Wooden multi-storey construction market development in Sweden

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Licentiate Thesis
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Abstract

The ongoing climate change is closely related to greenhouse gas emissions from industries. One of the contributors to these sustainability challenges is the house construction industry. Although residential and commercial construction is needed, the production practices needs to be altered in order to meet sustainability objectives. This licentiate dissertation focuses on conditions for wooden multi-storey construction (**WMC**) in a Swedish context. It explores the conditions for market development for residential WMC. The dissertation focuses on corporate perspectives, but it also integrates the role of end-consumers. A systematic literature review served as an orientation before conducting empirical case studies analysis. With an understanding of the industrial norm, currently reflected in materials such as concrete and steel, the empirical studies focused on wooden multi-storey construction case studies and end-consumer's perceptions. These case studies indicate that a transition to WMC is hindered by path dependence, strong market positions for the currently used materials, and dated understandings of wood as a construction material. In the production process of residential construction, wood or other material, the end-consumer, the resident of an apartment in the house to be, is relatively anonymous. This is a reflection of a product dominant logic of the value chain where the end-consumer is a buyer or renter of an apartment. Enabling factors for further WMC market development that were verbalised by the case study respondents are captured in four factors: the properties of wood in a pre-fabrication setting, shorter erection times on site, fewer transports, and awareness of legislative sustainability demands. The case study interviewees report focusing on efficiency and technical properties in their business models - and limited concern for marketing communication and co-creation with end-consumers. The new legislation was seen as an enabling factor for the WMC market development by the case interviewees. It is clear that a sustainability transition, such as a gradual change to renewable construction materials that have carbon capture capacity, will take time. Business models that foster co-creation of value in public private partnerships may enable a

WMC market development. The development of new legislation and increased awareness of sustainability aspects in construction is seen as future research areas for sustainable development.

Keywords: business development, business strategy, end-consumers, market development, public private partnership, sustainable business model, timber construction, wooden multi-storey construction

Marknadsutveckling av flervåningshus i trä i Sverige

Sammanfattning

De pågående klimatförändringarna är nära kopplade till utsläpp av växthusgaser från industrier. En av branscherna om står inför hållbarhetsutmaningar är husbyggnadsbranschen. Även om bostadsbyggande och kommersiellt byggande behövs, måste produktionsmetoderna ändras för att uppnå hållbarhetsmålen. Denna licentiatavhandling fokuserar på förutsättningar för byggande av flervåningshus i trä i en svensk kontext. Avhandlingen fokuserar på företagsperspektiv, men den integrerar också slutkonsumenters roll i marknadsutvecklingen. En systematisk litteraturöversikt fungerade som en orientering innan empiriska fallstudieanalyser. Med en förståelse för den industriella normen, med material så som betong och stål, fokuserade de empiriska studierna på fallstudier av träkonstruktioner i flera våningar och slutkonsumenternas uppfattningar. Dessa fallstudier indikerar att en övergång till flervåningshus i trä hindras av stigberoende, starka marknadspositioner för de nu mest använda materialen och daterade uppfattningar om trä som byggmaterial. I produktionsprocessen av bostäder, med trä eller andra material, är slutkonsumenten, som kommer vara bosatt i bostaden, relativt anonym. Detta är en återspegling av en produktdominerande logik i värdekedjan där slutkonsumenten är köpare eller hyresgäst av en lägenhet. Möjliggörande faktorer för ytterligare marknadsutveckling av flervåningshus i trä som uttrycktes av respondenterna i fallstudien fångas i fyra faktorer: egenskaperna hos trä i en prefabriceringsmiljö, kortare monteringstider på plats, färre transporter och medvetenhet om lagstiftande hållbarhetskrav. Fallstudieintervjupersonerna rapporterade att de fokuserar på effektivitet och tekniska egenskaper i sina affärsmodeller men inte så mycket på marknadskommunikation och samskapande av värde med slutkonsumenter. Den nya lagstiftningen sågs av de intervjuade som en möjliggörande faktor för marknadens flervånings hus i trä utveckling. Det är uppenbart att en hållbarhetsövergång, som en gradvis förändring till förnybara byggmaterial som har kolbindande kapacitet, kommer att ta tid. Affärsmodeller som främjar samskapande av värde i offentlig-

privata partnerskap kan möjliggöra marknadsutveckling för flervåningshus i trä. Utveckling av ny lagstiftning och ökad medvetenhet om hållbarhetsaspekter inom byggandet ses som framtida forskningsområden för hållbar utveckling.

Nyckelord: affärsstrategi, flervåningshus i trä, hållbara affärsmodeller, höghus i trä, marknadsutveckling, public private partnerships, slutkonsumenter

Preface

Before you, you have my licentiate dissertation. It was made out of blood, sweat and tears, although not so much blood. It has been a couple of rollercoaster years: mountains have been summited; valleys have been visited; but here you have it.

My journey in the forest started in Askim, south of Gothenburg, where we had to go out every day, otherwise me and my sisters would get quite fierce with each other. In the forest we played where the stream ran out from the bog among pines and spruces. We put sugar cubes on the ant-hills, swam in the lakes, ate Marie-kex when our lips got blue from all the swimming, smacked mosquitos, ran, played röda vita rosen, climbed trees, ate blueberries, wild strawberries and raspberries, skied, built snow fortresses and had snow wars. If we weren't on the football field, by the sea or indoors, we were in the forest.

When I started the forest science programme in Umeå my view of the forest changed: from a playground to something that was the livelihood for many and belonged to the history of others. We the Nordic people have used the forest always, as shelter, for building materials, recreation, religion and much, much more. I slowly understood the anthropological challenges we as humans project on the forest. Nature itself stands in silence while some of us want to get rich in the forest, some just want to look at the trees, some want to save the world by preserving it and others want to cut down trees to make products. Where do I stand in all this, I asked myself?

I became interested in the field of sustainability studies connected to business administration during my years at Ultuna. Here I met Cecilia "Cilla" Mark-Herbert, who slowly but surely steered me into the academic field. Thank you Cilla. I found myself in the middle of the emerging wooden multi-storey construction (**WMC**) market. WMC is a product which seems, for me,

like one of the smartest things we can do with the forest, locking in carbon for a long time and at the same time creating housing and interesting spaces for many people in generations to come. How the WMC market emerged, what regular people think and what professionals say about this emergence you can find in this dissertation. This thesis is for you who wants to know more about the hindering and enabling factors the WMC market stands in front of today. If you who reads this are an end-consumer or a professional in the construction sector, I hope I have shined some light on the situation for you to help you make informed choices and develop the market further.

In the year of grace 2023 the 26th of April.

Sincerely,

Emil Nagy

Dedication

Till morfar.

Jag kan flyga, jag är inte rädd – Stig Helmer Olsson

Contents

List of publications

This thesis is based on the work contained in the following papers, referred to by Roman numerals in the text:

I. Jussila J., Nagy E., Lähtinen K., Hurmekoski E., Häyrinen L., Mark-Herbert C., Roos A., Toivonen R., Toppinen A. (2022). Wooden multi-storey construction market development – systematic literature review within a global scope with insights on the Nordic region. *Silva Fennica* vol. 56 no. 1 article id 10609. https://doi.org/10.14214/sf.10609

II. Nagy, E.; Berg Rustas, C.; Mark-Herbert, C. Social Acceptance of Forest-Based Bioeconomy—Swedish Consumers' Perspectives on a Low Carbon Transition. *Sustainability* 2021, 13, 7628. https://doi.org/10.3390/su13147628Authors

III. Nagy, E., Roos, A., Mark-Herbert, C. Sustainable business models in the wooden multi-storey building sector– What are the key elements? (2023…) manuscript.

Papers I-II are reproduced with the permission of the publishers (open source).

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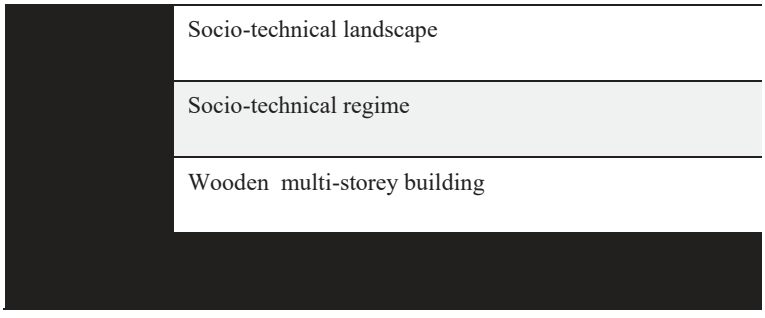
Abbreviations

CCS	Carbon Capture and Storage
	Cross laminated timber
	Dialogue, Access, Risk-Benefit and Transparency
	European Union
	General Data Protection Regulation
	Green House Gases
	Multilevel perspective
	The Preferred Reporting Items for Systematic reviews and Meta-Analyses
	Sustainable business model
	Statistics Sweden
	Sustainable Development Goal
	Structure of Housing Provision
	Socio-technical


Socio-technical landscape
Socio-technical regime
Wooden multi-storey building

1. Introduction

This chapter gives an introduction to the subject, frames the problem and gives the thesis's aim and research questions.

This thesis was written in an era of change: change in climate, change in regulations and laws and change in the political systems in Europe, all of which call for changes in the use of resources. For the Swedish forestry sector, this implies adaptation to changing policies, new technologies, and new ways of doing things, such as producing and constructing houses. This licentiate dissertation concerns one of the adaptations, where materials and techniques in construction are to an increasing degree assessed according to sustainability and climate-related criteria, an area within construction of particular interest for the sustainable resource use of wood in load-bearing structures is in multi-storey construction. This thesis is about the Swedish wooden multi-storey construction (**WMC**) market, how it has evolved, and how it may will continue to evolve in a sustainability context, and also in relation to the perspectives of end-consumers, local policymakers and professionals.

1.1 Setting the scene. Wood construction: old technique, new role

The rise in greenhouse gases (**GHG**) in the atmosphere is a serious global challenge. One main driving force for these GHG-emissions is the production of new housing around the world in part to accommodate a growing, and increasingly urban, population. About 21% of all the GHG is a derivate from global housing, and almost half (42 %) of these emissions are directly connected to the onsite emissions and embodied emissions from

steel and concrete (IPCC 2022: 957). Hence, the materials used in the buildings play an important role for the greenhouse gas (GHG) emissions (IPCC 2022). A fact that supports the importance of the choice of materials is that Clinker cement, the key ingredient in concrete, stands for as much as 14-17 % of all the global GHG emissions (IPCC 2022: 1190; Pädam *et al.* 2021).

To meet the Sustainable Development Goals (**SDGs**) (UN 2015) and Paris agreement (UNFCCC 2016) to lessen the impact of the GHG in the atmosphere, low carbon building solutions are needed. The material used in a building is of great concern to how much a building will emit in the construction phase. Concrete and steel, the two most used materials in residential buildings around the world, emit large quantities of GHG in the production phase of the materials (IPCC 2022). The concrete and steel industries are considering climate friendlier solutions such as climate-improved concrete and fossil free steel (Pädam *et al.* 2021). However, these products are still in the cradle with a limited potential to reduce GHG emissions (Pädam *et al.* 2021). The concrete market is also in need of Carbon Capture and Storage (**CCS**) technology, which will probably not be introduced in Sweden until 2030 and probably later (Pädam *et al.* 2021). There is also literature arguing for low reductions of GHG emissions in low carbon cement and steel production (IPCC 2022). The embodied GHG emissions of different materials in buildings are gaining more importance since modern buildings are becoming more energy efficient (Röck *et al.* 2020). An example is Sweden where the energy mix has low fossil sources, hence the importance of low embodied emissions will become even greater to lower the climate impact of the building sector (Petrović *et al.* 2023). One way to lower the climate impact of the embodied carbon in the building sector could therefore be to use wood and other bio based materials as a building material, *e.g.*, Gong *et al.* (2012); Geng *et al.* (2017); Hildebrandt *et al.* (2017); Peñaloza *et al.* (2018) and Churkina *et al.* (2020). Wood, which during its growth phase binds carbon from the atmosphere through photosynthesis, could be used as a long-term carbon binding solution by using it for loadbearing structures and other applications (Churkina *et al.* 2020). To make affordable and climate effective housing, one can build wooden multi-storey constructions, which are well suited for industrialised building practices and urban areas with a high density of houses (Peñaloza *et al.* 2018).

In Sweden, wood has been, and still is, one of the most important materials in the building sector. In Sweden, about 85-90 % of single family houses use wood in their load bearing structure (TMF 2023). For hundreds of years wood was the key building material in Sweden, but in the 18th and 19th century the opportunities to build WMC with wood changed. City fires in the 18th and 19th centuries became an increasingly serious problem due to densely built cities, a growing urban populations, and few fire regulations (Bengtson 2003). New fire regulations were established in 1874, and these banned the use of wood in three storey buildings or more.[1] The fires in Umeå and Sundsvall in 1888 were examples of two decisive incidents that contributed and sped up new building regulations, including restrictions (Bengtson 2003). The ban of WMC was effective, and shaped Sweden's building sector, until 1995 when Sweden entered the European Union (**EU**) and new building regulations were adopted the (BFS 1993:57 1994; BFS 1993:58 1994). The new regulations marked the end of the wood ban era and gave birth to a new market in Sweden for WMC, which had been dormant for almost a hundred years. The law went from pointing out specific materials to becoming a function law where, as long the building fulfils different functions, the material does not matter with respect to fire-standards and acoustics (Bengtson 2003; The Swedish National Board of Housing Building and Planning 2023).

After the city fires in the 19th century and the change in the regulation in 1874, the concrete era in Sweden settled in. In the 1950s, the concrete contractors became interested in building residential houses, after the Swedish government had created incentives to build residential houses with subsidies for industrialised building techniques (in concrete), for low-cost housing for middle- and low-income citizens (Mahapatra & Gustavsson 2008).

In 1965, "the million program" started where the goal from the Social Democratic government was that one million new apartments were to be built. The programme set the standard for concrete constructions, including prefabricated housing (Bengtson 2003). The building industry was subsidised by the Swedish government until the mid-1980s, which contributed to the dominance of concrete in the Swedish building market. However, in the 1980s, this support contributed to increasing building costs,

[1] Swedish: "1874 års byggnadsstadga och brandstadga för rikets städer"

and the Swedish government therefore decided in the 1980s and 1990s to deregulate the building sector and remove large parts of the subsidies (Mahapatra & Gustavsson 2008).

The market dominance of concrete has slowly been changing, and wood has taken a minor share in Swedish multi-storey construction. Hence, alongside an increasing construction since 1994, wood construction has also been growing as new specialised wood construction companies have emerged and more advanced building systems have been developed. The market share of wood construction has therefore gradually increased. Figure 1 describes the share of multifamily houses two stories or more since 1995, whereas Figure 2 presents the total volumes of housing units in different building materials.

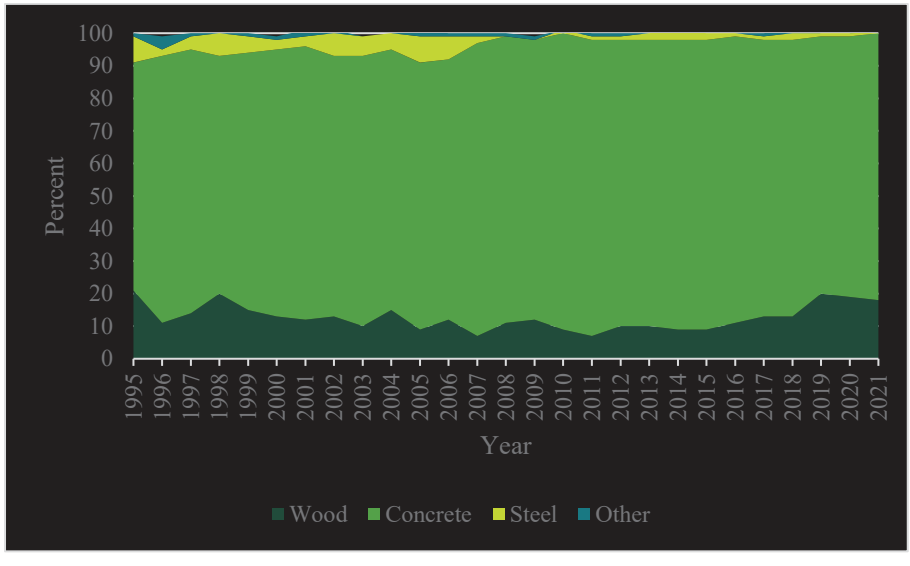


Figure 1. The percentage of materials used in structural frames in newly built Swedish multifamily houses (Statistics Sweden 2023)

Figure 1 indicates that concrete has been the dominant material representing between 70 and 91 % over the whole period, whereas the percentage of multifamily wood housing has remained relatively constant between seven and 21% during the same period. Steel and other types of building frame materials are marginal in the Swedish multifamily housing market. However, due to the increase in total housing production, the production of wood frame

multifamily housing has increased four times during the same period (Figure 2).

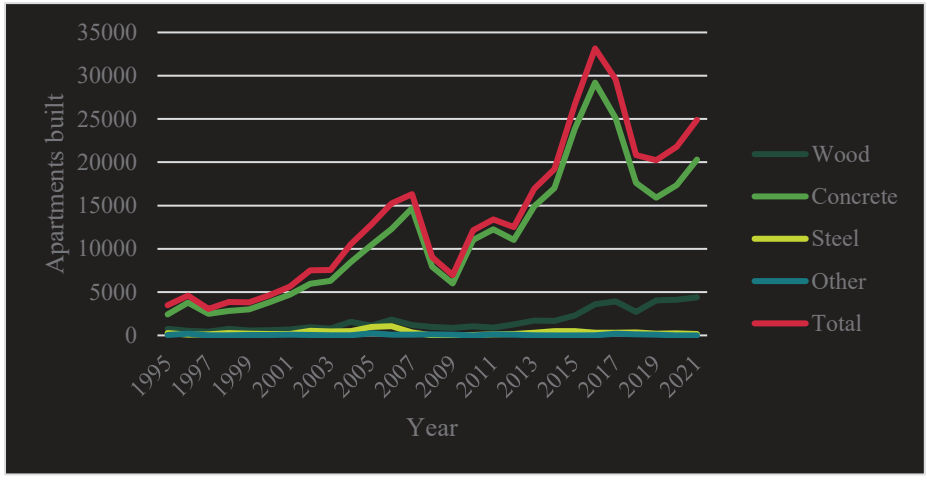


Figure 2. Number of built apartments in multifamily housing Sweden divided according to structural material (Statistics Sweden 2023).

The concrete and wooden frames dominate the market, and a steady rise can be seen in both wood and concrete construction since measuring started in 1995. However, one may ask whether this development means that WMC is on the verge of becoming a 'mainstream' construction technique.

The growth of wood construction is explained by the fact that several companies are producing wooden multi-storey components or turnkey houses for assembly. Several models of prefabrication processes have been developed. Aside from the climate impact, wood present both advantages as well as some drawbacks compared to alternative material in construction. On the positive side, wood is a suitable material for prefabrication, and the pre-fabrication rate of WMC in Sweden is therefore high. Due to the light weight of wood, it makes the material suitable for conducting several processes off site in dry and protected facilities for subsequent transport and installation on the building site. Prefabrication of WMC gives shorter erection times compared to most other building systems, a safer work environment for workers indoors, more efficient processes and less material waste (Brege *et al.* 2014). Wood can also present challenges as a building material with moisture, fire and acoustics.

The most common methods of WMC building techniques in Sweden are whole volume modules or the production and assembly of floor/wall elements. Massive Cross Laminated Timber (**CLT**) elements are also used, but to a lesser degree, and most commonly with a lower prefabrication grade (Brege *et al.* 2014). Some of the largest Swedish suppliers of wood construction solutions in the Swedish market are Setra, Lindbäcks bygg AB, Moelven, Derome and Holmen (Marintsons), Södra and Stora Enso. The companies have their own production plants in Sweden and abroad and deliver all over the country but also send some for export.

1.2 The Swedish residential housing sector

The Swedish building market and housing stock can be categorised in privately owned and rental houses. In the Nordic building market, private home ownership is high compared to many other European countries (Andersson *et al.* 2007). Of about 4.8 million households in Sweden 2020, 39.5% of which were detached privately owned single family houses, 28.6% were rental apartments in multifamily houses and 20.6 % privately owned housing co-operatives[2] (Statistics Sweden 2022a). A housing co-operative's apartment is owned as a share and membership in a co-operation association. Thus, the share price fluctuates in accordance with the market evaluation. This study focuses on housing co-operatives and rental apartments since these are the most common practices used in multi-storey construction market. Of the multifamily houses and apartments in Sweden, 42 % are owned by co-operatives, and the remaining 58 % are rental housing. In fig.

[2] Swedish: Bostadsrätter

3, the division of the ownership structure of multifamily houses is shown.

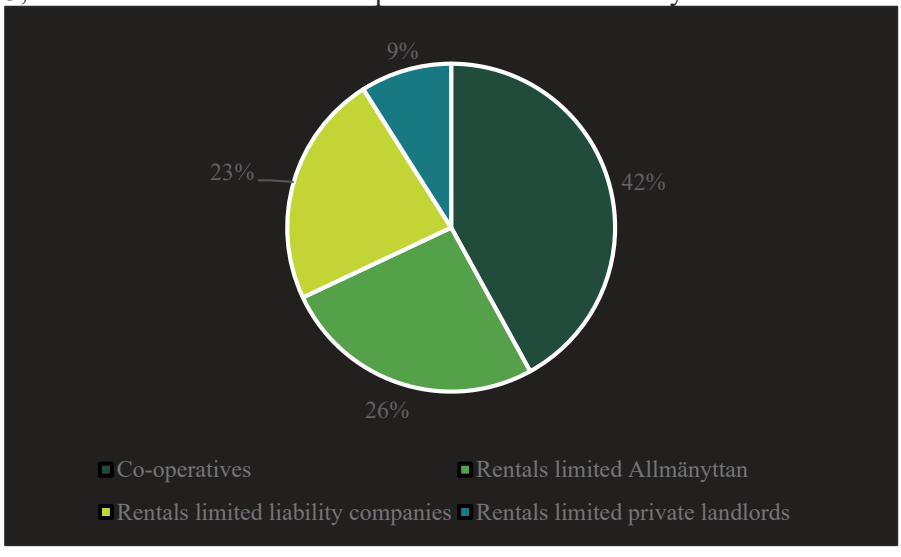


Figure 3. Ownership structure multifamily houses in Sweden (Statistics Sweden 2022b)

The share of 58% is divided between rental apartments owned by non-profit housing enterprises,[3] 26%; limited liability companies, 23%; and private landlords, 9%, as seen in fig. 3.

The co-operative houses are more often located in the bigger cities and dominate in Stockholm and Uppsala. Elsewhere rental apartments are the most common in 257 out of 290 (88.6%) municipalities in the country (Statistics Sweden 2022b).

1.3 Sustainability transitions in the Swedish construction sector

The two challenges the Swedish construction sector is facing is to meet an increasing demand for housing and transition to more sustainable methods. The shortage of apartments in Sweden reached 182 000 apartments in 2021 (The Swedish National Board of Housing Building and Planning 2022), and the greatest shortage is located in the larger cities and municipalities (The Swedish National Board of Housing Building and Planning 2022) due to a persistent urbanisation since the 19th century (Statistics Sweden 2015). The

[3] Swedish: Allmännyttan

construction sector is also expected to handle its sustainability performance, especially its climate impact: About one fifth of Sweden's total emissions in 2020, about 9.8 million tons of carbon dioxide equivalents, were connected to the building and real estate sector (The Swedish National Board of Housing Building and Planning 2023). When imported building materials are included, the climate impact of the sector increases to 15.9 million tons carbon dioxide equivalents. One can compare this with the total amount of Sweden's GHG emissions, *i.e.*, 46.2 million tons carbon dioxide equivalents. With the greater climate change challenges and a housing deficit in Sweden, the market needs to change to more sustainable practices. The sector needs to move from high to less GHG emitting materials, which would be important step toward achieving the net zero goal in 2045 (The Swedish Enivironmental Protection Agency 2023). According to the terminology, this calls for a *sustainability transition* in the sector, which can be described as long-term, multi-dimensional, and fundamental transformation processes through which established socio-technical systems shift to more sustainable modes of production and consumption Markard *et al.* (2012). Wood, with relatively low embodied GHG emissions, is one material that can contribute to this process by mitigating GHG emissions. Additionally, wood is a light material with good load bearing properties, which also leads to reduced energy needs in the production and construction phases. The material can consequently be an alternative for loadbearing functions compared to other materials with higher climate impacts.

Efforts have been made since 1995 by public and private actors to promote the use of wood in the building sector. The government of Sweden has issued two policy documents, the Orientation for Wood building[4] and More wood in construction[5] (Government Offices Sweden 2004; Government Offices Sweden 2018). These documents highlighted the positive impacts that more wood can have in the Swedish building sector, *e.g.*, by reducing the climate impact, reducing the dependency of non-renewable materials, and diversifying the applied methods and actors on the construction sector in Sweden.

However, the usage of wood in the construction sector in Sweden has its opponents. First, there has been and still is a debate about the forest

[4] Swedish: Inriktning för träbyggande

[5] Swedish: Mer trä i byggandet

management and harvesting methods in Sweden. Concerns are being raised both in scientific publications and media that the forest methods are driving biodiversity loss and also contributing to GHG emissions. However, the views on the forest sector's impact on biodiversity and climate is divided in the research community, media, as well as among those in the public sector (Roos *et al.* 2023). Other critical views are presented by the representatives for the concrete construction sector, and they argue that the promotion of wooden housing by municipalities and governments can lead to unfair competition in the construction sector (Source).

Parallel to ongoing discussions about material properties, a gradual political shift can change the market conditions for construction. It is enacted through the implementation of tighter national legislation and EU-climate requirements on construction. Accordingly, the Swedish Government implemented a new legislation in 2022 where climate declarations are needed to get the final approval of a building as a part of the Planning and building code (SFS 2021:787). The rules oblige the developer of a new building project over a certain size to calculate its climate impact. Differentiated obligatory schemes for climate impact reporting, with allowable cut-off points, are planned for 2027 or even earlier (The Swedish National Board of Housing Building and Planning 2020), alongside similar processes in Denmark and Finland (*Ibid.*). This could favour the WMC because of the material´s limited climate impacts since it can be implemented as soon as possible. For the concrete and steel industry, the carbon capture and storage (**CCS**) technology for cement will be in place at the earliest 2030 (Pädam *et al.* 2021). The increased climate requirements for the construction sector are expected to drive the transition to sustainability practices and the selection of building materials with low climate impact, as well as indirectly influence the WMC market in Sweden.

1.4 Strategy for change in the Swedish construction sector

The WMC companies, both builders and manufacturers, have historically not used the material as a marketing strategy. The diffusion of wood into the multi-storey market has also been a slow process in Sweden and the other Nordic countries during the past three decades. The advantages used as selling points by the WMC actors have not been the material in itself but

rather associated advantages, such as quick assembly, high degree of pre-fabrication and sometimes the price. However, new rules and an expected growth will prompt the building sector and the WMC sector to develop strategies for change to align with a sustainability transition in society at large and the construction sector.

This new development involving increasing housing needs and climate concerns presents new strategic challenges for the construction sector. Climate declarations are already in place, and more stringent laws are to come. To be adaptive and ready for the tighter regulations, the businesses need to change, and new actors and niche actors will develop and become mainstream. However, this development will warrant deeper insights within and about the wood construction sector.

Key questions relating to market development point to the importance of corporate strategies, business models and organisational aspects of managing a change process. Is the market ready for promoting wood as a sustainable building material? And how should the WMC sector's strategies be shaped, and the collaboration with stakeholders be developed, in the new landscape? What does scientific knowledge say about the WMC markets hindering and enabling factors? What do the consumers think about wood construction's role for a sustainability transition? Additional insights in these areas would strengthen the conditions to interact with key stakeholders and develop their competitive market offerings.

The stakeholder group end-consumers have not yet been overly scrutinised in literature, as have the end consumers in the building market in Sweden. The end-consumer plays an important role in the transition from fossil to renewable building materials since the end-consumers will buy, rent and use the buildings for generations to come. The end-consumer role should not be foreseen and why should they not have anything to say about the material used in the houses? It is, however, not clear what role the end consumers have in the building market yet, foremost not in the WMC market, although studies published show that the end-consumer usually has a very small or no influence on the building material choices in the structural framework in the buildings. Although there are models for more end-consumer influence in the structural material, it has not yet penetrated the Swedish market, such as the co-building groups [6] where the end-consumers

[6] Swedish: Byggemenskap German: Baugemeinschaft

take the role as the contractor and can cut costs. Although the sustainability transition in the multi-storey housing sector is a societal matter and not a private matter for the individual, the end-consumers view on both the bioeconomy and WMC are interesting, both from a value creating perspective and marketing perspective.

1.5 Aim of the thesis

The aim of this thesis is to explore conditions for market development in wooden multi-storey construction.

1.6 Research questions

Together with the aim of the study, four research questions have been formulated:

- What are the hindering factors for WMC market development?
- What are the enabling factors for WMC market development?
- How do end-consumers in Sweden perceive the bioeconomy and, more specifically, the WMC as a solution to lower the climate impact in Sweden?
- How do Swedish professionals in the wooden multi-storey sector perceive the co-creation of value aspect in their work when building and projecting houses?

These questions are connected to the respective articles. Questions one and two are connected to article I, question three to article II, and question four to article III.

1.7 Positioning of the articles

The thesis reflects the interaction among end-consumers, professionals and local policymakers, and the corpus is based on three articles. The general framework for the thesis is illustrated in Figure 3 and explained further

below.

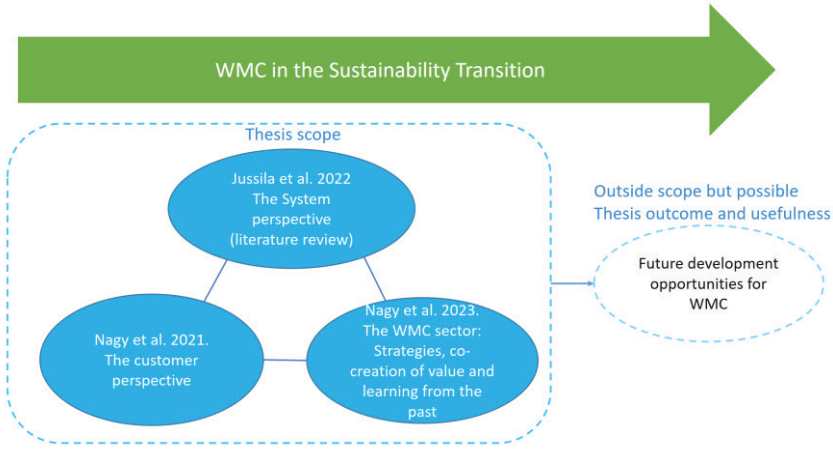


Figure 4. Illustration of the positioning of the articles.

As shown in Figure 4, the overarching theme and background of the thesis is the role of the WMC in the sustainability transition, where the socio-economic system moves from a less to a more climate friendly system. The thesis scope concentrates on three topics developed in the three papers (within the dotted line). The topics and sub-studies encompass the existing scientific knowledge about WMC, customer perceptions and preferences on wood construction in the bioeconomy and sustainability transition, and WMC business strategy and co-creation with different stakeholders. The underlying purpose was to shed more light on the WMC sector and indicate opportunities for the future use of WMC in the construction market.
The thesis explores the market from an inside and out perspective rather than an outside and in perspective. This implies that companies mobilise resources and competences to capture and adapt to a changing world.

1.8 Delimitations

In this thesis, delimitations have been made. Firstly, the market studied is foremost the Swedish market. The wooden multi-storey market is an international market with several different actors in different countries, but Sweden is one of the leaders in both building and industry. Therefore, the case of the Swedish market can serve as a good example and great forerunner

for others to take inspiration from and learn from the pitfalls already experienced by the Swedish market.

In the thesis, the buildings included in the studies are three floors or more, residential buildings with a load-bearing construction made primarily of wood. Although commercial buildings are interesting and business opportunities are arising in Sweden and abroad, they are not included in this thesis, although it should be said that this is certainly an area for future studies.

No technical or architectural aspects of the houses are considered. Other more specific empirical delimitations will be explained in the three respective included articles.

1.9 The outline of the thesis

The thesis in divided into different chapters presented in Table 1.

Table 1. Overview of the kappa and description of the different chapters

Overview of the Kappa	
	Description
1 Introduction	Gives a summary of the history leading up to the WMC market and frames the thesis aim and research questions.
	perspectives used in the different articles and the thesis.
3 Methods and data	Summarises the methods and the ethical considerations used in the articles and in the thesis.
	main results.
5 Discussion	Discusses the results in the articles
	proposes future studies

As of the outline of the thesis can be seen in Table 1, chapter one gives an introduction to wooden multi-storey construction in Sweden, how it became what it is today and why it is needed in a more sustainable world. Chapter

one also gives the aim and the research questions of the thesis. Further, chapter two describes the different theoretical backgrounds for the thesis, concentrating on sustainability- and socio-technical transitions, sustainable business models, multi-level perspectives on WMC, and the co-creation of value and structure of housing provisioning. Chapter three concerns the methods, ethics and trustworthiness of the thesis and the data collected. Chapter four summarises the different articles and their major contributions. Chapter five follows and brings up the articles for discussion in light of the theoretical background. In chapter six, the conclusions and contributions are presented. Further in chapter six, future research suggestions are presented. This marks the end of the thesis.

2. Theoretical perspectives

In this chapter the different theoretical perspectives used in the studies will be accounted for. The theoretical perspectives spring from sustainability transitions and socio-technical transitions to make the building sector in Sweden more sustainable.

2.1 Sustainability transitions

Sustainability transitions are long-term, multi-dimensional, and fundamental transformation processes through which established socio-technical systems shift to more sustainable modes of production and consumption (Markard *et al.* 2012). In this thesis, the change from fossil materials to renewable in the construction sector can be referred to as a sustainability transition; the WMC market development could be an example of this in Sweden. Geels (2002); Geels *et al.* (2017) describes the transition in terms of a multi-level perspective (**MLP**) focusing on socio-technical change processes. These processes may lead to genuine transitions and improvements with regard to sustainability criteria, but also become hampered by negative feedback loops that can stall the transition (Edmondson *et al.* 2019).

It is also clear, according to Geels, that these transitions are not private matters but driven from society since it is a public question of building a more sustainable society *e.g.*, Geels (2014). This makes the transitions complex and hard to grasp since it will be ongoing in so many directions and different ways. Although the transition is a societal challenge, enterprises around the world still need to adapt and drive the niche innovations (with some help) from society, and this calls for sustainable business models (**SBM**).

The transition in the Swedish multi-storey market, from less sustainable materials to more sustainable materials, could be seen as a sustainability transition, where an example is more use of WMC. Guidance and governance often play an important role in the sustainability transition (Smith *et al.* 2005). There could be long-term goals that are connected to the transition, informing of a direction for the transition. Different actors are expected to work in the same direction in a coordinated way, and the transition should be purposeful and intended (Markard *et al.* 2012). Institutional and regulatory as well as political actors are to play a major role in guided transitions (*Ibid.*). It should also be noted that what is considered sustainable can change over time, and it is a subject up for interpretation by different actors (Garud *et al.* 2010).

Although the transition is a societal challenge, enterprises around the world still need to adapt and drive the niche innovations (with some help) from society. In Sweden, the state has been a driving force both for "building away" the shortage of apartments but also in supporting the WMC businesses with research and development money, policy documents and other activities. Often when there is a sustainability transition taking place, some of the actors will be seen as winners and some as losers; the incumbent industries will fight over their positions and exercise power to protect their vested interests, while the new alternative socio-technical configurations will ask for more public support (Köhler *et al.* 2019). An example could be the debate in Sweden about wood vs. concrete in multi-storey housing, where the concrete industry has a rather defensive role in the discourse and debate climate.

The change from fossil materials and carbon intensive materials to renewable materials in the construction sector can be referred to as a sustainability transition. In, *e.g.,* Geels *et al.* (2017), the transition is described in terms of an MLP focusing on socio-technical change processes. The theory by Geels can be used to portray innovations such as the Wooden multi-storey buildings and how they can go from niche actors to challenging the current regime, in this case the concrete building sector. The MLP is used to analyse the transition from niche to regime, which is a very intricate and complex process, but the MLP gives a good viewpoint regarding the phenomena studied and can be used to explain a complex process in a simplified and manageable way.

2.2 Multi-level perspective on WMC and Socio-technical transitions

The Swedish building sector has been in an era of concrete and non-WMC, and a sustainability transition is needed to fulfil, *e.g.*, the Paris Agreement and other national goals, such as climate neutrality in 2045 (The Swedish Environmental Protection Agency 2023). In this section, the theory behind the multi-level perspective (**MLP**) will be explained, which helps illuminate the current market development of WMC. Sustainability transition are processes that proceed on different levels and time frames. Geels (2002) and Geels *et al.* (2017) describe the transition in terms of a multi-level perspective focusing on socio-technical change processes. In the MLP framework by Geels (2002), the socio-technical transitions are explained (Figure 5). The framework attempts to reveal how socio-technical transitions occur and how they behave in a big multi-actor/multi-level society system. This can help explain how a sustainability transition takes place through a socio-technical transition.

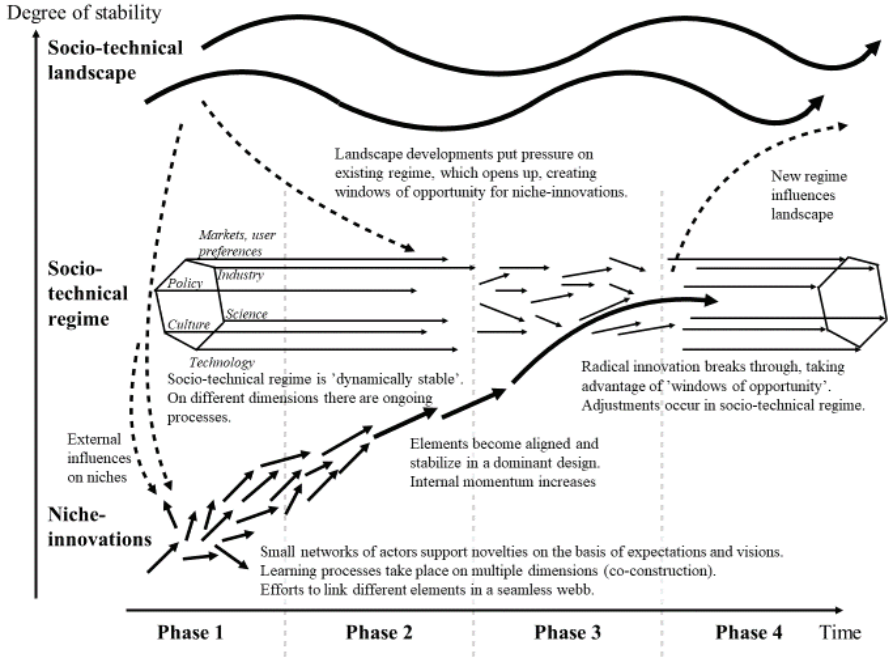


Figure 5. A theoretical perspective for socio-technical transition processes (inspired by Geels 2018:226).

The MLP is a built up in three different layers, as seen in Figure 5: the socio-technical landscape, the socio-technical regime and niche-innovations. The socio-technical landscape refers to,

> "… broader contextual developments that influence the sociotechnical regime and over which regime actors have little or no influence. Landscape developments comprise both slow-changing trends (*e.g.* demographics, ideology, spatial structures, geopolitics) and exogenous shocks (*e.g.* wars, economic crises, major accidents, political upheavals)" (Geels 2018: 225).

The landscape (**ST-landscape**) can be seen as the in-depth structural trends that influence the socio-technical regime (Geels 2002). The ST-landscape overlooks and influences the niches and the current socio-technical regime (**ST-regime**). What distinguishes the different levels from the landscape in the MLP is that it cannot be influenced by other actors in the MLP in the short term, although the ST-landscape can with its power put pressure on the ST-regime to create opportunities for new technologies to emerge (Geels 2018).

The socio-technical regime is the layer under the socio-technical landscape in the model. It is defined by Geels (2004); Geels (2011) as

> "The socio-technical regime forms the 'deep structure' that accounts for the stability of an existing socio-technical system (Geels, 2004). It refers to the semi-coherent set of rules that orient and coordinate the activities of the social groups that reproduce the various elements of socio-technical systems" (Geels, 2011: 27).

The socio-technical regime can also be described as the predominant paradigm determining practices and ways of thinking (Geels 2002 & Geels 2004). The ST regime illustrates the connection between the different sub-regimes and the stability it provides to the whole ST system. Pressure on the ST regime from both the niche and the ST landscape can lead to tensions that break up the ST regime, creating windows of opportunity for radical innovations (Geels 2011). The ST regime is at the centre of the MLP; therefore, the niches and the socio-technical landscape are defined in relation to the regime (Geels 2011). Changes within the ST system can be driven and

promoted through concerted action by different public and private actors (Edmondson *et al.* 2019)

The last layer to be described by the MLP is the niche-innovations level, where radical innovation takes place while incremental innovations occur in the socio-technical regime. Innovation is seen as radical when the results of the outcomes create new market infrastructures. The outcomes can be, *e.g.*, systems, technologies, or services; it is in this part of the MLP the WMC fits. Radical innovation's goal is to create something profoundly new that challenges and results in new market infrastructure, which is why radical innovation generates opportunities for new industries to emerge (Garcia & Calantone 2002), *e.g.*, the WMC-industry in Sweden after the regulation change in 1994. Niches are protected spaces in the MLP model, where radical innovation takes place. Radical innovations vary significantly from the existing regime and do not fulfil needs that exist in the market today. Examples of such protected spaces can be demonstration projects that are subsidised, small markets targeted with policy support, research and development (R&D) laboratories, or a fraction of a market that is willing to pay extra for potential innovations (Geels 2011).

A socio-technical transition can be many things; there are numerous examples in history, for instance, the shift from horse and carriage to automobiles, *etc.*. Socio-technical transitions take place when the socio-technical system changes. Although technology in itself does not have any function, it needs to be put in a context and acquires a function in a social setting (Geels 2002). The socio-technical systems can be tangible and represent different technologies such as wind turbines and power stations but also intangible such as the skills, routines, behaviours infrastructure, and the organisations needed to operate such technologies (Rip & Kemp 1998). Through the arrangements of these elements, social functions in society can be fulfilled, *e.g.*, road transportation. Other examples of social functions that are fulfilled through different socio-technical systems are sustenance, communications mobility, heating, and housing (Geels *et al.* 2017).

The MLP describes and divides the transition into four phases, which can be seen in figure 5. In the first phase, the radical innovation takes place in niches. In phase one, the networks are unstable, and many innovative solutions are created, but many fail to see the light. In phase two, the networks of actors start to stabilise, and a dominant design is created, which enters small niches in the market. In the third phase, the innovation gains

more ground and starts to compete with the dominant technology in the ST-regime. In the fourth and last phase, the technology in the ST-regime is substituted, making the innovation the dominant one. The substitution leads to the elements in the ST-regime being adapted to the new technology, and the transition is complete (Geels *et al.* 2017).

There are many ways for the socio-technical systems to resist change; some examples are dependence within systems and lock-in effects, system-bound habits where people are adapted to their lifestyle and certain artefacts such as the car, sunk investments in current technology and created economies of scale through the current technology (Geels 2004). These barriers may ultimately hamper the speed of sustainability transition. Here the dependence on concrete and steel in Sweden can serve as an example of the socio-technical regime, where sunk investments and the scale of the economy are indeed present after almost a century of low competition among those materials.

2.3 Value

For the businesses in the WMC market, some kind of value is made for the customers and end consumers when building the different houses and, of course, the businesses involved, but what is the value? And how can it be defined? In this thesis, the value creation will spring from the goods dominant logic since the Swedish WMC market still is dominated by the goods dominant logic in comparison with the service dominant logic. In the goods dominant logic, the tangible outcome and discrete transactions are central (Vargo & Lusch 2004). According to Grant (2018), businesses are something that create value, and value can be created in two ways, by production and by commerce. In production, raw materials are assembled into something of greater value for the customer than the raw material itself, *e.g.*, trees that become WMC. In commerce, the value is created not by the physical transformation but where the value is higher because of repositioning the goods in space and time, transferring them from locations in a point of time where they are less valued, to locations where they are more valued in a point of time, *i.e.*, creating arbitrage across time and space (Grant 2018). Grant (2018) argues that value creation is the total customer value minus the real costs of production. For whom the value is created has a split answer, according to Grant (2018). The value created can be

maximised either for stakeholders or shareholders. This business-centred view of value has become more questioned, and more views on what value is has been added to the discourse. Prahalad and Ramaswamy (2004) argue for a new way of creating value by co-creating value with the customer instead of for the customer. The firm-consumer interaction is, according to Prahalad and Ramaswamy (2004), the old way of creating value, as showcased in Figure 6.

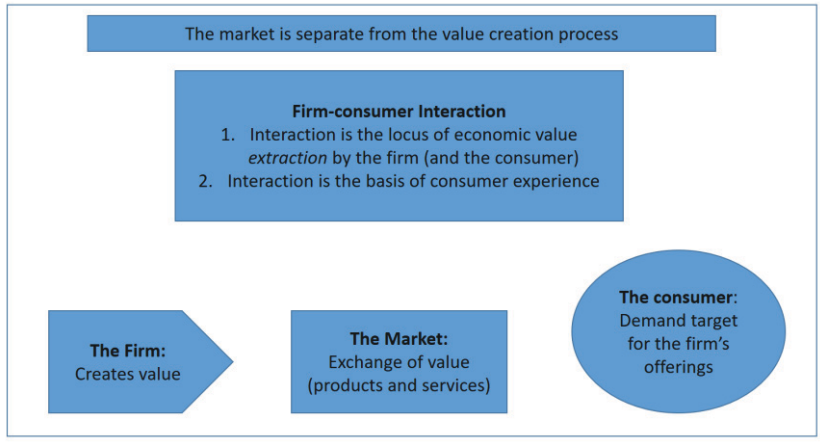


Figure 6. Traditional concept of a market (with inspiration from Prahalad and Ramasway, 2004:7).

It is the firm that creates the value, which is completely separate from the market. In the market, the exchange of value is made of products and services, and the consumer is seen as the demand target for the firm's offerings. However, a shift has been made according to Prahalad and Ramaswamy (2004) where the customers are gaining more knowledge from the more and more transparent market and are more willing to negotiate prices than before. Prahalad and Ramaswamy (2004) argue that the value creation process needs to be with the customer in the market and not away from the customer. In their article, Prahalad and Ramaswamy argue that the way of co-creating value is to use the Dialogue, Access, Risk-Benefit and Transparency (**DART**) model, shown in Figure 7.

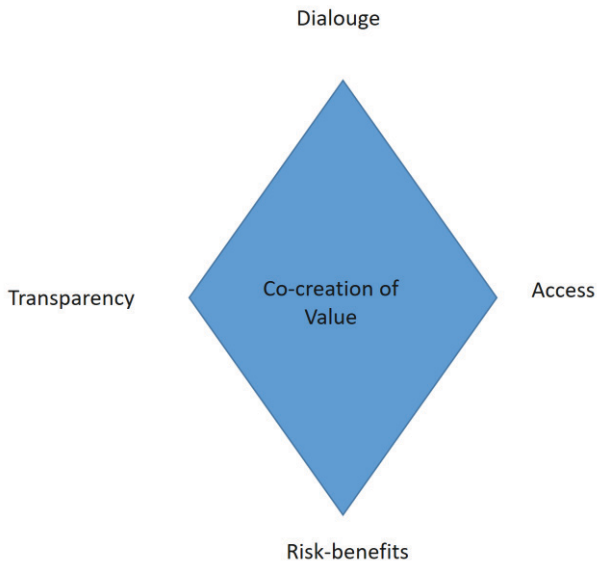


Figure 7. Market development in terms of co-creation of value (with inspiration from Prahalad & Ramasway 2004:9).

The DART model (Figure 7) is a way of describing the interactions on the market. Dialogue is important for co-creation since it implies interactivity and the ability and willingness to act on both sides, where the firm and the customer both need to be problem solvers, and where both transparency of information and access are important for the customer to be able to co-create value. From a firm-centric perspective, this has not been possible because of an information asymmetry between the customer and the firm. Further, the transparency of information and access and dialogue can help the customer to conduct a risk-benefit evaluation of the product. Here Prahalad and Ramaswamy (2004) suggest that the market should be seen as a forum to challenge the traditional economic theory (Figure 8).

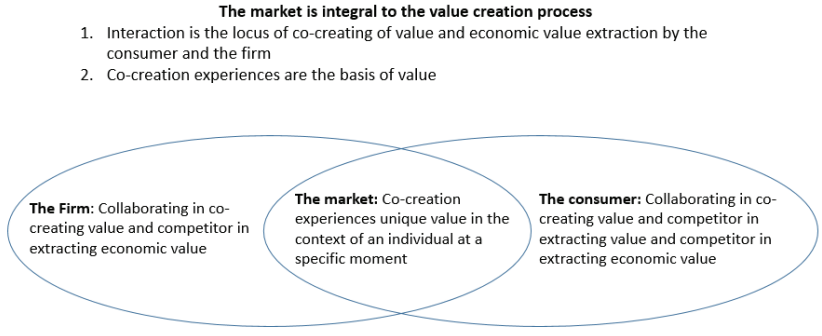


Figure 8 Firm consumer interaction with inspiration from Prahalad and Ramaswamy (2004:11).

In Figure 8, the form and consumer interaction are portrayed according to Prahalad and Ramaswamy (2004). Here the market is seen as the interaction between the consumer and the firm to co-create value, compared with Figure 6, where there is no interaction, rather just an exchange of value and no co-creating.

In WMC market there are many actors, from forestry operators to builders and end-consumers. How value is created and how the different actors co-create value together depend on how they interact and perform their tasks. Co-creation of value can involve collaborating between a for-profit organisation and its business partners, NGOs, state organisations, or consumers to develop a product or a service. It encourages innovation and the development of new ideas as part of relationship marketing. The building market in Sweden relies heavily on the municipalities since they are the legislative authority in Sweden and have a central role of creating value and co-creating value for their inhabitants, *i.e.*, the end-consumers. Here the Public Private Partnerships (**PPP**) come in and can in some cases be a part of the co-creation of value process. PPPs can also in some cases serve as a path towards finding solutions for sustainability challenges (Waddock 1991; Glasbergen 2011) PPP in Figure 9 is seen as a collaborative process (Glasbergen 2011).

Figure 9. A model for an idealised process for the development of public-private partnerships (Glasbergen, 2011: 4 with modifications).

In Figure 9, the ladder of partnership activity can be seen; there the idealised form of the partnering process is shown. The partnership can be developed in steps of establishing a shared agenda and forms for joint work, for example, sustainable blocks in a city where many actors are involved to make it work and to achieve more sustainability than the actors for themselves.

2.4 Sustainable business models

One way for the businesses to meet change in the WMC sector is to look into their own firms and examine how they pursue their business. A business model is a conceptual tool that can help to understand how a firm does business and can be used to analyse, compare and perform assessment, management, communication and innovation (Osterwalder *et al.* 2005). Business models can be defined in different ways and are described in the literature in different ways. Bocken *et al.* (2014:43) describe briefly some of the business model definitions in the literature, where

> "Margretta's (2002), Zott and Amit (2010) and Beattie and Smith (2013) describe business models as a holistic description on 'how a firm does business' and Teece (2010) describes that a business model articulates how the company will convert resources and capabilities into economic value. It is nothing less than the organisational and financial 'architecture' of a business and includes implicit assumptions about customers, their needs, and the behaviour of revenues, costs and competitors (Teece 2010)."

Bocken *et al.* (2014) describe further the literature from Osterwalder *et al.* (2005), and Richardson (2008) where Bocken *et al.* (2014) develop their definition of a business model, which will also be used in this thesis where the business model is defined by three elements, namely value proposition, value creation and value capture, as seen in Figure 10.

Figure 10. A conceptual business model framework from Bocken *et al.* (2014:43) with minor altercations.

According to Bocken *et al.* 2014 (Figure 10), the value proposition is the heart of the business model; businesses typically capture value by seizing new business opportunities and markets and revenue streams. The value proposition is usually connected to the product and service offering economic return. Value proposition should also in a sustainable business model provide measurable ecological and/or social value with the economic value (Bocken *et al.* 2014). Bocken *et al.* (2014) also stress that value is no longer only made by the business in itself but with other actors and parties external to the business and through formal or informal alliances.

Sustainable business models are needed in today's society to lower the impact on nature and deliver long-term sustainability solutions where businesses need to change how they operate. A sustainable business model can also serve as a vehicle to coordinate the technological and social innovations with system-level sustainability. A sustainable business model (**SBM**) is, according to Lüdeke-Freund (2010:23),

> "a business model that creates competitive advantage through superior customer value and contributes to a sustainable development of the company and society".

Within the growing body of literature on the subject, many studies categorise SBM according to development, uses, adoption and outputs. (Bocken *et al.* 2014) have developed an "archetypical" categorisation based upon a literature review and data from different company strategies. The archetypes in Bocken *et al.* (2014) show different examples of how the companies work in different groupings and what makes them an archetype. The Bocken *et al.* (2014) "archetypes" can be translated to the WMC market and used for further analysis of the company's business models.

Many of the largest companies in the Swedish WMC market have had their business models explored by, *e.g.*, Lessing and Brege (2015) and Brege *et al.* (2014) but have not been put in the light of the framework by Bocken *et al.* (2014), which was done in this thesis, where sustainability is scrutinised in the Bocken *et al.* (2014) archetype models.

2.5 Structure of housing provision

Structures of housing provision (**SHP**) refers to how the network of relationships associated with the provision of housing look at a specific point of time (Ball 1998). The SHP is not a theory but rather a meta-theoretical framework for different kinds of analysis of issues of housing provisions (Ball & Harloe 1992). Boelhouwer and van der Heijden (1993) contend that the SHP is not a theory on housing but rather a way to describe different housing structures to be further evaluated by other theories. The SHP can be used to illustrate the market, where different institutions and actors interact and in what spheres they operate in. The SHP may be illustrated in three different spheres (fig. 11).

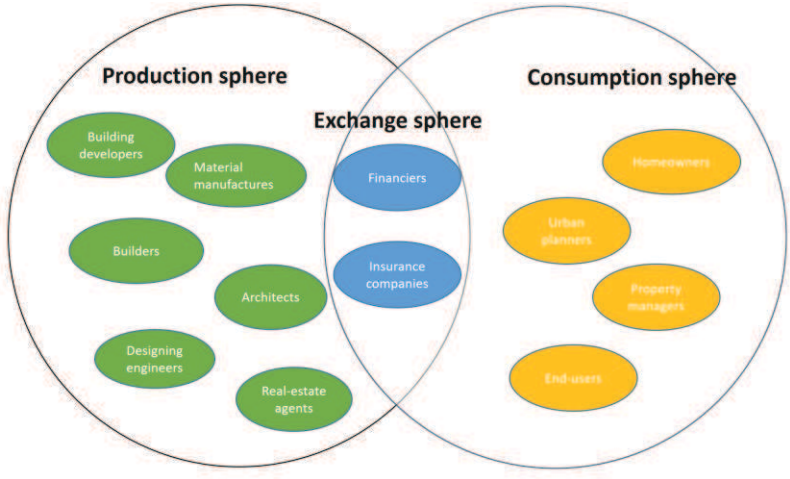


Figure 11. An illustration of the different spheres in the structure of housing provision.

The SHP explains that the supply and demand in the housing markets are dependent on geographic conditions at specific times, reflected in spheres of consumption, production and exchange, which can be seen in fig. 11, where some of the actors in the WMC market are displayed. The production sphere consists of the actors responsible for the construction, mainly builders, developers, architects, material manufactures, real estate agents, designing engineers, *etc.*. The exchange sphere consists financial institutions such as the financiers of housing projects and the insurance companies. In the consumption sphere are the end-consumers, property managers, urban planners and homeowners, where the actors in the consumption sphere are responsible for the fulfilment of the housing needs. In the spheres, the institutions (actors) are interconnected through management systems (Burke & Hulse 2010).

2.6 Summarising the theories

In Table 2, the different theories are connected to the respective research questions.

Table 2. The different theories and their connection to the research questions and their application.

Research question	Theory	Application
factors for WMC market development?	provision	and enabling factors, the SHP- framework is used to put the literature in the light of the different spheres and describe the chosen literature
What are the enabling factors for WMC market development?	Structure of housing provision	See above
Sweden perceive the **and, more specifically, the WMC as a solution to lower the climate impact in Sweden?**	Multi-level perspective and social acceptance	is used to analyse the social acceptance of WMC in Sweden among end-
How do Swedish professionals in the wooden multi-storey sector perceive the co-creation of value aspect in their work when building and projecting houses?	Sustainable business models, Co-creation of value and multi-level perspective.	To help analyse the business models portrayed by the professionals, how they perceive the co-creation of value and the transition in the Swedish residential building market.

In Table 2, the research questions are connected to the theories used in the kappa and in the articles. The MLP is used as a theory for many of the questions and will be used throughout the thesis as it serves as a way of defining and analysing transitions.

3. Methods and Data

This chapter describes the methods and data used in the different studies included in the thesis. The chapter contains the description of the three articles included in the thesis.

3.1 Article I

This chapter concerns article I, the literature study concerning WMC. A systematic literature study was chosen when conducting the literature study. The method used was The Preferred Reporting Items for Systematic reviews and Meta-Analyses (**PRISMA**) (Moher *et al.* 2009). With the PRISMA method, peer-reviewed articles between 2000 and 2020 were captured from two different databases, namely Web of Science and Scopus. The two databases were chosen since they represent a large quantity of the peer-reviewed scientific articles from around the globe. A systematic literature study is, according to Tranfield *et al.* (2003), as a method of analysis, a transparent, rigorous, and detailed method used to support decision making. According to Akobeng (2005) and Denicol *et al.* (2020), a systematic literature study could also build theory by accumulating knowledge and evidence after analysing a large number of studies and methods, thereby increasing the consistency of the results and the conclusions. The PRIMSA guidelines used in this study stem from the guidelines from Moher *et al.* (2009).

The study was performed in four phases. The first phase included a broad gathering and identification of literature. The outcome of the first phase identification resulted in 7117 document results in Scopus and 5491 in Web of Science. After excluding irrelevant articles and duplicates, 696 articles were included in the next phase. In phase two, the abstracts were read and

evaluated case by case. The list of excluded studies consisted of peer-reviewed articles, which did not address wood construction or had a strictly technical focus (*i.e.*, no information to add knowledge on WMC market development). After the screening phase, 168 studies were left for further consideration for phase 3. In the third phase, 42 peer-reviewed articles were left for the final and fourth phase. Articles were excluded mostly because they did not concern WMC, market development or non-residential buildings, or were unavailable or not peer reviewed.

In the last phase, the 42 remaining articles were analysed. The articles were categorised by materials into themes for enabling and hindering factors, which could affect the market development of WMC. The articles were also categorised by method and analytical development to show what would be needed in academic research to enhance the field of WMC market development studies.

3.2 Article II

In this study, the acceptance of the Swedish bioeconomy was perceived by some end-consumers at IKEA. A survey was chosen as the method used by the PERFROM team to map different European cities, although this study only concerns Swedish end-consumers. The answers from the survey served as a basis for an ad hoc investigation into the current of the social acceptance of the forest-based bioeconomy in Sweden.

The questionnaire was used as a field survey and divided into four parts. The first part discovered how the respondents perceived the wooden multi-storey buildings (**WMB**) in Sweden, foremost with questions concerning Wood vs. Concrete. The second part concerned how the respondents perceived carbon storage in Swedish forests. The third part concerned the perceptions of the forest-based bioeconomy. The final part of the questionnaire concerned personal data. A Likert scale of six was used for the respondents to give value to their answers. The benefit of using the Likert scale is the simplicity, but this must be balanced against the shortcomings of uni-dimensional answers on a scale that is not equidistant in the reply options, which may fail to give a true measure of respondents' attitudes (Bishop & Herron 2015).

The data collection took place at IKEA Uppsala (Sweden's fourth biggest city) and lasted one weekend in December 2018. IKEA was considered a

representative of a common place where many general consumers can be found from different socio-economic backgrounds. The passing consumers were invited to participate in the study, and efforts were made to have an equal representation between males and females. The respondents could use both English and Swedish in the electronic survey. A total of 204 persons participated in the survey, and the consumers represented in the study were approximately 1.4 % of the all the customers at IKEA during the two weekends. The respondents were offered a 50 SEK (Ca 5 USD) food coupon when they had finished the survey.

The analysis consisted of descriptive statistics, and not all the questions in the survey were included in the study.

3.3 Article III

In the last article included in this thesis, qualitative interviews were chosen to collect data from eight different professionals in the Swedish WMC market.

The interviews were, in light of the COVID pandemic, performed on the video platform Zoom. They were recorded and transcribed to text for further analysis and performed as semi-structured interviews with an interview guide used during the interviews. The interview guide was based on co-creation of value (Payne *et al.* 2008), sustainable business model archetypes (Bocken *et al.* 2014), the context of Sweden and the role of the municipalities in the building processes. Semi-structured interviews use pre-defined questions and sequencing of different themes, but there is an openness to follow up the answers and the stories told by the interviewees (Brinkmann & Kvale 2015).

Data was analysed by performing coding on the text transcriptions in the software NVIVO. First analytical notes were made to annotate interesting and important paragraphs and citations. After the annotations, the first cycle coding was performed by making descriptive coding, as this gives a basic label to the data to provide an inventory (Saldaña 2021). The descriptive coding was also mixed with some *in vivo* coding where the labels come from the interviewees' own language and terms. This meant that the coding not only springs from the theory but also from the language of interviewees and reality. In the second cycle, pattern coding was applied, grouping and

condensing the labels from the first cycle coding into themes to make meaningful units of the analysis (Saldaña 2021).

3.4 Ethical considerations

In the research process, one must take ethical consideration throughout the whole process (Silverman 2011). Ethics refer to rules of conduct, usually to conformity to a code or set of rules (Robson & McCartan 2016: 208). In this thesis, the following was considered when conducting the research in accordance with (Bryman & Bell 2017:141). The ethical principles can be seen Table 3 along with how they were accounted for.

Table 3. Needs for ethical consideration and how it was accounted for with influence from Bryman & Bell (2017:141)

Needs for ethical consideration	**How it was accounted for in this thesis**
purpose of the research and which elements are included.	The respondents in study II and III were informed about the purpose of the study both orally and in text.
***Consent*, the respondents must know that their participation is voluntary and that they have the right to abort their participation at any time.**	The respondents in study II and III were informed that the participation was voluntary and they could abort their participation at any time. The informants were informed orally and in text.
the information about the respondents should be treated with the highest degree of confidentiality.	about their anonymity and that their data would be handled confidentially, although it should be said that the survey was performed in a public environment. In that their data would not strictly be anonymous, and they were encouraged to participate with their name and branch. All participants in all studies gave their researchers.

***Usage of information*, the information collected should only be used for the research purpose.**	The data was only used for research purposes, and the participants were informed of the purpose of the studies and what the studies would result in.
delude the respondents about the research or give them false information.	There were no false promises and no false information given to the respondents during the data collections.

In Table 3, the most central ethical considerations have been disclosed. In study II and III, the participants were also informed that data were stored according to the General Data Protection Regulation (**GDPR**).

3.5 Trustworthiness

Trustworthiness in qualitative research refers to the overall quality of the procedures taken in the inquiry and whether the findings can be reasonably robust and believable (Robson & McCartan 2016). Shenton (2004) argues for the following criteria when trustworthiness is assessed: credibility, transferability, dependability and confirmability. The following will disclose how these concepts have been accounted for in this thesis.

Credibility parallels to internal validity—*i.e.*, how believable are the findings? Credibility is one of the important ways to create trustworthiness in qualitative research. In the following Table 4, the criteria to fulfil credibility is disclosed with guidance from Shenton (2004).

Table 4. Criteria and actions for credibility in the thesis (Shenton 2004:73) with minor changes

Criteria to fulfil credibility	Actions for credibility in the thesis
well recognised research methods	established and highly used in qualitative research. Semi- highly used and established methods of data collection.
Development of early familiarity with culture of participating organisations	Key informant interviews were used as a way to develop early familiarity and to gain an overview of the WMC market in Sweden. An advisory board in the research project KNOW was also utilised when looking for interesting cases and telling examples.
individuals serving as informants	purposive sampling. Random sampling was possible due to the nature of the interviews and the scarce number of respondents in the chosen case cities.
Triangulation via use of different methods, different types of informants and different sites	Triangulation accounted for by using different data collection methods in the thesis, and that the research sought to understand the perspectives of different actors or stakeholders at both the management and project level.
honesty in informants	participation at any time, and the researchers indicated that there are no right answers.
Iterative questioning in data collection dialogues	Iterative questioning in study III was accounted for by using semi-structured interviews.
between researcher and superiors	in the supervisor meetings and in the project group meetings. In study I, there were multiple meetings concerning data gathering and analysis; in study II, there were multiple meetings after the data gathering on both the project level and article level; and in study III, at least two researchers participated in the interviews at all times. Impressions and interpretations were compared and discussed afterwards with all researchers.
Peer scrutiny of the research project	A larger research consortium gave feedback on the different activities, namely the projects, workshops and conferences with international presence. Two of the articles also went through peer reviewing to be published.
background, qualifications and experience of the researcher	The researchers' backgrounds were given to the participant interviewees and showcased in the different articles; funding resources were also posted and described.
Member checks of data collected and interpretations/theories formed	The respondents where sent the transcripts for evaluation and correction.
phenomenon under scrutiny	A detailed description that uses several sources of the phenomenon has been made in the thesis.
Examination of previous research to frame findings	An in-depth literature study has been made in article I.

The different actions mentioned in the Table 4 account for the credibility in this thesis. Further, the transferability will be taken into account. Transferability refers to how well and to what extent the findings of one study can be transferred and applied to other situations. Shenton (2004) argues that qualitative projects often are specific and linked to particular environments. According to Shenton (2004: 70) it is:

> "…impossible to demonstrate that the findings and conclusions are applicable to other situations and populations."

It will, however, be almost impossible to replicate the studies in this thesis, and it is also probable that the WMC market in Sweden will evolve to something it was not when these studies were produced. Therefore, to account for transferability, the provision of data to establish the context of the studies and a detailed description of the phenomena are clarified to allow comparisons to be made, in accordance with Shenton (2004).

Addressing the positivist issue of reliability, the qualitative research tends to be problematic since the phenomena often change (Shenton, 2004). To enable duplication of research, the descriptions are presented in (Table 5)

Table 5. Criteria to fulfil dependability from Shenton (2004:73) with minor changes

Criteria to fulfil dependability	**Actions for dependability in the thesis**
[redacted]	Overlapping methods, *i.e.*, interviews and systematic literature reviews have been taken into account in this thesis.
In-depth methodological description to allow study to be repeated	In-depth methodological descriptions have been made for the study to be repeated, although it will be hard since reality changes, people change positions, *etc.*

The different criteria and actions mentioned in Table 5 accounts for the dependability in this thesis. Further, the concept of confirmability will be explained.

The concept of confirmability describes the qualitative investigator's comparable concern to objectivity. Although it is hard to maintain real

objectivity in qualitative research, since much stems from human interactions, Table 6 gives an overview of the actions taken in this sense.

Table 6. Criteria and actions for confirmability in the thesis from Shenton (2004:73) with minor changes

Criteria to fulfil confirmability	Actions for confirmability in the thesis
[redacted]	Triangulation has been accounted for by involving multiple researchers
Recognition of shortcomings in study's methods and their potential effects	Put to scrutiny in the discussion chapter.
[redacted] **allow the integrity of research results to be scrutinised**	The methods are described and with the results allowed to be scrutinised in the thesis

In Table 6, the criteria and actions for confirmability can be seen along with how these were accounted for in the thesis.

3.6 Method limitations

In this study, some different types of methods have been used, as previously described. How these methods were used to achieve trustworthiness was described in the previous chapter, although the methods used for both data gathering and data analysis have some shortcomings for the studied phenomena. Firstly, in article I the studied articles were only in English due to the language limitations in the group of the researchers; this could mean that other peer-reviewed articles in other languages of importance could have played a role in the analysis, although most of the research in the field is written in English. The rigour in method in article I was strong, but the limitations here are instead in the choosing of the search words. Of course, not all interesting search words could be picked since the data material would be too big to go through, although the search word choosing could be scrutinised. In Article II, the method limitations are in the data gathering; the gathering was not random, which could add rigour to the study. The people that answered the questionnaire were interested and also offered a lunch coupon. How much this would skew the participant list is, however, unclear, which makes it hard to evaluate the full effect, although the IKEA warehouse in Sweden has a large variety in its customer base. In article III, the method

of data gathering was interviews, where the key informants were interviewed to gain a larger scope of the market and see what types of cases would be interesting; the other interviews were held with the professionals. In study III, the shortcomings could be insufficient data material and that the data are personal, although in a professional setting that would not reflect the market as a whole. The study has tried to follow established methods, namely to (1) generate "Quality of research" and (2) convey a truthful picture for the reader's assessment.

4. Summaries of the articles

4.1 Article I

Title: Wooden multi-storey construction market development – systematic literature review within a global scope with insights into the Nordic region

4.1.1 Background and aims

The literature about WMC emergence has been largely unmapped, and few literature reviews have been conducted in the area. Some studies have addressed the emergence of WMC in recent years, *e.g.*, Gosselin *et al.* (2017); Hemström *et al.* (2017); Hurmekoski *et al.* (2018), although a large literature study had not yet been made in the area. The overarching aim for the study was to delimit the knowledge gap about the scientific literature connected to WMC market development and synthesise the literature concentrating on factors like demand, supply and local-level governance. To achieve the overarching goal, three aims were created. The first aim to achieve the overarching aim was to synthesise the key barriers and enabling factors for WMC market growth by going through literature from 2000 to 2020. The second aim was to identify the actors who have a key role in the WMC market development, whereas the third aim was to summarise the different methods and analytical approaches used to study the themes connected to the WMC market development and actor roles in the selected literature. PRSIMA guidelines were used in the systematic literature review, and 42 articles were included from the two databases chosen: Scopus and Web of Science.

4.1.2 Results and conclusions

In the results, there has been an increasing interest for WMC studies in the chosen literature, especially after 2017. The geographical focus has been heavily on the Nordic countries, concerning 37 of 42 included articles. The Structures of Housing Provision framework used in the study showed that only the production and consumption sphere were represented in the studied literature, leaving out the exchange sphere.

Connected to the first aim synthesising the key barriers and enabling factors for WMC market growth, eight different themes emerged from the literature. The eight themes were named as Sustainability in building, System development, Innovations, Business collaboration, Stakeholder awareness, Institutional changes, Urban planning, and Market demand. The articles connected to the production sphere were much more than the ones connected to the consumption sphere concerning the barriers and enabling factors. Enabling factors found in the included literature were connected to cost efficiency gains connected to pre-fabrication and perceived sustainability benefits by consumers and architects, which enabled WMC market diffusion. The most found barriers were connected to system development issues such as system development (*e.g.*, lack of knowledge and information, limited experience with building with wood) and Stakeholder awareness (*e.g.*, negative perceptions of product features such as fire safety, water control, durability), and Business collaboration (*e.g.*, lack of collaboration, lack of stable relationships). Other examples mentioned in the literature were the discrepancies in actor perception of the land allocation process in relation to urban planning and the deficiencies in the municipal public procurement process.

To fulfil the second aim, the key actors in the literature were identified and accounted for. The actors found were businesses (*e.g.*, contractors, manufacturers and architects) involved in the wood construction value-chains, while residents and actors in local governance were seldom addressed.

The third aim of this study was fulfilled through mapping the methods and approaches in the selected articles. There was a majority of qualitative approaches in the selected articles, where 28 out of 42 were represented. Moreover, ten out of the 42 selected articles had a qualitative approach and four out of 42 had a mixed approach. The selected articles that used a qualitative approach used case studies or multiple case studies as the most

common way of describing the studies. All except one of the quantitative case studies used the method survey. The methods in the qualitative studies used to collect data differed but the most common method was interviews, used in 25 out of the 28 articles, although only 14 of these articles used solely interviews as a data collection method. The other collection methods used was focus groups, literature collection, secondary data collection surveys and workshops. In the qualitative studies the most used collection method was questionnaire/survey.

The results of article I suggest that the enabling factors of WMC emergence are coming from increased pre-fabrication such as increased material efficiency resulting in lower material costs and quick and easy erection of the houses and fast installations. Wood is perceived as giving benefits to bring benefits in WMC, especially among wood manufacturing companies and architects, but this push is not sufficient to rapidly accelerate WMC business, at least not yet. As a barrier to system development, the lack of experience from using wood in multi-storey construction, and the path dependencies with concrete and steel construction, continue to be the key hindrances for mainstreaming of the WMC. However, the demand side enablers and barriers remain a great unknown, due to a gap in research.

In conclusion, there is a need for more research connected to the consumer sphere and the factors concerning the demand for WMC homes. The focus in the literature has clearly been in the production sphere focusing on supply in the housing market. There is also a lack of knowledge concerning financial issues in the exchange sphere, such as the role of mortgages and insurances, affecting both the supply and the demand in relation to WMC market development.

4.2 Article II

Title: Social Acceptance of Forest-Based Bioeconomy—Swedish Consumers' Perspectives on a Low Carbon Transition

4.2.1 Background and aims

In this study, the forest-based bioeconomy (**FBB**), in which forest resources are the primary biomass resource and which encompasses economic activities that relate to all forest ecosystem services, is used as a part of a low carbon transition. In the low carbon transition, wooden storey buildings are

used as a product inside the FBB using the socio-technical transition (**STT**) theory. The social acceptance among the different stakeholder groups will influence the implementation of a low carbon transition. Different studies have been made on stakeholder's social acceptance in the FBB, although the social acceptance of WMBs among consumers has not yet been studied nor their perceptions of WMBs. Therefore, the aim of the study was to explain how consumer understandings of the forest-based bioeconomy, with a particular focus on wooden multi-storey buildings, can influence a low carbon transition. The aim was fulfilled by doing a questionnaire that covered the perceptions of WMBs and FBB among some consumers in Uppsala, Sweden. The questionnaire was analysed through a theoretical framework and displayed through descriptive statistics.

4.2.2 Results and conclusions

A total of 204 persons answered the questionnaire at IKEA Uppsala, which accounted for approximately 1.4 % of all the visitors to IKEA Uppsala the weekend of the data gathering. Approximately 56 % of the respondents were female, and the average age of respondents was 46 years of age. Most of the respondents (75%) lived in an urban or suburban area. Very few of the respondents (10%) were forest owners. To the question about familiarity regarding how forests store carbon, *ca*. 64 % answered they were familiar. Regarding the meaning of FBB *ca.* 29 % answered they knew the meaning of FBB, and ca. 55 % answered that they were familiar with WMBs. The results showed that respondents who were older than 64 years old, lived in a rural area and owned more than one hectare of land were more likely to perceive that they had good knowledge of the FBB than other respondents. Despite a lack of knowledge about the meaning of the FBB, the majority of the respondents perceived the FBB to be a low carbon transition. Most of the respondents (*ca*. 90 %) agreed with the statements that FBB decreases the dependency on oil and fossil fuels and that the use of fossil fuels and non-renewable materials must be reduced as soon as possible. This indicates that a majority of the respondents also believed that there is a need for a low carbon transition to take place. The transition to FBB was not regarded without risk, and a majority (*ca*. 73%) thought the risks should be seriously considered before a successful implementation, although most respondents thought that the benefits with FBB were greater than the risk.

About half of the respondents expressed that they were familiar with wooden multi-storey buildings. Concerning the sustainability aspects of wooden multi-storey buildings, the respondents, *ca.* 65 %, believed that WMBs are faster and cheaper to build, and a marginal majority, *ca.* 65 %, believed that the WMB can stand as long as steel and concrete buildings. Most respondents (*ca.* 78%) thought that the WMBs are less harmful for the climate than concrete and steel buildings, although almost half of the respondents thought it would agree that WMBs would contribute to the global deforestation. Overall, the respondents saw clear economic benefits of WMBs but perceived various environmental aspects of WMBs offering climate benefits but causing deforestation. A majority (*ca.* 68 %) of respondents also perceived the risk of fire in the WMBs as higher than in steel and concrete buildings.

More knowledge among the consumers about FBB and WMBs could result in a higher socio-political acceptance, enabling a sustainability transition in the Swedish building market. Although it is debatable whether the consumers can enable such a transition as the consumers are not involved in making the choices of materials in the multi-storey market in Sweden and are merely able to make a choice in what is offered in the market. The choice of portfolios, materials and management are made by the construction companies (Roos *et al.* 2010). The acceptance among the consumers is also only one voice out of many in the societal landscape. The development of WMBs is moreover dependent of other actors (*Ibid*.). At the same time, the path dependency and strong interconnectedness affect the decisions made within the socio technical regime and can impede a sustainability transition to a bioeconomy.

It can be concluded that according to the respondents, the FBB has only been established in the Swedish housing system to a limited extent, with the niche innovation WMBs representing only 10% of the WMBs in Sweden. Some social-acceptance among the respondents could be found for WMBs and FBB, although disagreements among the respondents exist foremost about fire, perceived risks with FBB, deforestation, economic benefiters and social benefits compared to steel and concrete housing. Lastly, the results in this article indicate that the social-acceptance alone will not be the primary reason for a low carbon transition, concerning the FBB and WMBs, to be more widely adopted, but rather the interconnectedness and socio-technical regime.

4.3 Article III

Title: Sustainable business models in the wooden multi-storey building sector– What are the key elements?

4.3.1 Background and aims

The WMC market has been steadily growing in Sweden as has the literature about the market and its businesses. The literature has to a great extent been focusing on the business side and the business models used in the sector. Studies have also explored how the market can evolve and what hindering and enabling factors seem to exist for the market and how these can affect the market emergence. However, the value co-creation between the businesses, municipalities and end-consumers has not yet been explored in the scientific literature. In this study, some of the professionals of the WMC market in Sweden are interviewed about co-creation of value, sustainable business models and business strategies. A better understanding of this area could help identify key challenges for supporting sustainability transitions, as well as improve value creation from the interaction between the business actors in the WMC market, its contact with municipalities and its end-consumers and customers. This leads to the aim of the study.

The aim of this study is to explain conditions for the co-creation of value between construction companies and municipalities in the case of WMC. Key questions closely related to the aim focused on the understanding of wood as a construction material, business opportunities related to WMC, and organisational settings for doing business.

4.3.2 Results and conclusions

Eight different professionals from the WMC market in Sweden were interviewed electronically in Zoom. The interviewees were a mix of professionals ranging from CEOs to project managers. The companies and projects were picked from three different cities in Sweden, namely Uppsala, Göteborg and Växjö. The interviews were coded into different themes to be scrutinised and generalisable. The themes in the article were business

models, development work, costs, marketing and sustainability. From these themes interesting quotes and viewpoints were taken out and put into perspective of the theoretical framework. The results show that the there is a great learning process connected to the emerging market of WMC and that the development is slow, although on the move forward towards larger market shares. The studied enterprises are quite conform in their business models and put in perspective to Bocken *et al.* (2014), they had a priority to deliver technological solutions on time and with time-effective measures. Efficient resource use, low carbon solutions, Lean manufacturing, de-materialization, and increased functionality represented the respondents view on their business models conformed by Bocken *et al.* (2014). Although there are anomalies *e.g.* the co-building group where higher degree of co-creation of value was considered and more social sustainability throughout the process.

The safest way for market development for the enterprises is probably to deliver examples of good and quality housing. The legislative changes will also probably favour the WMC market according to the respondents. The industry, represented in the case studies, has a realistic view. The focus is on incremental improvements and adaptation to current and future legislative demands. Wood construction is developing but much remains to streamline and standardise various processes. These improvements will possibly improve the competitiveness and the market development of WMC, albeit at a moderate pace in order to synchronise processes and wood material supply.

5. Discussion

In this chapter, the results from the articles are summarised and put into perspective concerning the analytical framework of the thesis.

5.1 Summarisation of the results

In this thesis, the aim was to explore conditions for market development in wooden multi-storey construction. The aim reflects the perspectives of the scientific literature, the end-consumers and market professionals for co-creation of value in the WMC market.

The results in the three articles give three different facets from the WMC market: from the perspective of the global scientific literature, Swedish end-consumers and professionals from different Swedish WMC building companies and house production companies.

In article I, the scientific literature perspective on the WMC market emergence is explored along with whatever enabling and hindering factors that could be recognised in the literature. The results from article I showed that cost-efficiency gains from industrialised prefabrication and perceived sustainability benefits by consumers and architects enabled a WMC market diffusion. The lack of experience in the WMC market and the path dependency of concrete and steel is still a hindering factor for the WMC market to grow. It is also clear that most of the research made on WMC is found in the Nordic countries. The actors in the chosen literature are mainly drawn from businesses involved in the value chain of the WMC market and seldom from residents and actors in local governance. Case studies and qualitative sources of data were the most used in the literature.

To address the end-consumer side, article II was added. In article II, the results show end-consumer awareness of forest sequestration capacity but

less awareness of the connection to the forest-based bioeconomy and the role of wooden multi-storey buildings. The results indicate a slow transition that is hindered by path dependence and limited comprehension among consumers concerning the effects of their choices for a forest-based bioeconomy.

To get the view from the professionals, article III was added, the results indicating that the end-consumer is seldom addressed by the builders or the materials manufactures. From a marketing perspective, wood as a sustainable material has not yet been a part of the marketing, and it has not been important in the marketing. The different firms included in the study were positive to the co-creation of value, although a gradient could be seen between different ways of project management and ownership of the projects. It is also clear that most of the enterprises are following a goods dominant logic. This could indicate that the project and enterprise matters for what type of co-creation is produced and the extent of the co-creation. The path dependency is strong and the market is developing slowly but surely, the focus is and have been on incremental improvements, and delivering good quality, which probably is the safest way forward.

5.2 Interpretation of the results

The results of the articles showcase three different perspectives on the WMC market and the evolution of the emergence and development of the sector. The outcomes in the three articles included in this thesis reflect a market where concrete is still the dominant material in both people's minds and in the construction market for residential construction, which is also confirmed by, *e.g.*, Hemström *et al.* (2017). This is a pattern recognised in all the articles: in the literature, the end-consumer's perceptions, and among the professionals in the WMC market. Path dependence seems still to be an issue in many ways both in people's minds and in the physical market, although the WMC market is growing in numbers and is getting more and more attention in both literature and mainstream media; it is still the largest hindering factor for WMC market development. The fact that the WMC has not been in the market for too long and that the sociotechnical system is still under change may play a role here. It is also clear that the WMC market is not fully a part of the socio-technical regime, although it seems to be more and more mainstream, according to both market sales and the professionals

interviewed. If the innovation WMC would be defined by the phases in Geels' (2017) MLP system, it could be argued that the WMC is past phase one and two and is well established in phase three, where the WMC is starting to compete with the current regime of concrete buildings. It has not yet taken over totally, but more and more signs are given that the WMC market will grow, both by municipal involvement through procurement, and PPP and regulation changes that could in the long run favour the building material wood. Although among the professionals there is business as usual where wood as a material still garners little attention in the marketing and strategy work, this does not really include the material, but rather the processes, technical innovation, and logistics. Why is this the case, one can ask? Could it be because the historic value of fires, acoustics and moisture are still in the mind-set of professionals, urban planners, and end-consumers? There are still barriers to break through, such as the urban detail plans of the municipalities where many still favour concrete buildings and floor height.

The enabling factors for the WMC market development are foremost focused on technical, logistical, and pre-fabrication aspects. Climate benefits seem to come as a pleasant surprise, and the builders, and material manufacturers are not pushing for the unique selling point that the building material is wood but rather that there are the technical benefits to building with wood, with high pre-fabrication rates and fast assembly on site. Public perception could also be an enabling factor with higher social acceptance, foremost of the perceived climate benefits of wood, this is also confirmed by *e.g.* Roos *et al.* (2023).

The results in this thesis have been relatively straightforward and not very surprising. For example, the professionals reported that the marketing material that reaches the end-consumers are not putting much weight on the fact that they will live in a wooden house, but rather other unique selling points such as closeness to convenience stores, lakes, schools, and what type of household appliances *etc.* this was also found in Mark-Herbert *et al.* (2019), where many end-consumers didn't even know that they were living in a wooden house.

The fact that the builders and wooden house manufacturers didn't see themselves as wood builders and manufactures but rather just companies that build or produce wood is probably a sign that there is more work needed in the marketing strategies for the companies. Marketing strategies that could help enhance the market share and the public perception of WMC. The

question is still if this is needed and what the companies could win by having a more bold marketing strategy and if it is needed or if the future laws for climate emissions in the building sector will do it for "free" and no further marketing is needed. More research is needed in the field of marketing for the WMC companies, but also research about the necessity of marketing, is it needed? Or will the new legislation and more knowledgeable end-consumers do the job?

5.3 Discussion of the implications

The analytical framework fits well with the collected data. The MLP seems to be a good way of trying to define and measure the transition in the building sector in Sweden, when weighing in the perspectives from the end-consumers, the literature, and the professionals. The MLP is quite blunt and contains a lot of different perspectives and probably all of these perspectives can acquire a lot of research in themselves. This thesis only gives a way a small piece of the market and of the people in it, and does not give all the perspectives of the MLP. More research is needed to fully understand the extent of the WMC market in Sweden but the use of the MLP in this study gives a good hint of where it is going. The Sustainable business model archetypes model can help us understand how the WMC businesses work and how they can become more sustainable by using sustainable business models. Although in this thesis the studied companies are rather uniform with small differences. One can also ask, are the business models sustainable just because they are put into the light of being sustainable or are they in fact just business as usual? It is clear that this thesis does not contribute with any theoretical implications but rather empirical ones. From a theoretical perspective, the WMC market in Sweden could probably help give theoretical evidence in the sustainability transition theory where it could symbolise a sustainability transition and give more insights into sustainability transitions in a highly conservative and path dependent market.

Practical implications of this thesis could be higher awareness for both municipal officials and professionals, to give them the end-consumer perspective and a deeper understanding of the literature in the WMC field as well as the professional's view on both the market and the co-creation of value. This can help the WMC market forward towards higher market shares and lower path dependency in society as a whole. What remains to achieve

more mainstream is the implementation of laws, marketing efforts to both strengthen the public perception of WMC and the acceptance within the professional guild and municipal officials. The technical solutions seem to be there for the market to grow but not the full acceptance and knowledge base needed both among end-consumers, municipal officials and clients.

5.4 Limitations

There are some limitations to this thesis, foremost there are no longitudinal studies included in the empirical material, although there could be some longitudinal effects detected in the literature, otherwise, the articles just represent a snippet of time when the studies were conducted. Much has happened since the data was collected, the war in Ukraine, an economic slowdown with high inflation, and less production of housing. It is of course unclear how this will evolve, but it one thing is for sure, it will slow down the housing market in Sweden. The generalisability of the thesis could also be scrutinised although rigour has been accounted for. The data were not random and the interviewees were picked out and not all who were asked wanted or could participate. Albeit the three articles together paint a picture together of the development of the market and give a worthy picture of where the market is heading.

6. Conclusions and future studies

In this chapter the conclusions and answers to the research questions are given.

6.1 Conclusions

The aim of this thesis was to explore conditions for market development in wooden multi-storey construction. To fulfil the aim, four research questions were answered. The questions were the following and are answered one by one.

- What are the hindering factors for WMC market development?

In this thesis, a number of hindering factors have been found, foremost the path dependence of concrete and the inexperience of using wood in building residential multi-storey constructions. The path dependency can be different things, such as inexperience by the municipal officials and inert processes customised for concrete and not for wood such as zoning plans and finding the right competence in the market.

- What are the enabling factors for WMC market development?

The enabling factors for the WMC market development are the prefabrication rate of WMC, which increases material efficiency, resulting in lower costs and faster installation on site. Wood is also seen to bring benefits, foremost among architects and wood manufacturing companies, but also among end-consumers, although not enough to push the development

further and faster. Changes in the law is also seen as an enabling factor for the WMC market but the results of these changes still lie in the future.

- How do consumers in Sweden perceive the bioeconomy and, more specifically, the WMC as a solution to lower the climate impact in Sweden?

There is some social acceptance of WMC and the bioeconomy among the studied end-consumers. There was, however, disagreement in the group of end-consumers regarding whether the development would benefit the large companies or the rural areas. A majority of the end-consumers saw clear benefits, both social and economic, with FBB and WMC as well as climate benefits compared to concrete and steel buildings. However, the end-consumers also saw problems with WMC such as causing deforestation and biodiversity loss. It is, nevertheless, also clear that the social acceptance and perceptions of the end-consumers are not the primary reason why WMC and FBB are not more widely adopted in today's society, but rather path dependency and interconnectedness within the socio-technical regime.

- How do Swedish professionals in the wooden multi-storey sector perceive the co-creation of value aspect in their work when building and projecting houses?

Co-creation of value can be created in different ways in the WMC market. Most of the co-creation of value is quite naturally between the municipality and private public partnerships, and the end-consumer is most often left outside the co-creation of value, and is connected to the process in the end when to selling-buying process starts. Although there are exceptions with, for example, when the house built is a building association, the co-creation with the end-consumers is high since the end-consumers take on the role as developer to save money and own the process. The professionals also see the co-creation of value with other builders and municipalities as important to drive the market forward, but often it is not the material wood that is important but rather processes, logistics and social sustainability actions. The builders and manufacturers do not see the wood as a sole key for co-creation of value with the customer but rather just as a building material, and their building material just happens to be wood, since it is either good for pre-

fabrication or their customers ask for it. The end-consumer, on the other hand, is not in the loop of choosing material if it is not a building association that is building a new house.

To summarise, the path dependency is still strong and the WMC market is still an underdog in the greater Swedish building market among professionals, regular end-consumers and municipalities' minds. The professionals do not see wood as a unique selling point but rather consider what can be done with wood in a pre-fabrication milieu. There are exceptional projects where the end-consumers have a high impact on the co-creation of value and insight into the building process. These exceptions seem to be a niche themselves and more work from the end-consumers are needed, although they can steer and co-create value together with the building company and not be completely in the hands of a contractor. Although, in the classic case of residential multi-storey buildings, there is low co-creation together with the end-consumer and the market development is focused on incremental growth.

6.2 Future studies

It is clear that there is more research needed in the field and that there are blank dots in the market where no research has been performed, foremost in the consumer sphere, where almost no research has been performed. The end-consumer role seems to be of low importance in the building process and will probably still be in a society where there is a high housing shortage. However, how the end-consumer role changes in a co-building group compared to a regular rental or housing co-operation would be of interest to both municipalities and building companies, from both a public private partnership perspective and the co-creation of value.

All the research in this thesis should also be put in a time perspective, and longitudinal studies are needed to draw larger conclusions concerning the data. Among the professionals and end-consumers, future studies are needed after the implementation of the law of climate declarations, as well as follow up after the climate impact limiting laws planned for 2027 or earlier. Longitudinal studies could investigate if the laws had any impact on the WMC market and the view on wood, both in a co-creation of value aspect

and regarding the social acceptance of wood as a building material among end-consumers and professionals.

6.3 Recommendations

In accordance with the conclusions, some recommendations are presented. The municipal importance in the WMC sector should not be foreseen and is probably the most important actor in the co-creation of value. To speed up the WMC market development more public private partnerships can be implemented. Some suggestions are more architectural competitions with an emphasis on climate friendliness, and different types of land allocation agreements where the end-consumers are more directly involved in the building process *e.g.,* Co-building groups.

For the enterprises, more focus should be put on the material wood. Allocating marketing resources and tweaking their business models to be more sustainable could help the market development. To show that they can meet the new regulations or already are in line with the new regulations to come. Wooden enterprises have an advantage in the new regulations but cannot and should not sit still and wait for the new regulations, but rather be proactive and show why it is good to build with wood. Both for *e.g.* end-consumers and municipalities, since other actors in the market also will show their new climate friendly products and try to supress the up-and-coming WMC market.

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Popular science summary

Climate change is evident in Sweden and the world. In order to reduce climate change, reduced emissions of greenhouse gases are required. The construction and property sector accounts for approximately 15% of all emissions of greenhouse gases in Sweden. The emissions of greenhouse gases are mainly linked to the manufacture of materials, mainly cement, which is a part of concrete, and steel, which is often used as reinforcement in concrete. Other activities linked to the environmental load in the construction industry are heating, transport, and imported goods. An increased use of wood in construction is a way of reducing the environmental burdens from the construction sector since wood binds carbon and thus causes less emissions of greenhouse gases. One application where wood has proven to be suitable is in residential buildings of three stories or more. But what does the market for multi-storey buildings with wooden frames look like and how is it developing? What is required for it to develop further? In this study, the market development of multi-storey buildings with wooden frames has been studied in three sub-studies, by examining the scientific literature connected to the subject, the attitude of end consumers towards multi-storey construction in wood and forest-based bioeconomy, as well as the view of industry representatives on the challenges of wood construction and the cooperation with municipalities, and end consumers.

The results of this study show that there are obstacles for the wooden multi-storey construction market to develop and grow more. The largest obstacle found was the fact that it was illegal for a long time to build three stories or more in wood, and the building code practically only allowed construction in concrete for a long time. This means that sunk investments were made in a system that was adapted to technical solutions for concrete. Knowledge of less common materials in the construction industry is low and

this creates an obstacle using materials such as wood that have been widely used. Enabling factors for a more developed and growing market for wooden high-rise buildings include the prefabrication of building components and houses in a factory environment as well as perceived sustainability and climate benefits of wooden houses. Factors that favour wooden construction can also include sustainability requirements and the values of end-consumers. The studied end-consumers attitude towards high-rise wooden buildings was mostly positive and they see advantages in building with wood, foremost the climate benefits. There is, however, a concern that the wood raw material will not be enough and that there are risks connected to biodiversity. Professional actors in the construction market in the study are primarily focused on solving technical challenges and streamlining the construction process and have limited contact with those who will live in the buildings. The production focus of house producers can, however, be contrasted with a few projects built by co-building groups, where end-consumers themselves plan and carry out the house construction and are characterised by cooperation based on a customer need. The study also shows that wood itself was not used for marketing purposes, instead, the short construction time and the advantages of prefabrication are highlighted as a unique competitive advantage over concrete.

Overall, this study shows an industry that is gradually adapting to sustainability requirements and changing business models. Creating new methods and building new paths for how houses are built and what materials are used takes time. However, there are some things that will be able to speed up the use of wood in high-rise buildings, and these are foremost new legal requirements for climate declarations and upcoming limit values for climate impact for new houses in Sweden. Suggestions for measures that can speed up development are more cooperation between the actors and for the municipalities to enable wooden house projects through, for example, land specifications and architectural competitions.

Populärvetenskaplig sammanfattning

Klimatförändringarna är påtagliga i Sverige och världen. För att minska klimatförändringarna krävs minskade utsläpp av växthusgaser. Bygg- och fastighetsbranschen står ca 15% av alla utsläpp av växthusgaser i Sverige. Utsläppen av växthusgaser är främst kopplade till tillverkning av material, främst cement, som är en del i betong, och stål som ofta används som armering i betong. Andra miljöbelastningar som är kopplade till byggbranschen är, uppvärmning, transporter och importerade varor. En ökad träanvändning i byggandet är ett sätt att minska miljöbelastningarna från byggsektorn eftersom trä binder kol och därmed orsakar mindre emissioner av växthusgaser. En applikation där trä har visat sig vara lämplig är i bostadshus som är tre våningar eller mer. Men hur ser marknaden för flervåningshus med stomme av trä ut och hur utvecklas den? Vad krävs för att den skall utvecklas mer? I denna studie har marknadsutvecklingen av flervåningshus med trästommar studerats i delstudier, genom att undersöka den vetenskapliga litteraturen kopplad till ämnet, slutkonsumenters inställning till höghus i trä och skogsbaserad bioekonomi samt branschföreträdares syn på träbyggandets utmaningar och på samarbetet med kommun, och slutkonsumenter.

Resultaten i denna studie visar på att det föreligger hinder för att marknaden för flerfamiljshus med trästomme skall kunna utvecklas och växa mer. Det största hindret är att det länge var olagligt att bygga i trä mer än tre våningar, och byggnormen tillät praktiskt taget bara byggande i betong. Det innebär att historiska icke-återinvesteringsbara investeringar är gjorda i ett system som är anpassat till tekniska lösningar för betong. Kunskapen om mindre vanliga material i byggbranschen är låg och det skapar ett hinder för att använda sig av material så som trä som inte har använts. Möjliggörande faktorer för en mer utvecklad och växande marknad för höghus i trä omfattar

prefabricering av byggdelar och hus i fabriksmiljö samt upplevda hållbarhets och klimatfördelar i trähus. Till faktorer som gynnar träbyggande kan även inräknas hållbarhetskrav och slutkonsumenters värderingar. De studerade slutkonsumenternas inställning till höghus i trä var för det mesta positiv och de ser fördelar med att bygga i trä, framför allt klimatfördelarna. Det finns dock en oro för att träråvaran inte skall räcka till och att det finns risker för biologisk mångfald. Professionella aktörer på byggmarknaden i studien är i första hand inriktade på att lösa tekniska utmaningar och effektivisera processen i byggandet och har begränsad kontakt med dem som skall bo i husen. Produktionsfokuseringen hos husproducenter kan dock ställas i kontrast till ett fåtal projekt som byggts av en *byggemenskap*, där slutkonsumenter själva planerar och genomför ett husbygge som är präglat av samarbete utifrån ett kundbehov. Studien visar också på att trä inte använts i markandsföringssyfte utan snarare har kort byggtid och prefabriceringens fördelar lyfts fram som unik konkurrensfördel gentemot betong.

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In the year of grace 2023 the 26th of April.

Sincerely,

Emil Nagy

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Wooden multi-storey construction market development – systematic literature review within a global scope with insights on the Nordic region

Jussila J., Nagy E., Lähtinen K., Hurmekoski E., Häyrinen L., Mark-Herbert C., Roos A., Toivonen R., Toppinen A. (2022). Wooden multi-storey construction market development – systematic literature review within a global scope with insights on the Nordic region. Silva Fennica vol. 56 no. 1 article id 10609. 24 p. https://doi.org/10.14214/sf.10609

Highlights

- Enabling factors for WMC market diffusion include benefits from cost-efficiency gains from prefabrication and industrialization and perceived sustainability benefits.
- Inexperience of using wood, and path dependencies to use concrete and steel in multi-storey building are the key barriers for mainstreaming WMC market development.
- More research is needed on the development in the wood construction value-chains to challenge the dominant concrete-based construction regime in the housing markets.

Abstract

Climate change sets high pressures on the construction industry to decrease greenhouse gas emissions. Due to the carbon storage properties and potential to use renewable resources efficiently, wooden multi-storey construction (WMC) is an interesting alternative for the construction industry to enhance sustainable development combined with the aesthetic and well-being benefits of wood perceived among many consumers. For forest industry firms, industrial wood construction is a possibility to seek for business opportunities and bring socio-economic benefits for local economies. Despite positive drivers, WMC still remains a niche even in the forest-rich countries.The purpose of our study is to add understanding on the WMC market development by conducting a systematic literature analysis on international peer-reviewed studies from the past 20 years. Our special focus is on the role of WMC in the housing markets studied from the perspectives of the demand, supply and local governance factors. As specific aims, we 1) synthesize the key barriers and enabling factors for the WMC market growth; 2) identify the actors addressed in the existing studies connected to the WMC market development, and 3) summarize research methods and analytical approaches used in the previous studies. As a systematic method to make literature searches in Web of Science and Scopus for years 2000–2020, we employed PRISMA guidelines. By using pre-determined keywords, our searches resulted in a sample of 696 articles, of which 42 full articles were after selection procedure included in-depth content analysis. Our results showed cost-efficiency gains from industrialized prefabrication and perceived sustainability benefits by consumers and architects enabled a WMC market diffusion. The lack of experiences on the WMC, and path dependencies to use concrete and steel continue to be key barriers for increased WMC. Although our research scope was the global WMC market development, most of the literature concerned the Nordic region. The key actors covered in the literature were businesses (e.g., contractors, manufacturers and architects) involved in the wood construction value-chains, while residents and actors in the local governance were seldomly addressed. Currently, case stud-

ies, the use of qualitative data sets and focus on the Nordic region dominate the literature. This hinders the generalizability of findings in different regional contexts. In the future, more research is needed on how sustainability-driven wood construction value-chains are successfully shaping up in different geographical regions, and how they could challenge the dominant concrete-based construction regime.

Keywords construction industry; consumer; forest-wood value-chain; municipality; sustainability; urbanization
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1 Introduction

Climate change, as the most pressing global problem facing humanity, calls for a sustainable change towards adoption of low-carbon solutions in the emission intensive construction industry, for example, in relation to UN Sustainable Development Goals (SDGs) (Ogunmakinde et al. 2022). Since wood is a renewable material with relatively low embodied fossil carbon, timber structures have beneficial climate impacts compared to other construction materials (Geng et al. 2017; Hafner and Schäfer 2017; Hildebrand et al. 2017; Peñaloza et al. 2016). Building with wood has strong traditions all over the world, and prefabrication of modules is broadly used in the detached housing sector (DeAraujo 2021; Jussila and Lähtinen 2020). Contrastingly, wooden multi-storey construction (WMC) is still in the niche also in the forest-rich regions, although it has strong potential to enhance sustainability in urban housing and development of circular bioeconomy in cities (Toppinen et al. 2019a; Lähtinen et al. 2021).

Prefabrication and industrialization of the building processes has been emphasized in the construction industry especially in the 2000s (Jonsson and Rudberg 2014). At the same time, engineered wood products have entered in the markets to substitute concrete and steel, for example, in the load-bearing structures of multi-storey buildings (Schuler et al. 2001; Tettey et al. 2019). The rise of engineered wood products combined with updated building codes on fire protection have enabled the recent increase in wood use in Europe and building taller wooden buildings than before (Hildebrandt et al. 2017). This growing interest towards WMC may also be attributed to low costs, rapid construction phase, and perceived aesthetic and natural qualities of wood (Gold and Rubik 2009; Gosselin et al. 2017; Viholainen et al. 2021b).

Adoption of WMC technologies has gradually advanced through technical innovations (Lindgren 2017; Lazarevic et al. 2020). As previous research and experience from various countries indicate, the established modes of operating in multi-storey construction favor concrete as the framing material due to path-dependencies (e.g., established standards, regulation, construction culture) (Kadefors 1995; Hemström et al. 2017; Mark-Herbert et al. 2019). These path dependencies derived from the concrete-based industries have caused lock-ins, such as reliance on the existing traditions in the implementation of business models and management of risks that have slowed down the uptake of industrial wood building technologies (Nordin et al. 2010; Riala and Ilola 2014; Vihemäki et al. 2019). Yet, as construction is usually a domestic field of business and significantly affected by local governance, considerable variations may occur in the pace of WMC market development within individual countries (Hemström et al. 2017; Lähtinen et al. 2019a; Vihemäki et al. 2019).

The expectations for the market diffusion of the WMC in the context of housing markets relates to the global urbanization development (Dangel 2017). At the same time, societal pressures increase the need to develop and scale up building solutions that can better respond to social, economic and environmental sustainability goals, including the global climate change challenge (Lindblad and Schaurte 2017; Mark-Herbert et al. 2019; Vihemäki et al. 2019). For example, through linkages with the UN Sustainable Development goals (in particular SDG11 (Sustainable cities and communities), SDG12 (Responsible consumption) and SDG13 (Climate action) (https://sdgs.un.org/goals), construction industry and housing markets are linked with global policies and actions (Wolf et al. 2017).

Over time, customers, industries and other actors can co-create both user value and thereby promote the development of climate neutral municipalities (Edmondson 2018), provided that changes in legislation, political programs and education will effectively enhance the use of wood in multi-story construction (Toppinen et al. 2019a). For example, through collaboration, business actors (e.g., construction industries) and customers (e.g., future residents) can enhance knowledge accumulation and development of building processes for value increase and desirability of WMC (Lähtinen et al. 2022). Similarly, actors responsible for local governance mechanisms in municipalities can support uptake of building solutions with environmental benefits (Lähtinen et al. 2019a).

Overall, regarding the future market development, the prospects for WMC appear positive, based on the technological development of engineered wood products, modular building solutions, and increasing interest among professionals (architects, engineers and planners) all around the world (Dangel 2017). In addition, for example in the Nordic region, owner-occupancy plays an important role in the housing markets either in the form of owning a detached house or, owning a share of a housing company or being a member of a housing co-operative (Andersson et al. 2007). Due to this, residents' perceptions and value orientations on the role of sustainability, including the expected climate benefits, is critical for the market share development of WMC (Lähtinen et al. 2021). Abreast with the need to increase value in housing through communication with future residents, for example, on the load-bearing material choices in multi-storey construction (Lähtinen et al. 2022), consumers may also contribute to the fulfillment of sustainable construction initiatives during the life-cycles of the buildings (Ogumankinde et al. 2022). In addition, from the perspective of fulfillment of sustainable urbanization aims, e.g., SDG11, knowledge on demand factors in the housing markets is important (Wolff et al. 2017). In parallel, the potential of the WMC industry to produce solutions meeting these user expectations and criteria is fundamental for unlocking the growth potential of this niche field of construction (Toppinen et al. 2018).

A number of studies have been introduced in recent years addressing factors influencing the emergence of WMC (Gosselin et al. 2017; Hemström et al. 2017; Hurmekoski et al. 2018). Yet, the state of the art in the literature as a whole remains largely unmapped. The few existing systematic reviews have focused on the literature regarding sustainability in the residential construction in general (Lima et al. 2021). In those studies, it has been found out that social and economic aspects are less frequently addressed in comparison to environmental sustainability, and that wood material appears as a small but central node in the research from building materials perspective. However, evidence exist that, for example, in interior use wood connects with perceived psychologic human well-being effects (Rice et al. 2006; Nyrud and Bringlinsmark 2010). Other reviews like de Carvalho et al. (2017) have mapped integration of lean technology over a building's life-cycle without including aspects arising from the usage of renewable building materials, nor the ones connected to social science perspectives.

Considering the positive growth prospects in WMC market, there is a need to better understand how businesses involved in WMC are developing their strategies towards sustainability and

municipal carbon neutrality goals. In addition, information is needed how these connect to end-user needs, and how the actors can better engage in these processes with other actors, in particular with local municipalities. Better knowledge on these matters and about the roles of key actors, will enable WMC businesses to craft localized and collaborative strategies that would result in better value creation.

The interplay of producers, consumers, and regulators is also a key theme for this study, as the markets with unclear growth prospects often face a chicken-egg problem of producers having to invest in new production capacity without prospective customers, and consumers not being able to buy apartments when there is no supply. Related to that, little is known about how key actors in local wood construction – customers, local policymakers and builders – jointly contribute to sustainable construction and increased user value. Elements hereof involve sustainability and climate considerations (i.e., carbon stock and substitution effects) in the consumers' decision making.

This paper thus aims to delimit the knowledge-gap by synthesizing the current scientific literature on the factors related to WMC demand, supply and local-level governance that affect the circumstances in the housing markets. As a result of our analysis, we summarize and conceptualize the challenges of WMC market development and identify aspects, which requires to be addressed in future studies to establish new research agenda, as called by Zhang et al. (2019).

The first aim of our study is to synthesize the key barriers and enabling factors for the WMC market growth addressed in international peer-reviewed studies in 2000–2020. As the second aim, we identify the actors, who have been addressed in this literature to have a key role to affect the WMC market development. Third, we synthesize the types of research methods and analytical approaches used to study the themes related to the WMC market development and actor roles. Finally, based on the results, we present implications for future research needs. The past 20 years have been characterized both by the increasing emphasis in the construction industry for industrialization (Jonsson and Rudberg 2014) and development of wood-based solutions to substitute concrete and other fossil-based building materials also in multi-storey buildings (Schuler et al. 2001). Thus, by evaluating the state of the art in the WMC literature published in that period, we contribute to the understanding of dynamics of systemic change in the construction industry towards more sustainable practices in the housing markets. By doing this, we will gain not only an improved scientific understanding on the state of the art, and the related gaps in the knowledge, but the study will also will contribute with new insights how WMC industry could be revitalized or become more sustainable and competitive. The study is mainly focusing on market behavior, interaction and strategies by WMC actors. It does not explore in depth roles of international and national policies. This is a separate issue that merits a study on its own.

2 Analytical framework of the study to assess the potential for WMC market development

In the construction industry business environment and housing markets, socio-economic changes (e.g., increase of income and wealth) have diversified consumer demand (Gibler and Tyvimaa 2014). As a result of this, but also due to the need to enhance the efficiency and sustainability of the construction industry, expectations towards the businesses and other actors acting as suppliers of homes to make changes in their dominating practices have increased (ONeill and Gibbs 2014; Jussila and Lähtinen 2020). Changing sustainability practices do not only relate to businesses, but also concern needs and views of other stakeholders (e.g., authorities, consumers), who are involved in building processes or use of buildings (Ogunmakinde et al. 2022).

These needs for business changes do not concern specifically WMC, but all types of building processes in the global construction industry markets (Holt 2013; Jonsson and Rudberg 2014). For example, abreast with the need for more sustainable and resource-efficient use of materials, business development through evolvement of business ecosystems has been emphasized to bring new opportunities for the construction industry (Pulkka et al. 2016). As a result, it has been shown that positive impacts on value creation can be achieved through deepening collaboration, which extends beyond traditional transaction-based project-level subcontracting (Toppinen et al. 2019b). In the business ecosystems, actors involved in production, exchange and consumption spheres connect with each other, for example, through communication that enhances possibilities for value co-creation (Pulkka et al. 2016, Toppinen et al. 2019b).

For WMC, communication between companies, local governance actors (e.g., urban planners) and future residents within business ecosystems may enhance accumulation of know-how, which supports future business development possibilities (Toppinen et al. 2019b; Lähtinen 2022). In addition, communication with actors enables the sector to overcome prejudices against building with wood connecting, for example, deficiencies in the knowledge on fire safety and technological durability of wooden materials in multi-storey houses (e.g., load-bearing structures) (Lähtinen et al. 2021).

Production, consumption and exchange patterns in the housing markets may be illustrated with Structures of Housing Provision (SHP) framework (Ball and Harloe 1992; Ball 1998; Burke and Hulse 2010) (Fig. 1). According to SHP, supply and demand in the housing markets are dependent on geographic circumstances at specific points of time reflecting in spheres of consumption, production and exchange. In the context of Nordic countries, for example, traditions in building with wood and home ownership structures affect how especially WMC housing markets evolve (Lähtinen et al. 2021). In relation to sustainable urbanization and fulfillment of the UN Sustainable Development Goals, knowledge on housing markets as a system is needed instead of focusing merely on technological aspects of products and processes (Wolff et al. 2017).

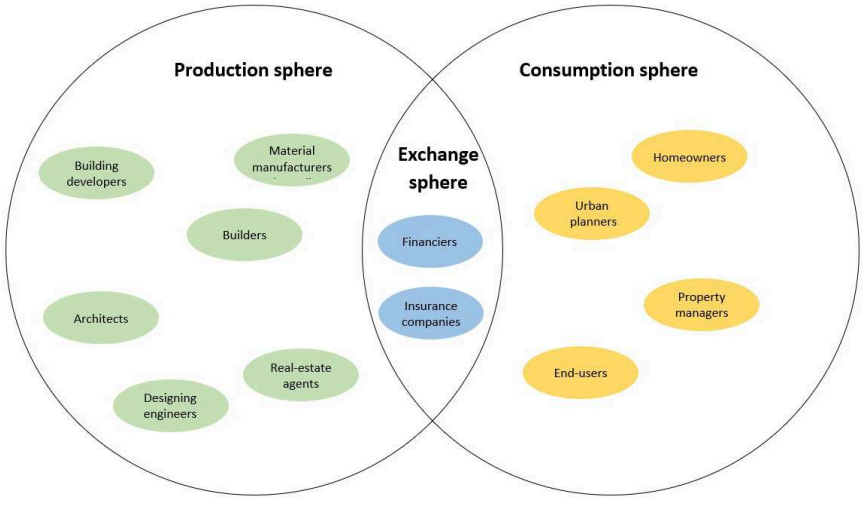

Fig. 1. Actors connected to structures of housing provision (SHP) with potential to affect WMC market development.

The consumer sphere describes housing values, which are reflected in consumer preferences and processes to rent, purchase and choose homes. In the context of WMC, those preferences and processes are connected with path dependencies, for example, in the ownership structures in the housing stock in specific regions and perceptions of consumers, for example, on WMC (Lähtinen et al. 2022). In comparison, supply structures in production sphere comprise business choices and capabilities of businesses involved in the construction value-chains (e.g., suppliers of building solutions) (Stehn et al. 2002), and decisions of public authorities to zone land for building and give associated regulations (Lähtinen et al. 2019a).

Abreast with companies involved in WMC value-chains and consumers renting or purchasing homes, local, municipal authorities have an impact on the development of WMC markets, and the achievement of sustainable urbanization goals. For instance, land zoning decisions and practices to grant building permits within municipalities (Lähtinen et al. 2019b; Jussila and Lähtinen 2020) affect the possibilities of companies to develop neighborhoods that can be perceived as attractive ones among residents. In line with this, local cultures to work with specific building material traditions can play a decisive role in WMC market development (Høibø et al. 2015, 2018). In the Nordic countries, especially in Finland and Sweden, municipalities have strong power in the land use governance (Mäntysalo et al. 2011), and thus their governance mechanisms are key for the prospects of wood construction.

Finally, abreast with businesses and public actors (e.g., municipalities) operating in production sphere and consumers in consumption sphere, financial institutions governing monetary instruments belong to the system of housing markets. In the context of the SHP framework, they operate in exchange sphere, that enable renting, selling and use of homes in the markets through governance of monetary instruments (Ball 2003; Burke and Hulse 2010). In practice, as funders of actors in production and consumption spheres, actors in exchange sphere enable both implementation of operations in the housing markets (e.g., building and purchasing homes), but also managing of different types of risks through assignment of insurances.

According to SHP, housing markets are a system of actors, who in multiple ways are connected to each other (Burke 2012). By evaluating WMC market development through SHP spheres, it is possible to gain a comprehensive understanding of how different actors (e.g., home purchasers and renters, building developers and builders, public authorities and urban planners) affect the potential for sustainable urbanization in reference to housing market mechanisms. Furthermore, employment of SHP also enables identifying how other actors (e.g., interest organizations, non-governmental organizations, research institutions and universities, politicians, or legislators) also belonging to the WMC business ecosystems (Lähtinen et al. 2022) have been addressed in previous studies on WMC. The analytical framework of our study to identify the enabling factors and barriers for WMC market development in relation to production, consumption and exchange spheres, and the actors involved are presented in Fig. 1.

3 Materials and methods

The data of the study are based on international peer-reviewed studies (herewith referred as peer-reviewed articles) published in 2000–2020. Searches were carried out in two databases (Scopus and Web of Science) by using predetermined search words for titles, abstracts, and keywords. The predetermined keywords were defined based on existing information received from literature employed, for example, in the empirical background of this study. Prior to implementation of the literature searches, the applicability and formulation of the keywords (e.g., use of hyphens, compound words) were tested by the research group members in three consecutive workshops. This

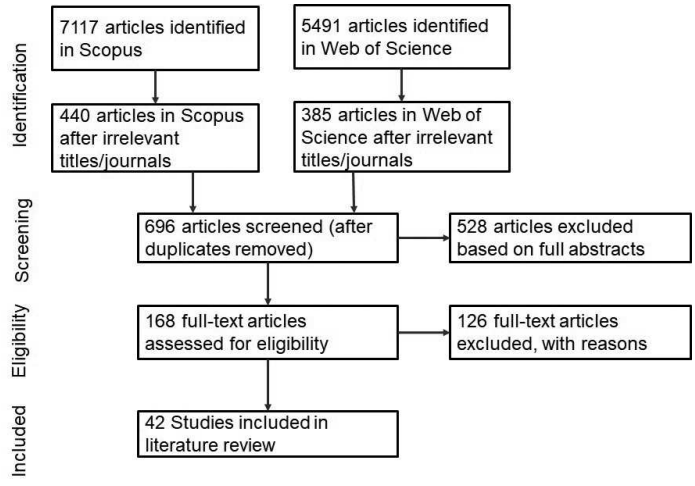

Fig. 2. Literature review process applied in the study (see PRISMA-method, e.g., Moher et al. 2019).

was done to enhance the validity (i.e., no exclusion of relevant literature, exclusion of literature entirely from different fields of research) of the material to be found.

As a method of analysis, a systematic literature approach was employed, since it is a transparent, rigorous, and detailed methodology used to support decision making (Tranfield et al. 2003). The method may also be used to build theory by accumulating knowledge and evidence after analyzing large number of studies and methods, thereby increasing the consistency of the results and the conclusions (Akobeng, 2005; Denicol et al. 2020). This study follows the PRISMA guidelines by Moher et al. (2009), and our systematic literature review was performed in four stages (Fig. 2). Details of the initial search phrases, methods and exclusion criteria are shown in Supplementary file S1, available at https://doi.org/10.14214/sf.10609.

The first phase of the literature review process comprised general identification of the literature. As an outcome of the database searches executed at the identification phase, 7117 document results were received in Scopus and 5491 in Web of Science, respectively. After exclusion of irrelevant journals and titles, a total number of 825 peer-reviewed articles remained for further screening (440 in Scopus and 385 in Web of Science). At this phase also duplicates were removed from the search results, which resulted in a total number of 696 peer-reviewed articles.

The second phase of the literature review was composed of screening of the 696 articles conducted by the research team as a case-by-case evaluation. In this phase, a total of 528 articles were excluded based on full abstract reading using preliminary addressed exclusion criteria. The list of excluded studies consisted of peer-reviewed articles, which were not addressing wood construction or had strictly technical focus (i.e., no information to add knowledge on WMC market development). After the screening phase, altogether 168 studies were left for further consideration at the eligibility phase.

The third phase, i.e., eligibility assessment, included full-text reading of the 168 peer-reviewed articles. In the beginning of the eligibility assessment phase, each article was read independently by two researchers. After this, the research group members discussed the evaluation results together to strengthen the validity of the results. As an outcome of the eligibility assessment phase, a total number of 126 peer-reviewed articles were excluded from further reading.

The excluded studies were not addressing multi-storey buildings, were not focusing on the market development perspectives, or were focusing on other types of houses than residential buildings. In addition, some peer-reviewed articles were excluded due to their unavailability in an electronic format. Furthermore, a few articles were found to be published in non-peer-reviewed journals and therefore excluded. After the eligibility assessment, a total number of 42 peer-reviewed articles were included in the initial material of this study.

As the final phase of the literature review, all 42 peer-reviewed articles were analyzed in depth. The first focus of this stage of the analysis was to categorize the contents of the materials into the themes of enabling factors and barriers, which affect the potential for WMC market development. As an analytical framework to link the results with the housing markets, SHP framework was employed. The categorization process also included identification of the key actors, who had been addressed in the peer-reviewed articles as parties with some kinds of roles in the WMC market development. At this phase, also the research methods and analytical approaches used in the 42 studies were evaluated to add knowledge on by what approaches the WMC market demand development had been addressed in the previous studies. By doing this, it was possible to add, for example, understanding on what types of methodological and analytical development would be needed in the academic research to provide new information on the WMC in the context of housing markets in the future.

4 Results

The general outcome of the analysis shows that the number of published peer-reviewed articles on WMC has increased especially after 2017 (Fig. 3). This is an indication of an increasing interest among scholars on the WMC especially in the recent past. Yet, although literature searches comprised studies published since the early 2000s, all 42 studies passing the final eligibility assessment in the review process were released after 2006 (Fig. 3). This shows that despite the WMC has been

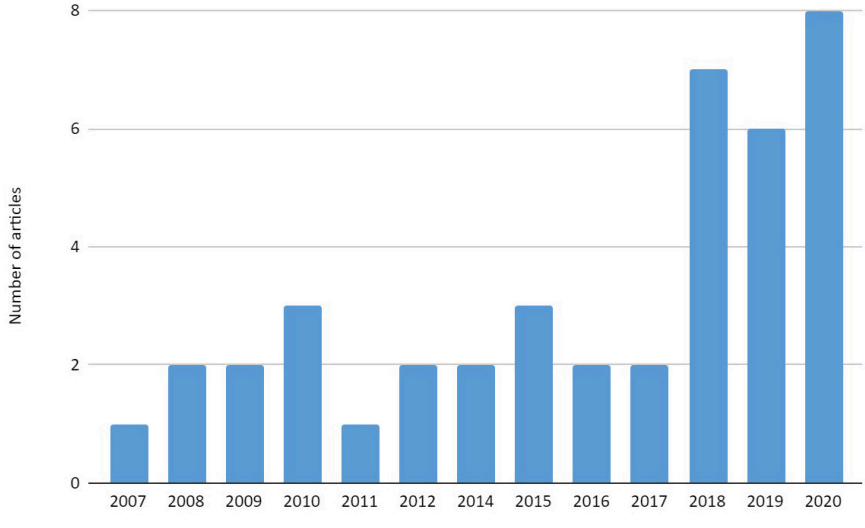

Fig. 3. Studies included in the literature review by publication year (total of 42 articles).

studied from different perspectives rather actively in the recent years, aspects connected to WMC market development in relation to views on demand, supply and local governance have gained much less attention among academics. This can also be perceived, for example, by comparing the number of publications found at the identification phase of the literature searches with the number of studies fulfilling the initial search criteria (Fig. 2).

The distribution of studies composing the final data of the study were published in 27 different journals, of which the most common ones were Wood Material Science and Engineering (5 studies, especially a special issue in 2019), Journal of Cleaner Production (4 studies) and Construction Management and Economics (4 studies). Regarding the geographical focus of the studies, the results of this study indicate that WMC market development research has been dominated by studies connected to the Nordic region. The empirical data in the final set of articles concerned Nordic countries (Finland, Sweden or Norway) in 37 out of 42 articles, while 8 articles covered also other geographical areas (e.g., US, UK and Central Europe).

In reference to SHP framework, our analysis showed that information in the literature addressed solely views linked with production and consumption spheres (Table 1). Contrastingly, no information related to exchange sphere existed in the 42 peer-reviewed articles employed as the material of this study, although, for example, financing significantly contributes to functionality of the housing market (Österling 2017; Jussila and Lähtinen 2020). Naturally, there are a myriad of policy drivers that are underlying the SHP framework although these could not be under our direct scrutiny, and some of the reviewed studies also addressed these (such as Tykkä et al. 2010, Hurmekoski et al. 2018, or Vihemäki et al. 2019).

As result of the categorization process to identify the themes affecting as enablers and/or barriers for the WMC market diffusion, eight general themes emerged in our literature review analysis. The eight themes were named as Sustainability in building, System development, Innovations, Business collaboration, Stakeholder awareness, Institutional changes, Urban planning, and Market demand. In all, Table 1 shows that the reviewed literature provided more nuanced understanding on production sphere enablers and barriers, while the availability of information on consumption sphere was considerably scarcer.

According to the detailed results on the enabling factors for WMC market development illustrated in Table 2, information on the possibilities was found for all other themes than Market demand. In general, aspects related to themes on the Sustainability in building, System development, Innovations, Stakeholder awareness, and Institutional changes was found to a higher extent than aspects on themes on Business collaboration and Urban planning. Business collaboration and Urban planning both relate to business ecosystems (Pulkka et al 2016), while the lack of information on the Market demand significantly shows the deficiencies linking the WMC with the broader housing market context (Burke and Hulse 2010).

Business ecosystems may significantly contribute to the construction industry development. Despite this, in the reviewed literature there were just few peer-reviewed articles addressing WMC market development through views on business collaboration. Related to this, also profound information on how different actors might contribute to WMC market development was largely lacking. In all, most of the studies addressed mainly element manufacturers, engineers, and construction companies as key actors in the WMC system. Yet, for instance, municipalities (e.g., urban planners and other civil servants) may contribute to WMC market development through their land zoning activities and accumulation of local know-how through their collaboration with local industries. Similarly, also future residents could add possibilities for the value co-creation in production sphere through their communication activities in the business ecosystems.

Table 3 shows the barriers, which in relation to production sphere were found to hinder WMC market development. As a difference to enabling factors, Sustainability in building was

Table 1. Categorization of the literature for themes of enablers (E) and barriers (B) for the WMC market development in connection production and consumption spheres within structures of housing provision.

		Production sphere								Consumption sphere							
Authors	Year	Sustain-ability in building	System develop-ment	Innova-tions	Business collabora-tion	Stake-holder awareness	Institu-tional changes	Urban planning	Market demand	Sustaina-bility in building	System develop-ment	Innova-tions	Business collabora-tion	Stake-holder awareness	Institu-tional changes	Urban planning	Market demand
Stehn and Bergström	2002		E/B														
Björnfot and Stehn	2007		E														
Sandberg et al.	2008		E	B													
Mahapatra and Gustavsson	2008		E/B		E	E	E										
Persson et al.	2009		E	B													
Bysheim and Nyrud	2009		B			E											
Tykkä et al.	2010	E	B	E			E										
Nordin et al.	2010		B	E													
Roos et al.	2010	E	E/B			B											
Hemström, et al.	2011	E	B				B		B								
Eriksson et al.	2012	E															
Mahapatra et al.	2012		E/B			E/B	E			E/B							
Brege et al.	2014		E	E					B								B
Riala and Ilola	2014		E/B	E		B											
Mallo and Espinoza	2015	E	B			B	B										
Hurmekoski et al.	2015		E/B			E/B	E/B										
Høibø et al.	2015									E				B		B	
Jones et al.	2016		B	E		E											
Hynynen	2016	E	B	E	B		E										B
Lindgren and Emmitt	2017	E	E	B			E										
Hemström et al.	2017		B			E											
Høibø et al.	2018															B	
Stern et al.	2018					E								B			
Gosselin et al.	2018		E/B	E	E	E	B										
Hurmekoski et al.	2018		B				E										
Franzini et al.	2018		E/B		B	B	B	E									
Toppinen et al.	2018						E							B			
Markström et al.	2018	E	E			E/B											
Toppinen et al.	2019				E/B												

Table 1 continued.

		Production sphere								Consumption sphere							
Authors	Year	Sustain-ability in building	System develop-ment	Innova-tions	Business collabora-tion	Stake-holder awareness	Institu-tional changes	Urban planning	Market demand	Sustaina-bility in building	System develop-ment	Innova-tions	Business collabora-tion	Stake-holder awareness	Institu-tional changes	Urban planning	Market demand
Lähtinen et al.	2019									E				B			
Vihemäki et al.	2019						E/B										
Lindblad	2019							B									
Toppinen et al.	2019				E/B	E											
Markström et al.	2019	E	E		B	E/B	E										
Riggio et al.	2020		B	E	E/B	B											
Pelli and Lähtinen	2020		E	B													
Peters et al.	2020		E	E		E	E										
Kylkilahti et al.	2020									E				E			
Viholainen et al.	2020									E/B							
Lindblad	2020							E/B									
Vihemäki et al.	2020				B	E	B										
Lazarevic et al.	2020		B				E/B										

Table 2. Categorization of the themes of enabling factors for the WMC market development in connection to production sphere within structures of housing provision.

Themes of production sphere enablers	Key role actors	Literature
Sustainability in building		
Low environmental impact; Aesthetic appeal; Carbon storage; Structural durability	Architects; Element manufacturers	Hynynen 2016; Hemstrom et al 2011; Mallo and Espinoza 2015; Roos et al. 2010; Markstrom et al. 2018; Markström et al. 2019; Tykkä et al. 2010; Lindgren and Emmitt 2017
System development		
Standardization; Industrialized production, Productivity; Technological development (e.g., IT tools); Low costs; Flexibility; Rapid construction	Construction companies; Element manufacturers	Sandberg et al.2008; Björnfot and Stehn 2007; Brege et al. 2014; Pelli and Lähtinen 2020; Peters et al. 2020; Stehn and Bergström 2002; Gosselin et al. 2018; Hurmekoski et al. 2015; Mahapatra amd Gustavsson 2008; Riala and Ilola 2014; Mahapatra et al. 2012; Roos et al. 2010; Markstrom et al. 2018; Markström et al. 2019; Tykkä et al. 2010; Persson et al. 2009; Franzini et al. 2018
Innovations		
New construction technologies; Prefabrication; Product innovations (e.g. CLT); System innovation (e.g. collaboration and integration of new solutions); Research collaboration	Construction companies; Engineers	Hynynen 2016; Riggio et al. 2020; Peters et al. 2020; Jones et al. 2018; Gosselin et al.2018; Nordin et al. 2010; Riala and Ilola 2014; Tykkä et al. 2010; Brege et al. 2014
Business collaboration		
Collaboration and co-operation between stakeholders; Communication and relationships in network	Product manufacturers; Engineers; Architects	Riggio et al. 2020; Gosselin et al. 2018; Toppinen et al. 2019a; Toppinen et al. 2019b
Stakeholder awareness		
High level of awareness of wood building systems and construction materials; Positive knowledge and experiences on use of wood; Promotional activities; Role of intermediaries; Resonance; Education and vocational training; Sustainability aspects (e.g., for marketing and branding)	Construction companies; Other stakeholders	Peters et al. 2020; Stern et al. 2018; Jones et al. 2018; Gosselin et al. 2018; Hurmekoski et al. 2015; Vihemäki et al. 2020; Bysheim and Nyrud 2009; Mahapatra et al. 2012; Hemström et al. 2017; Markström et al. 2019; Toppinen et al. 2019b
Institutional changes		
Policy measures and institutional frameworks; Law and regulation changes (e.g., Fire regulations, building regulations); Changes in building codes; Governmental support programs	Policymakers; Product manufacturers	Hynynen 2016; Peters et al. 2020; Hurmekoski et al. 2015; Hurmekoski et al. 2018; Vihemäki et al. 2019; Toppinen et al. 2018; Mahapatra et al. 2012; Tykkä et al. 2010; Lazarevic et al. 2020
Urban planning		
Improved transparency in the land allocation activity; Supporting local industries; Using locally sourced materials	Building developers; Municipal decision makers	Lindblad 2020; Franzini et al. 2018

Table 3. Categorization of the themes of barriers for WMC market development in production sphere within structures of housing provision.

Themes of production sphere barriers	Key role actors	Literature
System development		
Lock in effects: Path dependency (e.g., in concrete); Risk avoidance; High costs; Material availability; Lack of experience & education; Technical focus on construction	Construction companies; Architects	Jones et al. 2016: Mahapatra K., Gustavsson L. 2008; Hemström et al. 2017; Lazarevic et al. 2020; Nordin et al. 2010; Riala and Ilola 2014; Hurmekoski et al. 2018; Bysheim and Nyrud 2009; Tykkä et al. 2010; Mahapatra et al. 2012; Riggio et al. 2020; Mallo and Espinoza 2015; Hemström et al. 2011; Roos et al. 2010; Gosselin et al. 2018; Hurmekoski et al. 2015; Franzini et al. 2018; Hynynen 2016; Stehn et al. 2002
Innovations		
Inability to adapt changes; Recognition and tradition; Lack of requisites for efficient information management skills	Wood element manufacturers; Developers	Pelli and Lähtinen 2020; Lindgren and Emmitt 2017; Persson et al. 2009; Sandberg et al. 2008
Business collaboration		
Competitiveness of WMC (especially technical infrastructure); Multi-party environment, loose-couplings (lack of stable partnerships & collaboration); Limited number of industry actors; Mismatch in influence and material preferences among stakeholders; Conflict of interest; Lack of collaboration / co-operation; Fierce competition	Developers; Project actors; Other stakeholders	Toppinen et al. 2019a; Riggio et al. 2020; Franzini et al. 2018; Markström et al. 2019; Toppinen et al. 2019b; Hynynen 2016
Stakeholder awareness		
Lack of knowledge & information; Negative perceptions of product features (e.g., Fire performance, water control, durability concerns); Inadequate information distribution; Negative experience of wood products	Architects; Engineers; Construction companies; Municipal civil servants	Riala and Ilola 2014; Mahapatra et al. 2012; Riggio et al. 2020; Mallo and Espinoza 2015; Roos et al. 2010; Markström et al. 2018; Franzini et al. 2018; Markström et al. 2019
Institutional changes		
Institutional framework, lock-ins; Inefficient policy measures & processes; Building code compatibility	Municipal civil servants; Architects; Wooden building material producers	Lazarevic et al. 2020; Mallo and Espinoza 2015; Hemström et al. 2011; Gosselin et al. 2018; Vihemäki et al. 2020; Vihemäki et al. 2019; Franzini et al. 2018
Urban planning		
Discrepancies in perception of the land allocation process; Insufficient procurement processes for municipalities; Level of competence displayed by municipalities	Municipalities; Developers	Lindblad 2020; Lindblad 2021
Market demand		
Immature market, lack of pull effect, lack of consumer demand	Element manufacturers; Architects; Consumers	Brege et al. 2014; Hemström et al. 2011

Table 4. Categorization of the themes of enabling factors for WMC market development in connection with consumption sphere within structures of housing provision.

Themes of consumption sphere enablers	Key role actors	Literature
Sustainability in building		
Ecological, environmental values, natural material; Technical sustainability (e.g., usability and durability); Social sustainability (e.g., healthy, comfort, aesthetic)	Consumers, End users	Lähtinen et al. 2019b; Viholainen et al. 2020; Kylkilahti et al. 2020; Mahapatra et al. 2012; Høibø et al. 2015
Stakeholder awareness		
Ecological awareness	Consumers, End users	Kylkilahti et al. 2020

not addressed in any of the reviewed studies as a theme, which would comprise obstacles for the WMC. Instead, the barriers were identified in relation to all other seven themes, of which most were connected to System development (e.g., lack of knowledge and information, limited experience with building with wood) and Stakeholder awareness (e.g., negative perceptions of product features such as fire safety, water control, durability), and Business collaboration (e.g., lack of collaboration, lack of stable relationships). In addition, for example, in relation to Urban planning, discrepancies in actor perception of the land allocation process and deficiencies municipality capacities for public procurement processes were mentioned in the literature. Especially from the perspective of research on WMC market development potential it is worth of noticing that while information on the barriers were found for Market demand, such enablers were not addressed in the reviewed literature at all.

Compared to production sphere, information connected to consumption sphere especially on the enabling factors was almost non-existent in the reviewed literature. Like shown in Table 4, findings made on the enabling factors did not address any other themes than Sustainability in building, which were linked with views on ecological, technical and social sustainability benefits of wooden multi-storey houses. All other information on the potential of any other themes (e.g., Business collaboration, Stakeholder awareness) to affect positively WMC market development through consumption sphere was entirely lacking. In reference to issues arisen in the literature presented in the context of the analytical framework of this study, the gaps in information concerned, for example, insights on the possibilities of future residents to enhance value creation possibilities

Table 5. Categorization of the themes of barriers for WMC market development in connection with consumption sphere within structures of housing provision.

Themes of consumption sphere barriers	Key role actors	Literature
Sustainability in building		
Product features: Durability, robustness, stability, fire safety, acoustics; Higher maintenance; Resale value (UK)	Consumers; End users	Viholainen et al. 2020; Mahapatra et al. 2012
Stakeholder awareness		
Lack of awareness among end users; Prejudice against wood (material concerns, fire, moisture etc); Limited knowledge about building materials	Consumers; End users	Høibø et al. 2015; Lähtinen et al. 2019b; Stern et al. 2018; Toppinen et al. 2018
Urban planning		
(City) building material traditions	Consumers	Høibø et al. 2015 and 2018
Market demand		
Immature market, lack of pull effect; Lack of consumer demand	Consumers	Brege et al. 2014; Hynynen 2016; Hemström et al. 2011

through communication within business ecosystems (e.g., businesses and local governance actors).

Compared to enabling factors in consumption sphere, the number of identified barriers for WMC market development was considerably higher as presented in Table 5. They cover especially issues connected to the themes of Sustainability in building (e.g., especially product features) and Stakeholder awareness (e.g., limited knowledge on materials), but also to the themes of Urban planning (building traditions in cities), and Market development (e.g., lack of consumer demand). Similar to the results on the enabling factors consumption sphere, the only key actors identified in connections with the barriers in consumption sphere were the end users and residents. This also shows that in the existing research on WMC market development, both information on the linkages between consumption and production spheres, and possibilities of actors to affect the WMC marked development as stakeholders in the system is largely missing.

Fig. 4 summarizes the results on the linkages between the existing research information on the eight themes of enabling factors and barriers in relation to SHP. In the illustration, missing circles in consumption sphere (e.g., lack of circle on Market development) depict themes, which have not been addressed from that perspective in the reviewed literature. In themes, characteristics defined as enabling factors are marked with blue, while barriers are colored with red. As can be seen, from the perspective of housing markets, the focus of previous studies has been on the issues related to production sphere, while consumption sphere has gained considerably less attention. In addition, information on the issues connected to exchange sphere is according to our results currently non-existent. However, also information on issues connected to production sphere is also unbalanced and especially knowledge on Market demand is very narrow and linked dominantly with the identification of barriers instead of bringing a more balanced view on WMC market development potential.

Like described in the detailed results on the production and consumption spheres (Table 2, 3, 4, 5), also knowledge on the potential of actors to play key roles for WMC market development

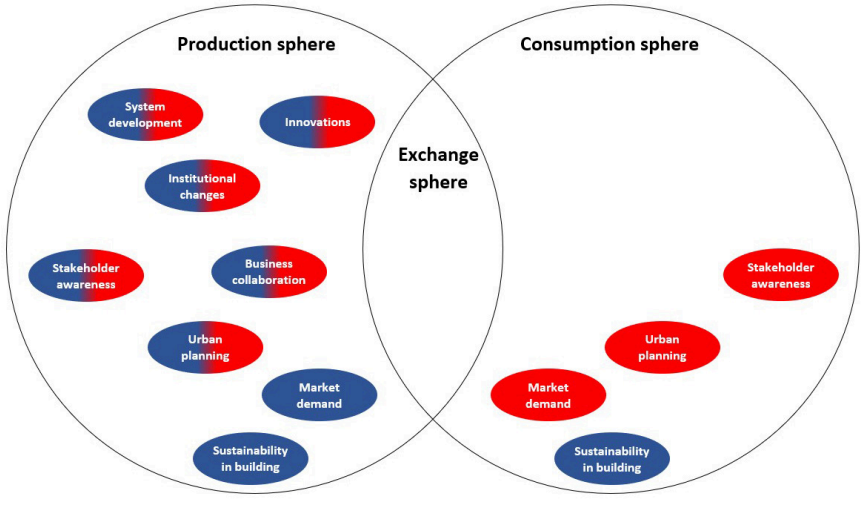

Fig. 4. Existing research information on the themes connected to the structures of housing provision. Enabling factors are denoted in the figure with blue, and barriers with red. Missing circles in exchange and consumption sphere illustrate lack of research information on those issues at the moment.

is limited and siloed. Regarding production sphere, the focus of research has been mainly on those value-chain actors, who are directly involved directly in the construction processes (i.e., product manufacturers, engineers, and construction companies). Contrastingly, the actors who could, for example, through business ecosystems enhance value co-creation (e.g., local-level governance actors or residents) have been largely by-passed in the existing research.

Regarding the third research aim on approaches used, of the 42 articles, 67% (n=28) articles used a qualitative approach, 24% (n=10) a quantitative approach and 9% (n=4) used a mixed approach. Among the articles that used qualitative approach the most used way to describe the study was to call it a case-study or a multiple case-study (n=16). Almost all the articles with a quantitative approach were described as a survey (n=9). In the case of data gathering method, the most commonly used method among the qualitative articles was interviews, which was used in 25 out of 28 articles, although only 14 of these articles relied solely with interview as a method to collect data. Other methods to collect data in the qualitative approaches were the use of focus groups, literature collection, secondary data collection, surveys and workshops. In the quantitative articles, nine out of 10 used a questionnaire/survey to collect the data.

5 Discussion

In this systematic literature review, we analyzed and synthesized the current scientific literature on the factors related to wooden multi-storey construction (WMC) demand, supply and local governance. Our specific aim was to synthesize the key barriers and enabling factors for WMC market development and identify the key actors mentioned in the WMC literature. In addition, we also summarized the types of research methods and analytical approaches used in the previous studies. As a method of analysis, we followed a PRISMA method.

Our results are based on 42 relevant peer-reviewed articles published in 2006–2020, while the volume of activity appeared to have increased in 2018–2020. Technological development towards industrialization in the construction industry and possibilities to use wood-based solutions in the multi-storey building started to gain increasing attention in the early 2000s (Schuler et al. 2001; Jonsson and Rudberg 2014). Our results indicate that research inputs on the WMC market development evolved after the phase of research focus on technological views on industrialization and wood building. Despite the increase in the number of peer-reviewed studies connected to WMC market development especially in the context of housing markets since 2006, international scientific research on theme is still very much in its' infancy.

Our results suggest that some of the key enablers include benefits arising from increased prefabrication, such as increased material efficiency in construction processes, resulting in lower material costs, and rapid installation (Persson et al. 2009; Roos et al. 2010; Markström et al. 2018). In addition, wood is perceived to bring benefits in the WMC, especially among wood manufacturing companies and architects (Nordin et al. 2010; Riggio et al. 2020; Peters et al. 2020), but this push is not sufficient to rapid acceleration of WMC business, at least not yet. As a barrier to system development, the lack of experience from using wood in multi-storey construction, and the path dependencies with concrete and steel construction continue to be the key hindrances for mainstreaming of the WMC (Mahapatra and Gustavsson 2008; Riala and Ilola 2014; Hemström et al. 2017). However, the demand side enablers and barriers remain a great unknown, due to a gap in research.

Although housing markets function as a system of production, consumption and exchange, our results show that the information on WMC market development is still under-developed. In reference to structures of housing production (SHP) (Burke and Hulse 2010), actors in exchange

sphere are important as intermediates in the housing markets (e.g., mortgages, insurances) (Österling 2017; Jussila and Lähtinen 2020), but according to our results no research has been made on their roles in the WMC market. In addition, literature on WMC market development has focused mostly on production sphere, while knowledge on consumption sphere is far more limited both regarding the themes and key actors to affect the changes in the construction industry systems. Furthermore, peer-reviewed article results addressing consumption sphere are geographically more limited than information on production sphere concerning mainly information on the Nordic region. Abreast with this, research on local governance mechanisms is also limited, drawing scattered evidence focusing on studies from only Sweden and Finland.

The key actors covered in the literature include businesses, for example, contractors, element manufacturers and architects, and the members of WMC business ecosystem, such as public authorities and residents. In addition, regarding business actors, most of the research information on companies connects directly to wood industries (e.g., manufacturers of modules). With construction industry being associated with a high degree of specialization, at local and project levels, future development would require a highly diverse set of actors and related skills to be incorporated in production sphere (Toppinen et al. 2019a). Small scale actors often have limited resources to uptake new technologies and acquire new skills. Possibilities to start to use new building systems and change business logics may be supported through collaboration activities (Brege et al. 2014), which enhance accumulation of special expertise and knowledge to build with wood also in as a part of project-driven business ecosystems (Viholainen et al. 2021a; Lähtinen et al. 2022).

From a methodological perspective, we can conclude that the literature is currently dominated by case studies and the use of qualitative data sets. This hinders the generalizability of findings in different regional contexts or across groups of different actors. A few surveys existing in the literature have been targeted to consumers and architects focusing mostly on the aspect to affect their demand and preferences for wood materials. To have broad understanding on the factors affecting WMC market development in different regional contexts, both qualitative and quantitative studies addressing views of multiple actors in relation to characteristics of housing markets would be needed.

In future studies, more in-depth information is needed on WMC market development. First, there is a need for more longitudinal research on the forms of collaboration with actors in the construction value-chains and emerging business ecosystems (e.g., actors related to exchange and consumption spheres in the system of housing provision). Research on municipal decision-making, land zoning, financing aspects and intermediaries involved in the housing markets were limited (see e.g., Vihemäki et al. 2020). Second, more information is also needed on how more open innovation culture between different actors could be enhanced to broaden the collaboration networks for value co-creation and accumulation of new skills. Third, there is a need to understand better factors enabling formation such forms of collaboration, which would better enable sharing the risks in WMC projects, since this topic was hardly touched upon in the sample. Fourth, studies could also explore ways to turn environmental performance into housing quality attributes through new construction industry practices. Finally, acknowledging better the versatile needs of end-users, for example in terms of modularity of housing, and flexibility in terms of changing uses over building life span, is still needed.

Implementation of a systematic literature review requires pre-determining the timespan and criteria for the material searches. Although the use of PRISMA framework adds transparency of the results, the method also has some limitations. Our literature searches were targeted in the timespan of 2000–2020. Due to that, it is possible that studies, which had been published earlier were not included in the initial material of this study. However, since the number of hits received at the identification phase of the literature review process was already considerably high (over 7000), it

would have not been feasible to have additional years included in the searches. In addition, since the research group made preliminary evaluations for the WMC literature, it was known that most of the studies addressing WMC market development had been published in the past two decades. Regarding selection of language, the systematic searches were targeted at peer-reviewed articles published in English in Web of Science and Scopus.

The research group would have had limited possibilities to read the articles also in several other languages. However, since English is the dominant language for peer-reviewed publishing, searches were implemented only in one language. This also added the conceptual coherency of the materials. Since the key words used were identified from previous literature connected to WMC market development, the research on building technologies and assessment of environmental impacts therefore were not in the scope of this study. Moreover, since we also explicitly wanted to focus on WMC, the larger body of literature around housing, especially the use of wood in single-family housing was omitted.

Our results show that information exists on how possibilities in production sphere, and more specifically, how issues connected to prefabrication and sustainability in building may contribute to WMC market development. Contrastingly, there is a critical gap of knowledge on the factors, which affect the demand of WMC homes (i.e., consumption sphere) in the housing markets. So far, the focus of research on WMC apartments has mostly been on their supply (i.e., production sphere) in the housing markets, while consumer expectations for WMC homes have gained considerably less of attention. In addition, information on the role of financial issues such as the role of mortgages and insurances (i.e., exchange sphere) affecting both supply and demand of homes is entirely lacking in relation to WMC market development.

As a conclusion of our study, there is momentum for the sustainability-driven forestry-wood construction value-chains to challenge the dominant concrete-based construction regime through WMC market development. However, to make a change in the construction industry, WMC must be viewed also in the context of the housing markets, not only through supply mechanisms mainly connected with technological benefits and cost-efficiency gains.

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Authors' contributions

Jaakko Jussila: Original idea of the article, planning and design of data gathering, formulation of the research questions, selection of the theoretical framework and design of the analysis, implementation of the analysis, interpretation of data and the results, scientific writing of the manuscript, finalization of the manuscript.

Emil Nagy: Planning and design of data gathering, selection of the theoretical framework and design of the analysis, implementation of the analysis, interpretation of data and the results, scientific writing of the article, finalization of the manuscript.

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Supplementary files

S1.pdf; Details of literature review process used in the article, available at https://doi.org/10.14214/sf.10609.

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Social Acceptance of Forest-Based Bioeconomy—Swedish Consumers' Perspectives on a Low Carbon Transition

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Abstract: The concept of the bioeconomy is associated with sustainable development changes and involves transitions in both production and consumption within systems. Many of these transitions relate to using renewable resources, like forest biomass, to meet basic needs, such as food, energy and housing. However, consumers must become aware of the forest-based bioeconomy so that they can contribute to the transition. This study aims to contribute to an understanding of this matter that may lead to social acceptance of the forest-based bioeconomy and, in particular, to Swedish consumer awareness of the concept and of a particular product (wooden multi-story buildings) representing the forest-based bioeconomy. The results show consumer awareness of forest sequestration capacity but less awareness of the connection to the forest-based bioeconomy and the role of wooden multi-story buildings. The results indicate a slow transition that is hindered by path dependence and limited comprehension among consumers of the effects of their choices for a forest-based bioeconomy. This study provides valuable insights for future studies of how consumer awareness and social acceptance of the forest-based bioeconomy are interconnected.

Keywords: consumers; citizens; forest-based bioeconomy; low carbon transition; perceptions; wooden multi-story buildings

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1. Introduction

During recent decades, there has been a rapid acceleration in global greenhouse gas emissions [1]. Scientists, societies and politicians around the world agree that human activities are contributing to global warming and that actions need to be taken. One example of such action is the Paris Agreement, ratified in November 2016 [2], which stresses the importance of low carbon solutions [3]. To fulfil the goals of the Paris Agreement, substantial low carbon transitions have to take place [4].

Low carbon transitions are seen as substantial changes in the systems that serve society, so that these systems have less impact on the climate. Such systems include transportation, energy, agriculture and housing. Low carbon transitions in these systems would mean increasing energy efficiency and/or using fewer resources or renewable resources [5]. The feasibility of low carbon transitions can be studied by applying socio-technical transition (STT) theory. It can be used to assess the socio-political feasibility, social acceptance and legitimacy of various low carbon options by analysing the interpretations, strategies and resources of different social groups [5] (p. 580).

1.1. Bioeconomy and Forest-Based Bioeconomy

Socio-technical transition theory provides information about how different actors influence the implementation of technical change, in this case specific low carbon options. One example of a low carbon transition that has not previously been studied using STT theory is the bioeconomy, or bio-based economy.

The bioeconomy is described as:

- A system that relies on biological processes where resources in production are reused [6];
- Part of societal transformation [7];
- An area for system innovation and transformation to the use of new technologies and materials [6].

From a practical perspective, the bioeconomy means using renewable bio-based materials, for example forest biomass, instead of fossil-based materials as part of sustainable development to reduce the greenhouse gas effect [6,8,9]. There is a difference between the bioeconomy, which is generally perceived as a sector, and the "bio-based economy", which refers to a shift in the conventional economy [10]. Thus, the bioeconomy primarily focuses on parts of the economy that involve biotechnical and life science elements, while the bio-based economy describes an economy that mainly uses biomass resources rather than fossil-based resources. One example of the latter is the forest-based bioeconomy (FBB), in which forest resources are the primary biomass resource and which encompasses economic activities that relate to all forest ecosystem services [11] (p. 4).

1.2. Low Carbon Transitions

Low carbon transitions are substantial changes in the systems that serve society, so that these systems have less impact on the climate. One such system is housing. According to the International Energy Agency and the United Nations Environmental Program, 28% of the CO_2 emissions related to buildings originate from the use of different materials, with most of the emissions coming from cement and steel manufacturing [12] (p. 43). The International Energy Agency therefore suggests that a change towards bio-based materials would have the potential to reduce the carbon emissions originating from the use of materials in buildings [12] (p. 46). This suggestion is supported by findings in the literature [13–16].

In Sweden, the building and real estate sectors produce approximately 21% of total greenhouse gas emissions [17]. Of these emissions, 40% are directly connected to newly built housing and building renovations. Although total emissions from the building and real estate sector decreased during the period between 1993 and 2016, the contribution from the construction of new housing and building renovations has remained constant [17]. One part of the Swedish housing system that could decrease its carbon emissions is the multi-story buildings sector. Approximately 85–90% of the multi-story buildings in Sweden are built around a concrete or steel frame, while the remaining 10–15% are built around a wooden frame [18]. A wooden multi-story building (WMB) is a building with more than two storeys and a mainly wooden frame. Building multi-story buildings with wood is a relatively new technique, serving as an alternative to the dominant steel and concrete techniques [19].

1.3. Needs for Social Acceptance—Research Aim with Focus on Consumers

Social acceptance among different stakeholder groups will influence the implementation of a low carbon transition [5]. For example, in a study of low carbon transitions in the energy system, Wüstenhagen, et al. [20] found that social acceptance could be a constraining factor for establishing renewable energy innovations on the market and enabling a low carbon transition. For the low carbon transition of the FBB, the social acceptance among some stakeholder groups has been studied. For example, Hodge et al. [21] examined how forestry stakeholders (forest owners, the forest industry and environmental non-governmental organisations) have interpreted and perceived the FBB concept. Perspectives on FBB products such as WMBs have been reported for key stakeholder groups, e.g., structural engineers [22], architects [23], contract managers [24] and civil servants [25]. However, consumer perceptions of WMBs have not yet been studied thoroughly, even though their importance in the transition has been emphasised, e.g., by Mustalahti [26]. Little attention has been given to consumer understandings despite the importance of social acceptance of a low carbon housing system. Therefore, the aim of this project is to

explain how consumer understandings of the forest-based bioeconomy, with a particular focus on wooden multi-story buildings, can influence a low carbon transition.

A system perspective for a low carbon transition to a forest-based bioeconomy is described below. The description is structured in accordance with a multi-level understanding of conditions for transitions influenced by both technological and social development. The approach and conditions for the field survey that was undertaken are then outlined. This is followed by a presentation of the results from the survey, which was intended to capture consumer understandings and acceptance of a technological transition to a bio-based economy in terms of construction materials in residential multi-story buildings. Finally, some conclusions are presented.

2. Approach—A Theoretical Framework

A low carbon transition can be explained using socio-technical transition (STT) theory, which states that technology in itself has no function, but acquires a function in social settings [27] (p. 1257). Socio-technical transition takes place when a socio-technical system changes [28]. Socio-technical systems may be tangible, such as wind power stations, but also intangible, such as the skills, routines, behaviours, infrastructures and organisations needed to operate the tangible item [29]. It is through the arrangement of these elements that social functions in society (e.g., road transportation) are fulfilled. Other examples of social functions that are fulfilled through different socio-technical systems are sustenance, communication, mobility, heat and housing [30].

There are various inter-related reasons why socio-technical systems are resistant to change. These include:

- Dependence within systems [28], which can lead to lock-in effects [30];
- Tangible elements of socio-technical system investment costs [28];
- System-bound habits where people adapt their lifestyle to an artefact, such as having a car (ibid.);
- Sunk investments that have been made in the current technology and socio-technical system, making it unfavourable to invest in new technology (ibid.);
- Companies also tend to stick to established technologies because of advantages created through economies of scale and because of knowledge about the current technology (ibid.).

When a change in a socio-technical system occurs, it is called a socio-technical transition [27,30]. The overall dynamic of such transitions can be described through the analytical framework of the multi-level perspective (MLP). This consists of three analytical and heuristic levels, which are closely linked to each other [27]. The MLP describes socio-technical transitions as nonlinear processes, which emerge as a result of developments at three levels (Figure 1). These levels are: (1) niches, where radical innovation takes place; (2) the socio-technical regime, which upholds the stability of the existing system as it is and where established practices and rules are located; and (3) the socio-technical landscape, which is the context influencing the other two levels [31]. At higher levels of the MLP, more actors are more strongly linked to each other in norms reflected in institutional arrangements, resulting in system stability [31].

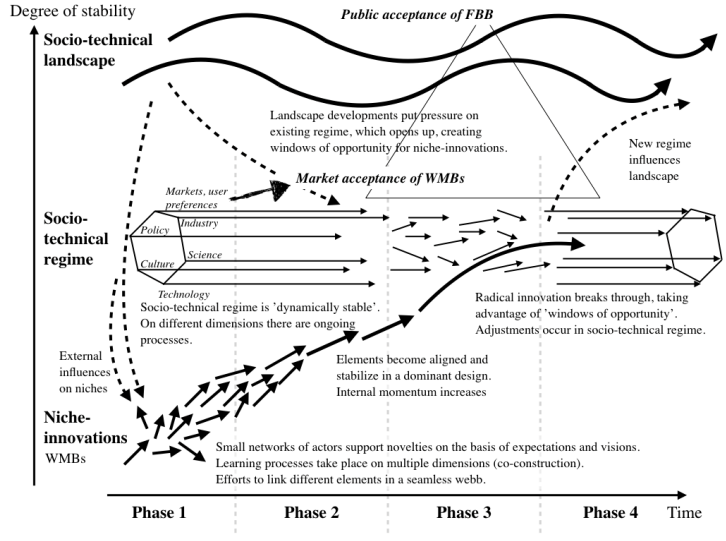

Figure 1. Overview of the theoretical framework, a multi-level perspective theory on pathways for socio-technical transitions and the role of social acceptance, constructed with inspiration from [32] (p. 226) and [20] (p. 2684).

In this study, the system of housing in Sweden represented the socio-technical system, while the socio-technical regime was the dominant multi-story building technique that uses steel and concrete as building materials. The niche innovation was represented by WMBs, with FBB being the change at the socio-technical landscape level (level 3) that influences the other levels of the MLP (Figure 1).

One criticism of using the MLP approach to assess socio-technological change is that it does not include reciprocal influential powers between levels in the MLP [33] (p. 62). This is where the societal, market and consumer dimensions of social acceptance can offer additional explanatory value. Moreover, the limitations in reciprocal influence between the levels in the MLP model serve as a visual representation of system-bound inertia.

2.1. Social Acceptance

There are several reasons why social acceptance could be important when seeking to establish low carbon innovations on the market. Public acceptance is needed to implement low carbon policies [30], while customer acceptance is needed for low carbon innovations to take place on the market [31]. In the renewable energy sector, the importance of social acceptance has become increasingly recognized. Ambitious political targets have been set by several governments since the 1980s to increase the amount of renewable energy offered on the market. Despite some success, social acceptance of renewable energy innovations has been identified as a constraining factor for market implementation of these innovations [20].

The three dimensions of social acceptance are socio-political acceptance, community acceptance and market acceptance. Socio-political acceptance concerns the acceptance of technologies and policies, and is the most general level of the social acceptance triangle (Figure 1). The socio-political acceptance level is made up of three groups; the public, key stakeholders and policymakers. An example of an issue that these three groups might handle is general acceptance in society of wind power parks [20]. Community acceptance is a more local level of acceptance, involving local stakeholders (e.g., residents or local authorities) affected by renewable energy innovations in specific places. Market acceptance

primarily concerns market adoption of renewable energy innovation and involves end-consumer acceptance, but also investor and intra-firm acceptance [20].

Previous studies on FBB have focused on socio-political acceptance by key stakeholder groups [21]. However, several key aspects of the social acceptance part of the model still remain unexplored. Therefore, this study focused on the market acceptance of WMBs and FBB by consumers in Sweden.

2.2. Dynamics of the Multi-Level Perspective

Socio-technical transitions are the result of interactions between processes on different levels of the MLP diagram [31]. These transitions can be described as three steps of a general pattern. The first step is when a niche innovation builds up internal momentum. The second step relates to changes at the landscape level that create pressure on the socio-technical regime. These changes lead to the third step, where destabilisation of the regime creates windows of opportunity for the niche innovation.

The MLP stresses that transitions are not initiated by a single actor, cause or driver, but rather by interconnected processes in multiple dimensions that reinforce each other and create transitions [31]. Socio-technical transition theory provides information about how actors influence the implementation of specific low-carbon options. The influence can either be hindering or stimulating and can be traced by applying the MLP to STT theory. According to Geels, Berkhout and Van Vuuren [5], MLP studies in such cases as this typically analyse developments in the recent past to help identify drivers and barriers of low-carbon innovations and transition pathways in the present. Examples of areas where low carbon transitions have been studied using the MLP approach include electricity systems [34,35], energy systems [36], transportation [37] and the building sector [38,39].

3. Materials and Methods

The bioeconomy is frequently perceived as an alternative system to the current unsustainable use of resources [26]. Changes to production and consumption stages are key to achieving the United Nations Sustainable Development Goals (SDGs). In the present study, particular interest was devoted to consumption aspects and the role of consumers in development of economic systems that support sustainable development (https://perform-bioeconomy.info/, accessed on 6 July 2021. The study was part of a project on the bioeconomy conducted by researchers in six European countries.

Transition to a bioeconomy in this study was envisaged to be a low carbon transition and the study object was the FBB, an important part of the Swedish bioeconomy. A widely held belief within the forest industry is that growing forests store carbon and that the carbon remains within constructions when the trees are processed into wood and used for construction. Based on the carbon storage capacity of sustainably managed forests, the forest industry argues that the FBB can be seen as a low carbon transition [40,41]. Therefore, the respondents in the present study were asked if they were familiar with how forests store carbon.

For a low carbon transition to take place, a low carbon innovation must be known to citizens, but also accepted on the market and by consumers. To analyse the social acceptance of consumers, i.e., market acceptance, the respondents in this study were asked about their perceptions of the FBB. Wooden multi-story buildings were chosen as an example of a product representing the FBB, mainly because of their capacity to store carbon. To analyse market acceptance of the FBB, the respondents were asked about their perceptions of the niche innovation of WMBs, in contrast to the dominant socio-technical regime in the housing system in Sweden today. A few questions were also aimed at investigating how the respondents perceived the niche innovation of WMBs to affect elements of the socio-technical landscape, such as the climate, nature and the economy.

A questionnaire was developed and used in a field survey to map respondents' understanding of the bioeconomy concept and of the FBB and WMBs in particular. The responses obtained served as the base for an ad hoc investigation of current understandings

and social acceptance of the FBB in Sweden. Diverse understandings of the bioeconomy among respondents were expected to lead to differing interpretations of the questions in the survey.

3.1. Definitions

In this study, the FBB was defined as an economy that mainly uses forest biomass resources, where appropriate. The FBB can therefore be seen as a transition to the use of renewable and sustainably managed forest resources in the whole economy, or part of it. It encompasses economic activities relating to all forest ecosystem services, from forest biomass in the form of wood products to services such as tourism [11]. The respondents were not given a definition of the FBB and instead answered the survey questions based on their personal understanding of the circular economy and the FBB. Thus, respondents may have had any one of the generic components—a biological system, a societal transformation or an innovation—or a combination of these in mind when completing the survey.

In the questionnaire, WMBs were defined as "multi-story buildings with a mostly wooden frame". The number of storeys needed in a building in order for it to be considered multi-story was not defined for the respondents.

3.2. The Questionnaire

The questionnaire was divided in four parts (Appendix A). The first part examined how the respondents perceived WMBs in Sweden, with questions and statements about WMBs compared with concrete. The second part of the questionnaire examined how the respondents perceived carbon storage in forests in Sweden. The third part concerned perceptions of the FBB in Sweden. The final part covered personal information and sought the respondent's informed consent to participate in the study.

Developing a questionnaire is an art that offers much scope for error in how the questions are expressed, the possible answers and the scale of close-ended questions. The questionnaire in the present study offered six reply options on a Likert scale: 1 = Strongly disagree, 2 = Disagree, 3 = Mildly disagree, 4 = Mildly agree, 5 = Agree and 6 = Strongly agree. The benefit of using the Likert scale is the simplicity, but this must be balanced against the shortcomings of uni-dimensional answers on a scale that is not equidistant in the reply options, which may fail to give a true measure of respondents' attitudes [42].

3.3. Data Collection

Data were collected at a common location where many general consumers can be found, namely by an IKEA warehouse. The field survey was carried out on 8–9 December 2018 in Uppsala, Sweden's fourth largest city [43]. Passing consumers were invited to participate, and efforts were made to include an age and gender spread among respondents. The consumer selection process can be classified as convenience sampling, which means that the consumers cannot be assumed to represent a larger population (i.e., the Swedish population). Frequency distribution and graphical displays were therefore used to present the results.

Respondents were given the option to fill out the survey in Swedish or English, using the digital Netigate system. They were rewarded with a SEK 50 (USD 5) gift card for a local restaurant. Respondents were also given assistance in understanding the questions by two students (a male and a female). Some 204 respondents completed the questionnaire and another 22 respondents began the questionnaire but did not complete it. The respondents represented approximately 1.4% of all visitors to IKEA Uppsala during the data collection period [44].

3.4. Data Analysis

Understanding of low carbon transition to a bioeconomy is seen as a precursor for social acceptance. In the case of WMBs, it has not previously been studied, which points to the need to explore understandings as conditions for social acceptance. The data collected

were a snapshot of perceptions from among people in Sweden visiting IKEA in Uppsala during winter 2018 and therefore the work can be regarded as a case study. The data obtained were used to provide an example of social acceptance in the theoretical model used. Descriptive statistics for the 204 responses obtained in the survey were compiled in frequency distribution tables and bar charts.

First, the demographic background of the respondents was assessed (Table 1). Next, the respondents were grouped into two categories ("Yes" or "No") based on their perceived familiarity or knowledge about three different concepts relating to the FBB in order to get a clear overview of respondents knowledge (Table 2). Respondents who selected "Strongly agree" or "Agree" were seen as having knowledge of or familiarity with the bioeconomy concept, while those who selected one of the other four answer categories ("Mildly agree", "Mildly disagree", "Disagree" and "Strongly disagree") were seen as not having knowledge of or familiarity with the concept. "Mildly agree" was not included in the "Yes" category because of the uncertainty associated with that response, since if the respondent had been entirely sure about the meaning of the concept, they would have given a stronger answer.

Table 1. Numbers and percentages of respondents within each demographic category.

Demographic Category:	Sub-Category	Per Cent
Gender	Female	55.9%
	Male	43.1%
	Other	1.0%
	Total	100.0%
Age category	18–39	39.7%
	40–64	44.6%
	65+	15.7%
	Total	100.0%
Which of the following best matches your current area of residence?	Urban	58.8%
	Suburb	17.2%
	Rural	24.0%
	Total	100.0%
Do you own more than one hectare (10,000 m^2) of land or forest?	No	91.2%
	Yes	8.8%
	Total	100.0%

Table 2. Frequency distribution table of respondents' perceived familiarity with and knowledge about elements and products of the forest-based bioeconomy.

Question	Yes (Agree and Strongly Agree)	No (Strongly Disagree, Disagree, Mildly Disagree, Mildly Agree)	Total
I am familiar with how forests store carbon	63.7%	36.3%	100.0%
I know the meaning of forest-based bioeconomy	28.9%	71.1%	100.0%
I am familiar with wooden multi-story buildings	54.9%	45.1%	100.0%

Some of the questions in the survey were double-barrelled, which is not desirable from a statistical point of view. However, since this was an explorative study rather than a statistical analysis, the responses to the double-barrelled questions were taken to reflect the respondents' general perceptions about the three dimensions of sustainability, environmental, social and economic. Questions 12–15 and 27–34 are not included in this article since they were not needed to fulfil the aim of the article.

4. Results

4.1. Understandings of Bio-Based Forest Products and Wooden Multi-Story Buildings

Background information about the respondents (based on section four in the questionnaire) is presented in Table 1. There was a minor skew towards women among the respondents, and the average age of respondents was 46 years of age. Most of the respondents (75%) lived in an urban or suburban area. Very few of the respondents (10%) were forest owners.

The majority of the respondents were familiar with how forests store carbon (Table 2). However, when the respondents were asked if they knew the meaning of "FBB", most replied that they did not. The respondents were familiar with the ecological processes which could explain the FBB as a low carbon transition, but their knowledge about the low carbon transition itself was limited. Moreover, the respondents seemed to be more familiar with WMBs, a product within the FBB, than with the FBB per se (Table 2).

Knowledge among the respondents about the FBB was assessed for different demographic categories (gender, age, area of residency and land ownership) (Figure 2). The results showed that respondents who were older than 64 years old, lived in a rural area and owned more than one hectare of land were more likely to perceive that they had good knowledge of the FBB than other respondents.

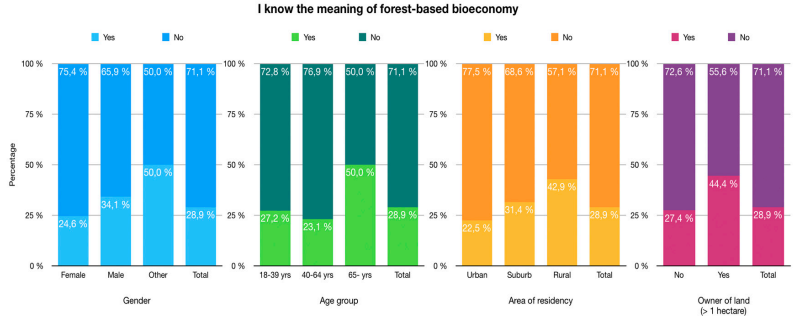

Figure 2. Perceived knowledge about the forest-based bioeconomy among groups of Swedish citizens based on gender, age, area of residence and ownership of land.

The respondents were also asked about their perceptions of the FBB (Figure 3). The frequency distribution of the respondents' responses, divided into Likert answer categories, is shown as a bar chart in Figure 3. A positive percentage indicates that the respondents agreed with the statement, while a negative percentage indicates that the respondents disagreed.

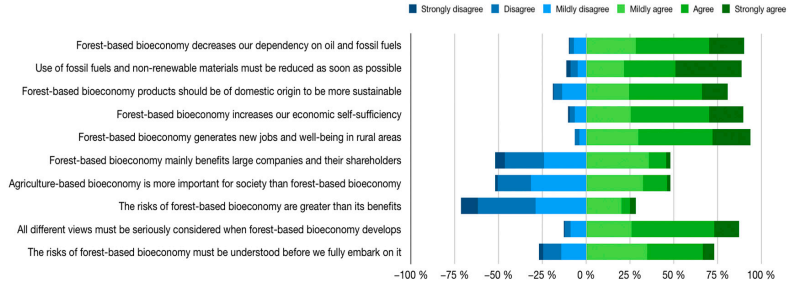

Figure 3. Frequency distribution bar chart of how the respondents perceived the forest-based bioeconomy.

Despite a lack of knowledge about the meaning of the FBB, the majority of the respondents perceived the FBB to be a low carbon transition (Figure 3). Most of the respondents (90.2%) agreed with the statements that FBB decreases the dependency on oil and fossil fuels and that the use of fossil fuels and non-renewable materials must be reduced as soon as possible. This indicates that a majority of the respondents also believed that there is a need for a low carbon transition to take place. However, most respondents (80.9%) perceived that a domestic FBB socio-technical transition would be more sustainable than a non-domestic transition, based on the perception among respondents that FBB products are more sustainable if they are produced domestically. The group that knew the meaning of the FBB was in general more positive towards this low carbon transition than the group that did not know about the FBB. A similar analysis was undertaken to investigate whether familiarity with WMBs had any effect on their market acceptance by consumers. Similarly to the findings for socio-political acceptance of FBB, the consumers who were familiar with WMBs were in general more positive towards this low carbon innovation.

Economic value was attributed to the FBB by the majority of the respondents, who saw economic value in terms of economic self-sufficiency (89.7%) and as a source of new jobs and well-being in rural areas (93.6%). Apart from the perceived positive economic development in rural areas, however, a large proportion of the respondents (48.0%) believed that the FBB would mainly benefit large companies and their shareholders. Thus, there seemed to be some disagreement among the respondents on who would benefit the most from the FBB in society. Moreover, there was disagreement about whether the FBB is more important than agriculture.

Regarding the transition to the FBB, the majority of the respondents (73.0%) believed that the risks of the FBB must be understood before it is fully implemented and that all different perspectives must be seriously considered for successful implementation. However, most respondents disagreed with the statement that the risks of the FBB are greater than its benefits.

4.2. *Sustainability Aspects of Wooden Multi-Story Buildings*

As shown in Table 2, approximately half of the respondents (54.9%) were familiar with WMBs. Further analysis (Figure 4) showed that respondents aged 40–64 years, respondents living in a rural area and respondents who owned more than one hectare of land were more familiar with WMBs than other respondents.

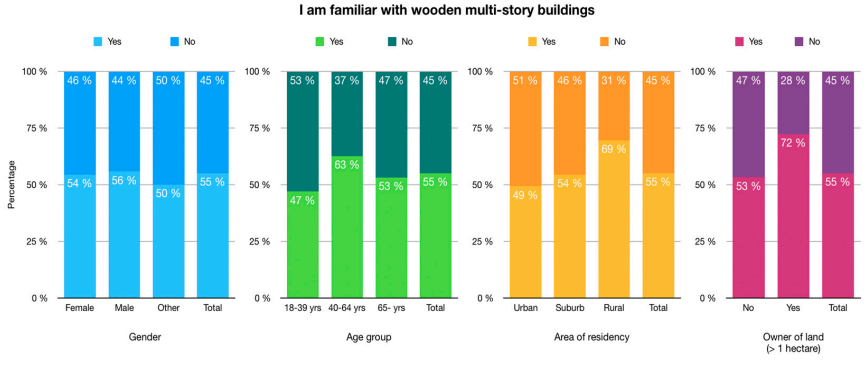

Figure 4. Perceived knowledge about wooden multi-story buildings among groups of Swedish consumers based on gender, age, area of residence and ownership of land.

Figure 5 shows the respondents' responses (agree/disagree) to statements related to wood construction (i.e., WMBs). First, the respondents were asked about their perceptions of the construction and maintenance properties of WMBs. Here, the majority (65.7%)

believed that WMBs are faster and cheaper to build than steel and concrete buildings. A marginal majority (56.4%) also believed that WMBs last as long as steel and concrete buildings, do not need more repairs and maintenance and need less insulation than steel or concrete buildings. Thus, some respondents believed that WMBs can offer construction and maintenance benefits compared with the current dominant practice of steel and concrete buildings. However, large proportions of the respondents did not recognise these benefits (Figure 5).

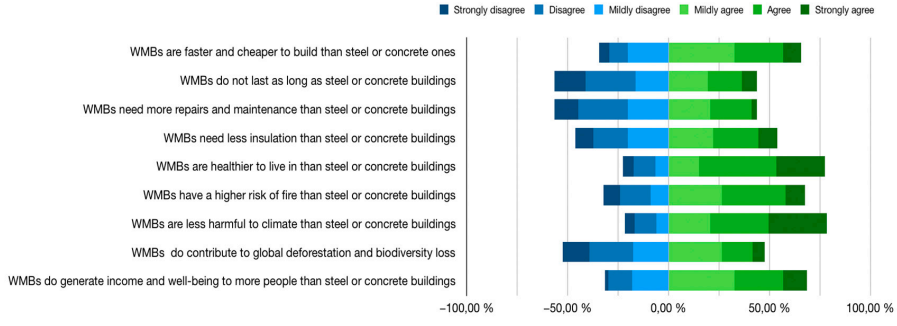

Figure 5. Frequency distribution bar chart of how the respondents perceived wooden multi-story buildings (WMBs) in comparison with steel and concrete buildings.

Most respondents (78.4%) believed that WMBs are less harmful to the climate than steel and concrete buildings. This means that a majority of the consumers recognised that WMBs offer benefits to the climate that are not provided by the current socio-technical regime. However, approximately half of the respondents (47.5%) agreed with the statement that WMBs contribute to global deforestation and biodiversity loss, which suggests that WMBs were also seen as a potential threat to environmental aspects other than the climate. A majority (68.6%) believed that WMBs generate income and well-being for more people than steel and concrete buildings.

Thus, overall, a majority saw clear economic and social benefits from WMBs compared with steel and concrete buildings but perceived various environmental aspects of WMBs to be both promoting and hindering factors when implementing the low carbon transition of FBB, i.e., as offering climate benefits but causing deforestation and biodiversity loss.

In terms of the housing environment, the respondents were highly positive regarding the health benefits of WMBs compared with the dominant socio-technical regime, as the majority of the respondents (77.5%) perceived that WMBs were healthier to live in than steel and concrete buildings. WMBs could therefore be seen as having a competitive advantage, assuming consumers associate WMBs with health benefits. In the long run, this could enable a low carbon transition, as the WMB carbon innovation was perceived as offering benefits not only to the climate, but also to the individual, possibly encouraging consumers to invest in WMBs rather than in the current steel and concrete buildings. However, WMBs were also perceived by a majority (67.6%) as having a greater risk of fire than steel and concrete buildings, which could be seen as hindering a low carbon transition.

5. Discussion

It is claimed that socio-political acceptance by citizens is important when seeking to make sustainability transitions, such as implementing a FBB [26,45]. This claim is supported by findings in studies on other low carbon transitions [20,30]. In this study, respondents had a relatively positive view of the FBB, but their in-depth understanding of what the FBB entails was limited. Many respondents interpreted the FBB as a sustainable approach that will play a great or greater role in the future. This positive view is in

line with that on the bioeconomy held by the forestry stakeholder groups studied by Hodge, Brukas and Giurca [21]. However, Hodge, Brukas and Giurca [21] found that some of the stakeholder groups studied viewed the societal disconnect from nature due to urbanization as a major obstacle to implementing the bioeconomy. In the present study, respondents under the age of 65 years, living in an urban or suburban area and who were not landowners seemed to have a low understanding of the concept of the FBB. On the other hand, most respondents were familiar with the capacity of forests to store carbon. This indicates that there is an understanding of the ecological processes on which the FBB is based. However, it is unknown whether perceived knowledge about the concepts will have an effect on transition to a bioeconomy or FBB.

Limited understanding of the FBB among the public could hinder transition to a low carbon housing system in Sweden and, more widely, to a low carbon Swedish economy [46]. This is primarily because low carbon transitions are not driven by private economic benefits in the same way as socio-technical transitions, but rather are problem-oriented [47] and purposive [48]. The goal with low carbon transitions is to mitigate climate effects, which is a societal good [47]. Private actors therefore have limited incentives to engage in low carbon transitions, so the strong motivating force of private economic benefits is absent [30]. Geels, Sovacool, Schwanen and Sorrell [30] argue that, because of the limited incentives for private actors to engage in low carbon transitions, public policy is needed to create the economic conditions to support successful development and implementation of low carbon innovations on the market. Examples of suitable policy instruments are regulations, taxes, subsidies and standards [30] and the use of social media [49].

However, governments tend to be reluctant to implement low carbon policies, as it is viewed as "bad politics" with a risk of public backlash or bad public opinion figures [50]. The yellow vest movement in France and movements in other parts of the European Union are examples of this backlash [51]. Despite this, Ockwell, Whitmarsh and O'Neill [50] point out that there are examples of low carbon policies that have been politically neutral or positive. According to Giddens [52], the key to success for policymakers when implementing climate change mitigation policies is to gain widespread political support from citizens. Therefore, it seems likely that there is a need to gain widespread political support in order to implement the FBB in the Swedish economy, especially since the present study indicated that respondents who were more familiar with the concept were also more positive towards it.

5.1. Conditions for a Sustainability Transitions

The results of this study indicated that there is some market acceptance of WMBs among the Swedish consumers that participated in the survey, even though WMBs are not well established in the marketplace and the concept is not understood and accepted by all. An interesting finding was that respondents who lived in rural areas and were landowners were most familiar with WMBs. However, the data also revealed diverse perceptions of WMBs in the group of respondents surveyed. The respondents were most positive regarding the lower climate impact of WMBs compared with steel and concrete buildings, which could serve as an enabling factor for establishing the niche innovation of WMBs in the socio-technical regime. However, a study by the World Business Council for Sustainable Development [53] found that increased awareness and concern about sustainability issues among consumers is not a guarantee of sustainable consumption. According to Geels [31], this might be due to lack of incentives for consumers to buy a sustainably superior product from a personal perspective, primarily because a sustainable product might offer unsatisfactory quality or cost more.

Similarly, Mark-Herbert, Kvennefeldt and Roos [46] found that residents in WMBs were relatively unaware of living in a WMB and chose their housing based on perceived personal benefits, rather than the sustainability of the construction material. Placing more focus on the function of WMB housing, rather than its sustainability properties, as suggested by Zhao, et al. [54], could perhaps attract more interest in WMBs among

prospective residents. The results in this study suggested that a majority of the respondents perceived houses built from wood to be healthier, and faster and cheaper to build, than steel and concrete buildings (Figure 5), so WMBs seem to offer benefits directly to consumers as well as to the climate. These benefits imply a perceived higher living standard, health benefits and lower purchasing and living costs for the end-consumer.

More knowledge among the respondents about the FBB and WMBs could increase the socio-political acceptance and serve as an enabling factor for a low carbon transition within the housing system in Sweden. However, the power of consumers to enable such a transition is debatable, as consumers are not responsible for building multi-story houses and are merely able to make a choice among what is offered on a market. Portfolio management decisions, including on construction materials, are made by construction companies [22]. Moreover, consumer acceptance represents only one voice in the transition to a bioeconomy. In this particular empirical context, the development of WMBs is determined by a number of other actors [22–25]. Decisions that are based on previous decisions or experience (path dependency) and strong interconnectedness within the current socio-technical regime can impede transition to a bioeconomy [19,22–24,55].

5.2. Methodological Reflections

To our knowledge, the two models that made up the theoretical framework in this study (STT theory and the MLP) have not previously been combined. This theoretical framework placed the focus on the importance of social acceptance in a socio-technical transition but failed to recognise all the dimensions of social acceptance suggested by Wüstenhagen, Wolsink and Bürer [20], as it omitted community acceptance. This is a significant omission, as a low carbon transition such as the FBB cannot proceed without community acceptance of harvesting of forest biomass. There is therefore room for refinement of the theoretical framework in future studies.

One limitation of this study was that the collection of data was not random and that participation was encouraged by offering a gift card. This form of data collection was chosen in order to collect as many answers as possible, since persuading people to spend 10–15 min of their time on a survey is not an easy task. The gift card may have generated a respondent bias, but also more answers (n = 204), which is preferable from a scientific point of view. The gift card also attracted people who were not familiar with the university logo used in the survey setting and who were not interested in forests or forestry.

Another limitation is that the questionnaire contained several double-barrelled questions, which could be interpreted in several ways. It is therefore not possible to say how each respondent interpreted each question, but the data obtained provide a general view of the respondents' opinions and provide guidance for future work.

6. Conclusions

At present, a forest-based economy (FBB) has been established in the Swedish housing system only to a limited extent, with the niche innovation of wooden multi-story buildings (WMBs) representing approximately 10% of newly built multi-story houses. This indicates that this niche innovation has gained some momentum but is still not well-established in the Swedish socio-technical regime. This study found some social acceptance of the FBB and WMBs among the consumer group surveyed. However, the results showed some disagreement among the respondents on who would benefit the most from the FBB in society (rural areas or large companies). The majority of the consumers saw clear economic and social benefits with WMBs compared with steel and concrete buildings, as well as climate benefits, but they also perceived WMBs as causing deforestation and biodiversity loss. Overall, the results indicate that social acceptance is not the primary reason why the low carbon transition involving the FBB and WMBs is not more widely adopted in the market today, but rather path dependency and strong interconnectedness within the current socio-technical regime.

The results of this case study cannot be generalized to other sectors or regions, but consumer perspectives are crucial for future implementation of a wide bioeconomy. This study may provide a foundation for future longitudinal comparisons of changes in public perceptions of the FBB and WMBs. Moreover, social acceptance of the FBB and WMBs could be studied with a more qualitative approach, generating in-depth information about stakeholders' perceptions and practices within a low carbon transition.

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Institutional Review Board Statement: Not applicable. The research project was conducted in agreement with university ethical guidelines, which can be found here https://internt.slu.se/en/support-services/administrative-support/legal-affairs-data-protection-info-management/info-and-archives-mgmt/manual-research-material/legal-prerequisites/funders-requirements-research-ethics/ (accessed on 6 July 2021).

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: Data is available through the link https://stud.epsilon.slu.se/15056/ (accessed on 6 July 2021) and through the link https://perform-bioeconomy.info/ (accessed on 6 July 2021). The data can also be accessed through contact with the corresponding author.

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Appendix A

Table A1. The complete questionnarie used in the study.

UNDERSTANDING URBAN CITIZENS' PERCEPTIONS OF THE BIOECONOMY *This questionnaire is by a European-wide research network on Bioeconomy: PerForm–Perceiving the Forest-based Sector in the Bioeconomy (www.perform-bioeconomy.info (accessed on 6 July 2021)). The project is funded by the European Forest Institute (www.efi.int (accessed on 6 July 2021)) and facilitated through network member organisations in Austria/BOKU, Finland/Univ. Helsinki, France/IRSTEA, Germany/Univ. Freiburg, Italy/Univ. Padova, Russia/Univ. Saint Petersburg, Slovakia/Tech. Univ. Zvolen and Sweden/SLU.*		Strongly disagree	Disagree	Mildly disagree	Mildly agree	Agree	Strongly agree
My opinion of multi-storey building with a mostly wooden frame in [COUNTRY] [Choose what best corresponds your opinion]							
1	I am familiar with wooden multi-storey buildings	1	2	3	4	5	6
2	Are faster and cheaper to build than steel or concrete ones	1	2	3	4	5	6
3	Do not last as long as steel or concrete buildings	1	2	3	4	5	6
4	Need more repairs and maintenance than steel or concrete buildings	1	2	3	4	5	6
5	Need less insulation than steel or concrete buildings	1	2	3	4	5	6
6	Are healthier to live in than steel or concrete buildings	1	2	3	4	5	6
7	Have a higher risk of fire than steel or concrete buildings	1	2	3	4	5	6
8	Are less harmful to climate than steel or concrete buildings	1	2	3	4	5	6

Table A1. *Cont.*

9	Do contribute to global deforestation and biodiversity loss	1	2	3	4	5	6
10	Do generate income and well-being to more people than steel or concrete buildings	1	2	3	4	5	6
My opinion of storing carbon in forests in [COUNTRY]							
11	I am familiar with how forests store carbon	1	2	3	4	5	6
12	Managed forests have great potential to reduce carbon emissions	1	2	3	4	5	6
13	How forests are being managed can threaten carbon stocks in forests	1	2	3	4	5	6
14	Land/forest owners need support to maintain and manage forests	1	2	3	4	5	6
15	Land/forest owners must be compensated monetarily for storing carbon in forests	1	2	3	4	5	6
My opinion of forest-based bioeconomy in [COUNTRY]							
16	I know the meaning of forest-based bioeconomy	1	2	3	4	5	6
17	Forest-based bioeconomy decreases our dependency on oil and fossil fuels	1	2	3	4	5	6
18	Forest-based bioeconomy increases our economic self-sufficiency	1	2	3	4	5	6
19	Forest-based bioeconomy generates new jobs and well-being in rural areas	1	2	3	4	5	6
20	Forest-based bioeconomy mainly benefits large companies and their shareholders	1	2	3	4	5	6
21	Forest-based bioeconomy products should be of domestic origin to be more sustainable	1	2	3	4	5	6
22	Agriculture-based bioeconomy is more important for society than forest-based bioeconomy	1	2	3	4	5	6
23	The risks of forest-based bioeconomy are greater than its benefits	1	2	3	4	5	6
24	The risks of forest-based bioeconomy must be understood before we fully embark on it	1	2	3	4	5	6
25	All different views must be seriously considered when forest-based bioeconomy develops	1	2	3	4	5	6
26	Use of fossil fuels and non-renewable materials must be reduced as soon as possible	1	2	3	4	5	6
27	Environmental regulation limits overall economic development and growth	1	2	3	4	5	6
28	Humans will be able to solve environmental problems when technology develops	1	2	3	4	5	6
29	Despite our special abilities, humans are still subject to laws of nature	1	2	3	4	5	6
30	Humans have the right to modify the natural environment to suit their needs	1	2	3	4	5	6
31	The balance of nature is very delicate and easily upset	1	2	3	4	5	6
32	I trust information on forest-based bioeconomy from government officials	1	2	3	4	5	6
33	I trust information on forest-based bioeconomy from researchers and experts	1	2	3	4	5	6
34	I trust information on forest-based bioeconomy from environmental and civic organizations	1	2	3	4	5	6
Respondent background information							
35	Age						
36	Gender	Female		Male		Other	
37	Do you own more than one hectare of land or forest?	No			Yes		
38	Which of the following best suits your current area of residence?	Urban		Suburb		Rural	
Data collected through this survey will be treated confidentially and anonymously for the purposes of the PerForm project, in compliance with the General Data Protection Regulation (GDPR), Regulation (EU) 2016/679. By filling the questionnaire you give PerForm network staff the permission to process data you provide for the purposes of the PerForm project.							
To be completed by the surveyor							
Who collected:		*Where collected:*			*When collected:*		

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The greenhouse gas emissions from the construction sector are high; one of the main contributors is the materials used in the buildings. One way to lower the greenhouse gas emissions from construction is to use wood in multi-storey construction. This thesis explores the market development of wooden multi-storey construction in Sweden from three perspectives, end-consumers, professionals, and literature. The results suggest that the largest hindering factors for further market development are path dependency and that the largest enabling factor is the technical properties of wood when used in multi-storey construction.

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SLU generates knowledge for the sustainable use of biological natural resources. Research, education, extension, as well as environmental monitoring and assessment are used to achieve this goal.

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