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

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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 (Topinen 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 Lahntinen 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).

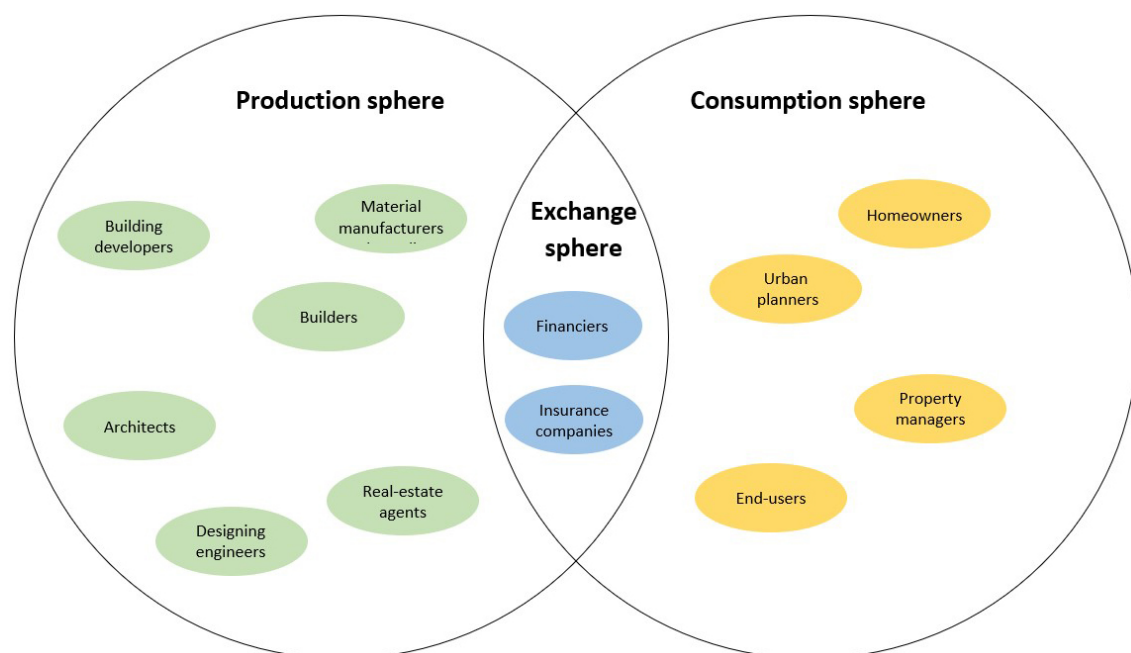


Fig. 1. Actors connected to structures of housing provision (SHP) with potential to affect WMC market development.

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

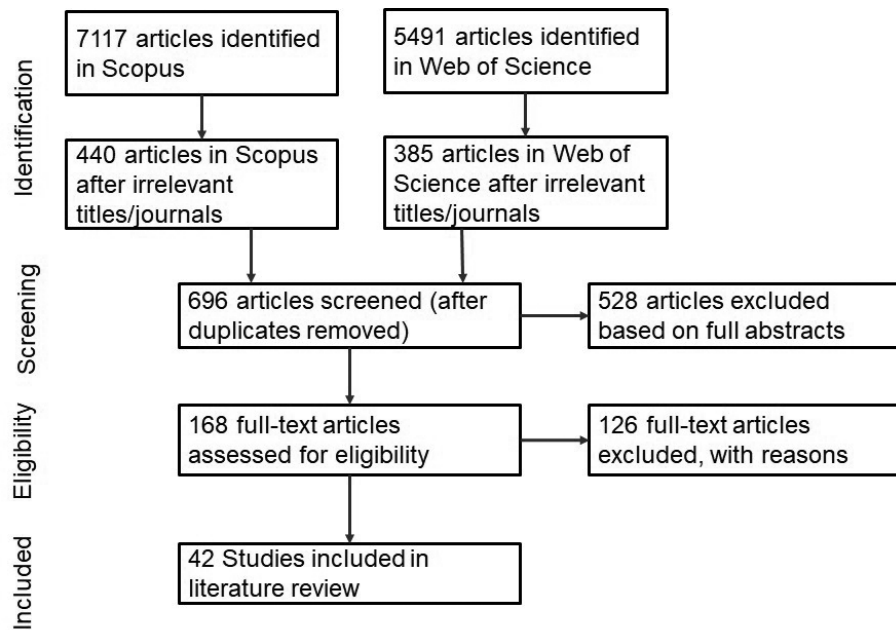


Fig. 2. Literature review process applied in the study (see PRISMA-method, e.g., Moher et al. 2019).

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

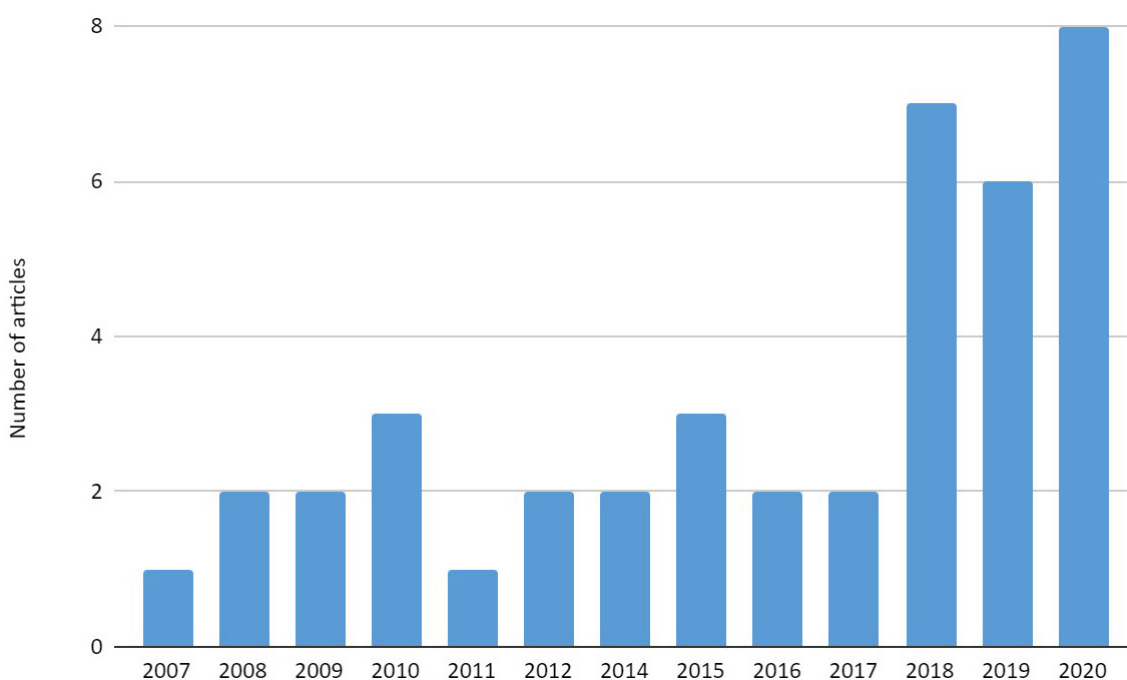


Fig. 3. Studies included in the literature review by publication year (total of 42 articles).

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.

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

Table 1 continued.

Authors	Year	Production sphere						Consumption sphere										
		Sustain-ability in building	System development	Innova-tions	Business collab-oration	Stake-holder awareness	Institu-tional changes	Urban planning	Market demand	Sustain-ability in building	System development	Innova-tions	Business collab-oration	Stake-holder awareness	Institu-tional changes	Urban planning	Market demand	
Lähtinen et al.	2019																	E
Vihemäki et al.	2019																	
Lindblad	2019																	
Toppinen et al.	2019																	
Markström et al.	2019	E	E	E/B	E	E	E	E	E	E	E	E	E	E	E	E	E	B
Riggio et al.	2020		B	E	B	E/B	B											
Pelli and Lähtinen	2020		E	B	E/B	B												
Peters et al.	2020		E	E														
Kyölälahti et al.	2020																	E
Viholainen et al.	2020																	E/B
Lindblad	2020																	
Vihemäki et al.	2020																	
Lazarevic et al.	2020		B		B	E	E	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; Björmfot and Stehn 2007; Brege et al. 2014; Pelli and Lähinen 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; Petsson 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; Vilhemäki 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	Polycymakers; Product manufacturers	Hynynen 2016; Peters et al. 2020; Hurmekoski et al. 2015; Hurmekoski et al. 2018; Vilhemäki 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; Riiala 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	Riiala 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. 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 market 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

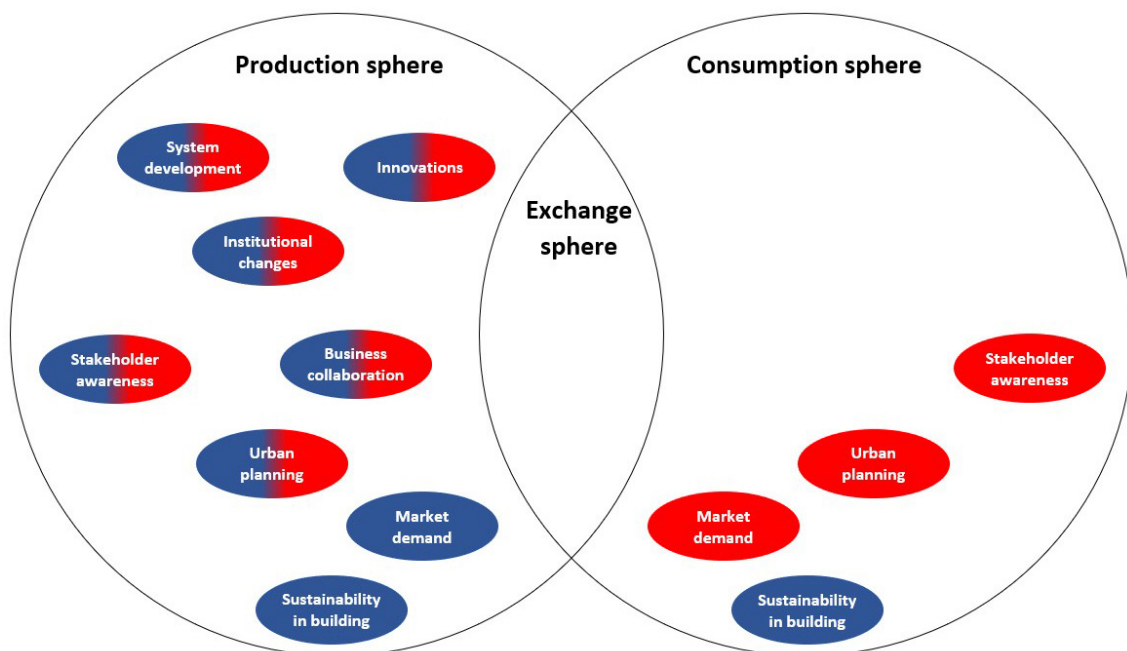


Fig. 4. Existing research information on the themes connected to the structures of housing provision. Enabling factors are denoted in the figure with blue, and barriers with red. Missing circles in exchange and consumption sphere illustrate lack of research information on those issues at the moment.

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; Hemstöm 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.

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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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