialpreise beim HB einen stärkeren Einfluss als bei herkömmlichen Bauarten?
- Sehen Sie den HB als langfristige Antwort auf den Klimawandel oder eher als Übergangslösung?
- Wurden standardisierte, vorgefertigte Materialien, oder eigens für das Projekt designte Elemente verwendet?
- Setzen sich Regionen/Bundesländer mit einer hohen Walddichte/Holzproduktion stärker für den HB ein?
- Sind in den letzten Jahren wahrnehmbare Veränderungen in der Holzbaubranche erkennbar?
- Welche Art Mieter sind Ihre Zielgruppe?

Waldwirtschaft & lokale Nutzung

- Wie stark hängt die politische Unterstützung von Großprojekten in Massivholzbauweise von der Ausrichtung des lokalen Arbeitsmarktes auf die Holzproduktion und Forstwirtschaft ab?
- Welche Rolle spielt die Zertifizierung der nachhaltigen Bauweise?
- Reicht der langfristige Holzbestand aus, um die Nachfrage zu decken?

<u>Outro</u>

- Wo erwarten Sie in Zukunft die einflussreichsten Veränderungen beim MHB?
- Fallen Ihnen noch Themen ein, die ich noch nicht angesprochen habe?

Appendix 2: Interview Guideline (English)

MT = Mass Timber *MTC = Mass Timber Construction*

Introduction

- Explanation of the interview procedure and goals of the thesis
- Requesting permission to record the interview and ensure confidentiality
- Introduction by the interviewee about personal and company background

Topics

General Decision-Making Process

- What is the key incentive behind green building business practices?
- What are the most effective incentives/policies/drivers pushing for a greening of the construction industry?
- What are the biggest obstacles regarding MTC?
- Have you thought about an overall lifecycle concept?

Legal and Political Conditions

- Is there still a regulatory burden for the green transition of the building industry, and how does that affect the decision-making process?
- Is the idea of a possible future pollution tax/increase in carbon pricing an incentive?
- Does a duty of disclosure exist for CO2 emissions during the production & construction process?
- Is the permitting process different for MTC?
- Do you see building code adaptions rather as a reaction to the popularity of MTC or as an incentivizing factor for innovation?
- Do sustainability requirements in public/governmental architectural project tenders play a role in the demission-making process?
- Does the code for technical requirements reflect the latest technical developments of MTC?
- Did you have any communication problems with government agencies, architects, engineers, or craftsmen, due to a lack of familiarity with MTC?

Research & Education

- Do you/your employees/coworkers have additional training on ESG or sustainability?
- How prevalent are established, independent resources/communication networks in the market, and have they been used yet?
- Are there good opportunities for professionals to continue their education in the direction of MTC/sustainable building?

Suppliers & Know-How

- Do you feel there is a lack of know-how around MTC?
- Do you have access to the necessary skills, products & know-how locally or internationally?
- Can MTC be an answer to skilled labor shortage due to a high degree of prefabrication and automation?
- Does ‘re-use’ already play a role during the planning process?

- Is there a trend towards standardization in the field of wood construction/what efforts are being made?

Public Perception and Demand

- Was product differentiation a decision factor advocating for the use of MTC?
- How strongly has the public pressure/market demand influenced your decision?
- How does the general public perceive MTC, and what are prejudices that exist?
- Is there a difference in leasing-/vacancy-rates of MT buildings compared to other construction techniques?
- Does the local building history of the region/familiarity with wood as a building material influence the choice of material?
- Is there public awareness about the climate impact of different building practices?

Funding Programs & Subsidies

- Are there private or public programs available that support/subsidize MTC?
- What are your experiences in cooperating & collaborating with (non-) governmental agencies and organizations on MTC?
- Are there government subsidies that exclusively focus on MTC?

Financial Structures & Investments

- Where do you see a potential to optimize/reduce costs through higher efficiency?
- Is it still difficult to find investors for green business models?
- Is there a noticeable pressure from investors for detailed ESG reporting?
- Is a green building strategy a measurement to ensure/increase the long-term value of a building?
- Is MTC a measurement to get ahead of possible future regulations?
- Can MT's strong ESG be seen as an advantage to attract investments in a time when money gets more expensive?
- Do you observe significant differences in cost (allocation) compared to common building practices?

Market Development

- Where do you see obstacles that prohibit a faster adoption?
- What role does lobbying play?
- Can you already feel labor market implications?
- How do large corporations affect the demand and supply of MTC products?
- Do uncertainties around material prices have a stronger impact on MTC than on common building materials?
- Do you see MTC as a long-term solution to climate change or an interim trend?
- Is a 'manufacturing-to-market' approach or 'design-to-construction' used to supply the building materials?
- Do states with a high forest density/timber production push stronger for adopting MT?
- How has the MTC industry changed over the last years?
- What kind of tenants are you aiming for?

Forestation & local Usage

- How strongly is the political support for MTC linked to a push for job growth in rural areas and local production?
- How does certification affect sustainable construction/MTC?
- Is enough wood available to sustain the growing demand in the long term?

Outro

- Where do you see important future developments in the MTC industry?
- Can you think of any important topics I forgot?

Appendix 3: Interview Transcripts

In order to safeguard the privacy and confidentiality of the individuals involved, the transcribed interviews found within the pages 81 to 164 have been redacted. This decision has been made in recognition of the sensitive nature of the information shared during these interviews and to ensure that the participants' identities and personal details remain protected. By implementing these measures, the aim is to uphold ethical standards and respect the privacy rights of those who took part in the interviews.

Appendix 4: Additional Illustrations

Rank	Building Name	City, Country	Height (m)	Floor Count	Structural System	Function	Status (as of Feb 2022)	Completion Year
1	Ascent	Milwaukee, USA	86.6	25	Concrete-Timber Hybrid	Residential	Under Construction	2022
2	Mjøstårnet	Brumunddal, Norway	85.4	18	All-Timber	Mixed-Use	Completed	2019
3	HoHo	Vienna, Austria	84.0	24	Concrete-Timber Hybrid	Mixed-Use	Completed	2020
4	Haut	Amsterdam, Netherlands	73.0	22	Concrete-Timber Hybrid	Residential	Under Construction	2022
5	Sara Kulturhus	Skellefteå, Sweden	72.8	19	Steel-Timber Hybrid	Mixed-Use	Completed	2021
6	De Karel Doorman	Rotterdam, Netherlands	70.5	22	Concrete-Steel-Timber Hybrid	Mixed-Use	Completed	2012
7	55 Southbank	Melbourne, Australia	69.7	19	Concrete-Steel-Timber Hybrid	Mixed-Use	Completed	2020
= 8	Roots Tower	Hamburg, Germany	65.0*	19	Concrete-Timber Hybrid	Residential	Under Construction	2023
= 8	Wellington	Melbourne, Australia	65.0*	15	Concrete-Timber Hybrid	Office	Under Construction	2023
= 10	Baufeld 1 Suurstoffi Abro	Risch-Rotkreuz, Switzerland	60.0	15	Concrete-Timber Hybrid	Mixed-Use	Completed	2019
= 10	Kromet	Gothenburg, Sweden	60.0*	15	Concrete-Timber Hybrid	Mixed-Use	Under Construction	2022
12	Brock Commons Tallwood House	Vancouver, Canada	57.9	18	Concrete-Timber Hybrid	Residential	Completed	2017
13	Eunoia Junior College	Singapore, Singapore	56.0	12	Concrete-Timber Hybrid	Institutional	Completed	2019
= 14	Hyperion	Bordeaux, France	55.0	16	Concrete-Steel-Timber Hybrid	Residential	Completed	2021
= 14	Rundeskogen Hus B	Sandnes, Norway	55.0*	16	Concrete-Timber Hybrid	Residential	Completed	2013
16	Albizzia	Lyon, France	53.0	17	Concrete-Timber Hybrid	Mixed-Use	Under Construction	2023
17	Ngytan Koriayo Geelong Civic Precinct	Greater Geelong, Australia	52.0*	12	Concrete-Timber Hybrid	Office	Under Construction	2022
18	503 on Tenth	Portland, USA	50.0	10	All-Timber	Office	Under Construction	2023
19	Treet	Bergen, Norway	49.0	14	All-Timber	Residential	Completed	2015
20	Lighthouse Joensuu	Joensuu, Finland	48.0	14	Steel-Timber Hybrid	Residential	Completed	2019
21	25 King	Brisbane, Australia	46.8	11	All-Timber	Office	Completed	2018
22	2150 Keith Drive	Vancouver, Canada	45.0	10	Concrete-Timber Hybrid	Office	Under Construction	2022
= 23	Cederhusen	Stockholm, Sweden	44.0*	13	All-Timber	Residential	Under Construction	2023
= 23	Hoas Tuuliniitty	Espoo, Finland	44.0*	13	All-Timber	Residential	Completed	2021
= 23	Palazzo Nice Meridia	Nice, France	44.0*	10	Concrete-Timber Hybrid	Office	Completed	2019
26	T3 Bayside	Toronto, Canada	42.0	10	All-Timber	Office	Under Construction	2023
27	Tallwood 1 at District 56	Langford, Canada	41.6	12	Steel-Timber Hybrid	Residential	Under Construction	2022
28	Origine	Quebec, Canada	40.9	13	All-Timber	Residential	Completed	2017
29	T3 Sterling Road Building 5A	Toronto, Canada	39.8	8	Steel-Timber Hybrid	Office	Under Construction	2023
30	INTRO Residential Tower	Cleveland, USA	39.6	9	Concrete-Timber Hybrid	Mixed-Use	Under Construction	2022
31	77 Wade	Toronto, Canada	38.2	8	Concrete-Steel-Timber Hybrid	Office	Under Construction	2022
32	Sensations	Strasbourg, France	38.0	11	All-Timber	Mixed-Use	Completed	2018
= 33	Monterey	Brisbane, Australia	37.0	11	Concrete-Steel-Timber Hybrid	Residential	Under Construction	2022
= 33	Rundeskogen Hus C	Sandnes, Norway	37.0*	11	Concrete-Timber Hybrid	Residential	Completed	2013
35	Trafalgar Place	London, UK	36.3	10	All-Timber	Residential	Completed	2015
= 36	Aveo Bella Vista	Sydney, Australia	36.0	11	Concrete-Timber Hybrid	Residential	Completed	2018
= 36	Suurstoffi 22	Risch-Rotkreuz, Switzerland	36.0	10	Concrete-Timber Hybrid	Office	Completed	2018
= 38	Green Office Enjoy	Paris, France	35.0*	8	Concrete-Steel-Timber Hybrid	Office	Completed	2018
= 38	Opalia	Saint-Ouen-sur-Seine, France	35.0*	8	Concrete-Steel-Timber Hybrid	Office	Completed	2017
= 38	Pont de Flandres Batiment 007	Paris, France	35.0*	8	Concrete-Steel-Timber Hybrid	Office	Completed	2019
= 38	Wood and Innovation Design Centre	Prince George, Canada	35.0*	8	All-Timber	Office	Completed	2014

Table 1. The tallest 40 mass timber buildings worldwide, completed or under construction, as of February 2022. Please note that heights marked with an (*) are estimated, based on the floor count of the building. The estimate has been arrived at by analyzing thousands of other buildings of the same function on the CTBUH database that do have confirmed heights. See height calculator at skyscrapercenter.com/height-calculator. For the full list of 84 mass timber buildings, eight stories and higher, go to ctbuh.org/mass-timber-buildings.

Table 2. Tallest 40 Mass Timber Buildings Worldwide
Source: Safarik, et al. (2022, p. 24)

Construction Type	III-A	III-B	IV	V-A	V-
Exterior wall materials	FRTW	FRTW	FRTW or CLT	Any wood including mass timber	Any wood including mass timber
Exterior bearing wall FRR	2-hour	2-hour	2-hour	1-hour	0-hour
Interior framing materials	Any wood including mass timber	Any wood including mass timber	Heavy timber including mass timber	Any wood including mass timber	Any wood including mass timber
Primary frame, floor & roof construction FRR	1-hour	0-hour*	HT	1-hour	0-hour*

Table 3. Comparison of Construction Types III, IV, and V
Source: WoodWorks (2023a, online)

	Type III-A	Type IV	IBC 2018 (IBC 2015) Reference
Allowable Height/Area			
Base allowable area per story[1, 2]	85,500	108,000	Table 506.2
Allowable stories[1]	6	6	Table 504.4
Allowable building height[1]	85'	85'	Table 504.3
[1]NFPA 13 sprinklered throughout building per IBC Section 903.3.1.1			
[2]No frontage increase included			
Rating Requirements			
Primary structural frame	1-hour	HT	Table 601
Exterior bearing walls	2-hours	2-hours	
Interior bearing walls	1-hour	1-hour/HT	
Nonbearing exterior walls	Table 602	Table 602	
Nonbearing interior walls	0-hour	1-hour or per 602.4.8.1	
Floor construction & associated secondary members	1-hour	HT	
Roof construction & associated secondary members	1-hour[3]	HT	
[3]Note ability to use heavy timber in Type III-A roof construction in lieu of FRR HT = Heavy Timber – See minimum wood member sizes per IBC 2018 2304.11 (IBC 2015 602.4)			Table 601 footnote c
Other Considerations			
FRTW required in exterior walls	Yes	Yes	Sections 602.3 & 602.4.1
CLT allowed in exterior walls	No	Yes with stipulations	Section 602.4.2
Concealed spaces in floor systems allowed	Yes	No[4]	Sections 602.3 & 2304.11.3 (602.4.6)
Exterior wall projections	Any approved material	Any approved material	Section 705.2.2
Interior finish requirements	Table 803.11	Exempt	Section 803.3
Minimum roof covering classification	B	B	Section 1505.1
[4]2021 IBC will allow concealed spaces in type IV-HT under certain conditions as noted			

Table 4. Comparison of Construction Types III and IV
Source: WoodWorks (2023a, online)

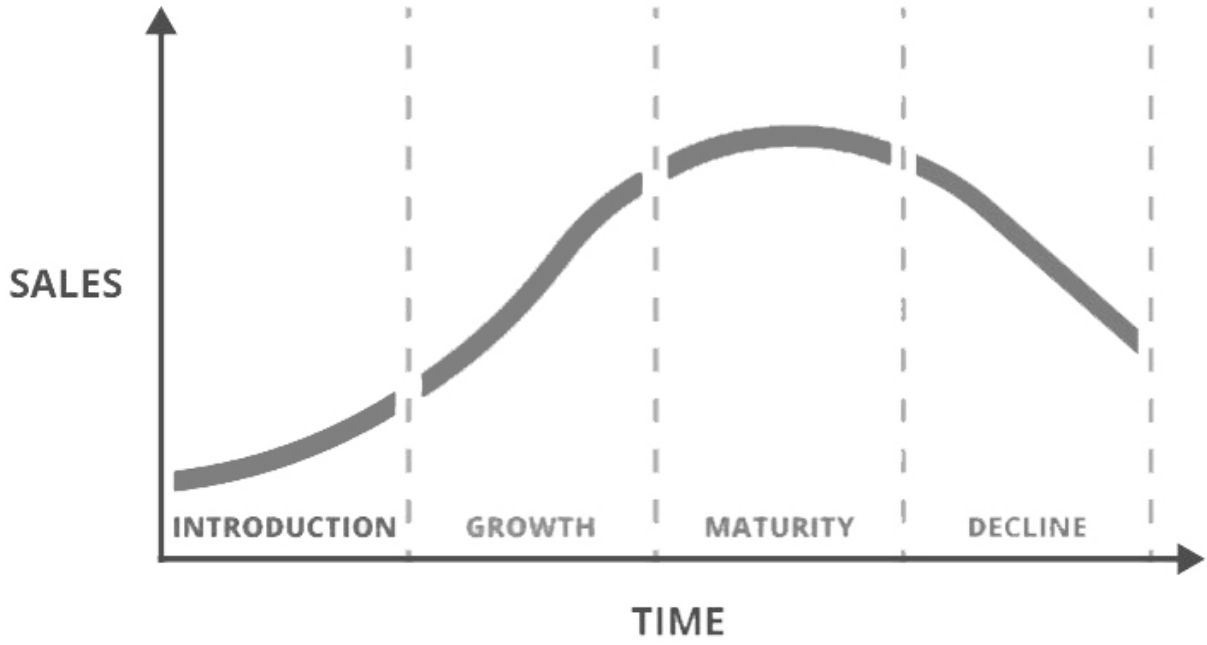

Figure 7. Product Life Cycle
Source: TWI (2023, online)