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Business ecosystem and end-user lenses in wooden multistorey construction

Noora Viholainen

Department of Forest Sciences
Faculty of Agriculture and Forestry
University of Helsinki

Academic Dissertation

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Author: Noora Viholainen

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Thesis supervisors:
Professor Anne Toppinen
Department of Forest Sciences, University of Helsinki, Finland

Professor Minna Autio
Department of Education, University of Helsinki, Finland

Research Professor Katja Lähtinen
Natural Resources Institute Finland (LUKE), Finland

Pre-examiners:
Professor emeritus Staffan Brege
Department of Management and Engineering, Linköping University, Sweden

Docent Henna Syrjälä
School of Marketing and Communication, University of Vaasa, Finland

Opponent:
Professor Seppo Junnila
Department of Built Environment, Aalto University, Finland

Cover photo: Noora Viholainen

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ABSTRACT

This dissertation examines current collaborative practices in wooden multistorey construction (WMC) projects through a business ecosystem approach to detect effective and ineffective practices when working with novel wooden materials and gaining knowledge of them. Furthermore, it deepens our understanding of citizen perceptions and homeowner experiences towards WMC, to ensure that professionals are able to construct buildings that are not only profitable, but also appreciated by end-users and functional in daily use. Qualitative means are used to provide an in-depth view of the matters.

The findings reveal that while construction projects are essentially collaborative efforts, the novelty of WMC materials and methods requires increased communication and learning between the business ecosystem participants. The keystone of a business ecosystem has a fundamental role in enabling deeper, long-term commitment between participants through procurement practices and meetings. These allow participants to work towards a common goal and to accumulate knowledge of wooden construction also between projects. Feedback processes should be improved between the participants, but homeowner experiences should also be utilized more efficiently. The results imply that while the business ecosystem approach provides a usable lens to study collaboration in WMC projects, it should not be seen as a static system concentrating on the design and construction phases, but one that evolves throughout a building's life cycle, incorporating end-users as the ecosystem keystones when moving to the use phase of the building.

Furthermore, the results support previous literature in that end-users appreciate soft aspects of wood material, such as aesthetics and ambiance, while durability and maintenance needs create concerns. However, the qualitative approach used in this study reveals that some aspects are multifaceted, carrying both positive and negative meanings for the end-users. Homeowner experiences indicate the importance of the everyday usability of home materials. Furthermore, the 'liveliness' of the wooden material seemed to surprise some of the homeowners, indicating that they are more familiar with other urban construction materials. Communication with end-users should therefore be improved to decrease concerns, but also to inform about the material's practical benefits such as pleasant soundscapes.

Keywords: wood material; construction project; collaboration; end-user involvement; perceptions and experiences; qualitative research

LIST OF ORIGINAL PUBLICATIONS

This thesis is based on four published research articles. The articles are reprinted with the permission of the publishers. The articles are referred to in the text by their roman numerals.

I **Viholainen N**, Kylkilahti E, Autio M, Pöyhönen J, Toppinen A (2020) Bringing ecosystem thinking to sustainability-driven wooden construction business. J Clean Prod 292, article id 126029. https://doi.org/10.1016/j.jclepro.2021.126029

II Toppinen A, **Miilumäki N**, Vihemäki H, Toivonen R, Lähtinen K (2019) Collaboration and shared logic for creating value-added in three Finnish wooden multi-storey building projects. Wood Mater Sci Eng 14: 269-279. https://doi.org/10.1080/17480272.2019.1653365

III **Viholainen N**, Kylkilahti E, Autio M, Toppinen A (2020) A home made of wood: Consumer experiences of wooden building materials. Int J Consum Stud 44: 542-551. https://doi.org/10.1111/ijcs.12586

IV **Viholainen N**, Franzini F, Lähtinen K, Nyrud AQ, Widmark C, Hoen HF, Toppinen A (2020) Citizen views on wood as a construction material: results from seven European countries. Can J For Res (e-First) https://doi.org/10.1139/cjfr-2020-0274

AUTHORS CONTRUBUTIONS IN CO-AUTHORED ARTICLES

	I	II	III	IV
Conception and design	NV, AT, EK, MA	AT, NV	MA, EK, NV	HFH, AT, AQN, KL
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Data collection	JP	NV	NV	HFH
Data analysis and interpretation	JP, NV, AT, EK, MA	NV, AT	NV, MA, EK	NV, FF
Writing the article	NV, EK, MA, AT	AT, NV, HV, RT, KL	MA, NV, EK, AT	NV, FF, KL, AQN, CW, HFH, AT
Editing and reviewing	NV, EK, MA, AT	AT, NV, HV, RT, KL	NV, MA, EK, AT	NV, FF, KL, AQN, CW, HFH, AT
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NV = Noora Viholainen (neé Miilumäki), EK = Eliisa Kylkilahti, MA = Minna Autio, AT = Anne Toppinen, FF = Florencia Franzini, KL = Katja Lähtinen, AQN = Anders Qvale Nyrud, CW = Camilla Widmark, HFH = Hans Fredrik Hoen, JP = Juho Pöyhönen, HV = Heini Vihemäki, RT = Ritva Toivonen

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INTRODUCTION

Among the measures to increase sustainability in the construction industry, wooden multistorey construction (WMC) has been proclaimed as a housing megatrend of the near future (Toppinen et al. 2018b). Multistorey wooden buildings, i.e. buildings with two or more floors and load-bearing structures constructed primarily of wood (Hurmekoski et al. 2018), have been visioned to provide an environmentally friendlier alternative to reinforced concrete buildings, which most urban city areas are constituted of (Hildebrandt et al. 2017). The development of engineered wood products, such as cross-laminated timber (CLT), which provide high quality and durability comparable to concrete, has increased the worldwide interest in tall wooden buildings (e.g. Gosselin et al. 2017).

In addition to renewability, recyclability, and the ability to act as a carbon storage that generates lower carbon emissions compared to concrete and steel (e.g. Hurmekoski et al, 2015; Liu et al. 2016; Santi et al. 2016), wood has also been suggested to possess other features that make it an attractive solution among construction materials. For example, owing mostly to the low weight of wood materials, it allows industrial prefabrication, which may generate renewal in the construction sector and its business models (e.g. Brege et al. 2013). Compared to on-site construction, assembling element walls and even complete rooms and apartments in the shelter of factories may increase efficiency (Ruuska and Häkkinen 2016), along with meeting the needs for affordable housing (e.g. Lehmann 2013). Furthermore, wood has also been indicated to provide a pleasant and healthy environment for building end-users (e.g. Burnard and Kutnar 2015; Conroy et al. 2019).

Finland, among other countries, is aiming to substantially increase its wood use in construction in upcoming years. Wooden buildings are promoted, for example, via the national bioeconomy strategy (e.g. Toppinen et al. 2018a; Vihemäki et al. 2019) and through governmental programmes such as the ongoing Wood Building Programme (Ministry of the Environment 2021). Easily accessible domestic forest resources and a strong forest industry have resulted in skilled and versatile use of wood and a high share of wooden single-family buildings and cottages (e.g. Riala and Ilola 2014; Jussila and Lähtinen 2020). While the Finnish forest resource trend and building culture indicates a high likelihood for WMC to penetrate markets in upcoming years (Hurmekoski et al. 2015), and the number of multistorey wooden buildings has begun increasing, the current market share is only estimated at 6% (Hurmekoski et al. 2018). This makes WMC a niche in the total volume of residential construction.

The conservativeness of the construction industry (Riala and Ilola 2014; Hurmekoski et al. 2015) and its path-dependent nature (Mahapatra and Gustavsson 2008; Hurmekoski et al. 2015) have been suggested as root causes for the slow acceptance of WMC. Until recently, WMC was prohibited due to fire-safety issues in many countries, including Finland (Vihemäki et al. 2019), giving ample room for concrete to consolidate its position as the leading structural material in multistorey buildings. Path-dependency, focusing on cost and risk reduction, has led to companies being unmotivated to adopt unconventional approaches, such as CLT, which are seen as commercially undesirable (Jones et al. 2016). Individual buildings and areas with WMC have been erected worldwide (e.g. Gosselin et al. 2017), but most such buildings remain curiosities, for example in Finland (Lazarevic et al. 2020). A limited number of WMC projects translates into limited experience and skills, which in turn act as barriers for companies to implement WMC projects (Franzini et al. 2018). Furthermore,

communication and learning between projects has been lacking (Ruuska and Häkkinen 2016), hindering knowledge development.

Breaking the path-dependency of the construction industry has been proposed to be facilitated by developing new types of actor networks (Mahapatra and Gustavsson 2008). For example, Matinaro and Liu (2017) express the need for stronger collaboration and more active communication as a means to improve innovativeness and sustainability in the industry, yet they also acknowledge that these aspects are not adequately stressed in the current construction sector culture. Furthermore, interest in collaborating with actors or stakeholders outside the construction project has been limited (Bygballe and Ingemansson 2014), while e.g. Franzini et al. (2018) have found that increased acceptability and demand for WMC among end-users is beneficial for its uptake. Similar to construction professionals, end-users have also become accustomed to the use of concrete in urban areas, showing reservations — but also sympathy — towards wood material use in multistorey buildings (e.g. Høibø et al. 2015, 2018). Homeowners in particular may want to steer away from unfamiliar solutions to maintain the value of their housing investment (e.g. Jussila and Lähtinen 2020).

This study applies a business ecosystem approach to provide insights to the collaboration taking place in Finnish residential WMC projects. As argued by Pulkka et al. (2016), the business ecosystem concept may trigger a shift in the construction industry mindset, as it underlines the importance of collaborative efforts in the face of change, such as the one created by the sustainability transition. According to Moore (1998), business ecosystems are communities with members, such as producers, suppliers, and customers, who all bring complementary inputs that are used in creating innovations and value in the network. Only a handful of studies have applied the concept to the construction industry, for example Pulkka et al. (2016) and Aksenova et al. (2019), but the context of WMC is yet to be covered by existing business ecosystem research. Additionally, while the business ecosystem concept also considers the users (Moore 2006), studies on end-user involvement in business ecosystems have been left without much attention (however, see Joo and Shin 2018). This dissertation provides empirical insights on the subject in the WMC context.

Furthermore, this study examines end-user perspectives towards WMC and how end-users and their needs and expectations are involved in WMC projects undertaken in business ecosystems. The importance of informing end-users and communicating with them about the nature of WMC has been acknowledged (e.g. Häkkinen and Belloni 2011; Lähtinen et al. 2019), and research has been conducted to gain understanding on how end-users perceive (see e.g. Gold and Rubik 2009; Larasatie et al. 2018) and experience multistorey wooden buildings (Karjalainen 2002; 2017). However, previous research has concentrated on survey-based methods along with mapping general opinions, while paying less attention to deeper qualitative descriptions and particularly homeowners. This study fills these gaps by utilizing a qualitative approach to understanding the various perceptions[1] and meanings that citizens relate to wooden materials on the one hand and how homeowners make wood a part of their everyday lives on the other.

This dissertation therefore contributes to the improved understanding of the collaboration and end-user involvement taking place in WMC projects using the business ecosystem as a lens for analysis (Articles I and II). Furthermore, the existing end-user research is enriched with homeowner experiences of living with wood (Article III) and with citizen perspectives

[1] Perception refers to the process in which individuals select, organize, and interpret sensations to produce meaning. This is done according to unique individual biases, needs, and experiences. (e.g. Kapoor and Madichie 2012).

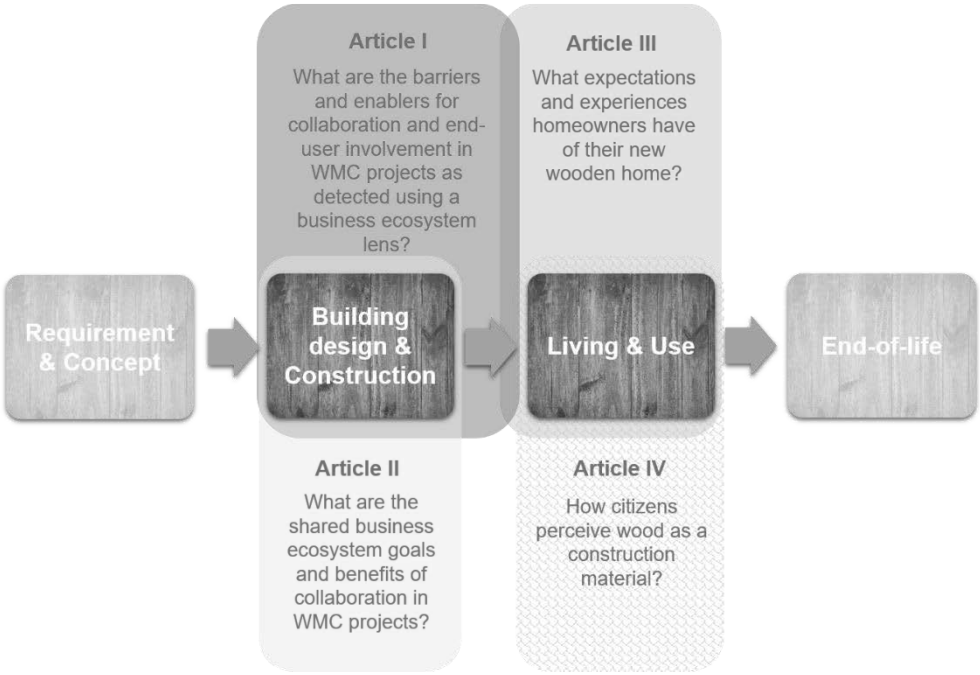

Figure 1. Original articles and their main research questions in connection to simplified building lifecycle phases. The blocks represent the order of the phases, but the blocks do not represent the lengths of the phases.

from seven European countries concerning wood material use in construction (Article IV), bringing both depth and breadth to the subject. The original articles and their main research questions are presented in Figure 1, in connection with the simplified life cycle phases of a building. The articles can be seen to address two distinct life cycle phases, i.e. 'Building design & Construction' (Articles I and II), and 'Living & Use' (Articles III and IV), with Article I generating an overlap by considering end-user involvement in the construction project business ecosystem. This study answers the following two research questions: 1) how collaboration in WMC projects appears through a business ecosystem lens, and 2) how end-users perceive and experience wooden living and how end-users are involved in WMC project business ecosystems.

CONCEPTUAL BACKGROUND

A business ecosystem approach to WMC projects

The business ecosystem concept was introduced in 1993 by James F. Moore, who argued that a company cannot innovate and evolve effectively on its own, but rather, similar to its

biological counterpart, a business ecosystem as a cooperative network needs resources from partners to flourish. In Moore's (1998, p.168) words:

> *"Business ecosystems are communities of customers, suppliers, lead producers, and other stakeholders — interacting with one another to produce goods and services."*

A logic that places increased emphasis on co-evolution, interdependency, dynamism, and stability is said to distinguish the business ecosystem concept from more traditional project relationships and networks (Aarikka-Stenroos and Ritala 2017). Furthermore, a business ecosystem is suggested to comprise a wider set of actors, including end-users, compared to more traditional business networks (Aarikka-Stenroos and Ritala 2017). The concept was therefore seen as an interesting lens through which to study collaboration and end-user involvement in the novel WMC context.

A business ecosystem functions around a keystone player (Iansiti and Levien 2004). The keystone has an important role in harnessing the abilities of the ecosystem participants and facilitating knowledge sharing (de Meyer and Williamson 2020, p. 117). The keystone encourages both individual and joint innovation (de Meyer and Williamson 2020, p. 117): the participants should aim to constantly improve their own capabilities while also respecting and utilizing the skills and intelligence of the participants surrounding them and creating new innovations together (Moore 1998). Moore (1998) calls this co-evolution, which enables the whole ecosystem to keep up with changes posed by the surrounding environment.

As already stated, a business ecosystem includes participants from not only the production side but also from the user side (Moore, 2006; Thomas and Autio 2012), as illustrated in Figure 2. A business ecosystem aims to meet the needs of consumers, who then

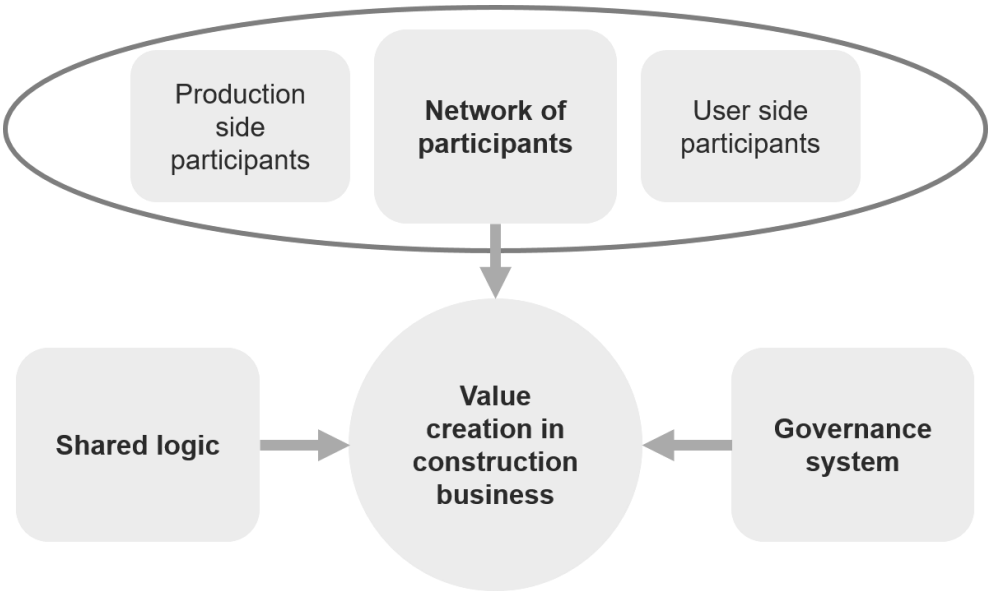

Figure 2. Business ecosystem characteristics creating value in construction business (modified from Pulkka et al. 2016).

provide sustenance and feedback to the ecosystem by either purchasing the products or services — or by leaving them on the shelves (Moore 2006). Furthermore, as argued by Moore (2006), business ecosystems can enable further transparency for consumer-driven feedback by revealing which part of the ecosystem performs which function. However, Joo and Shin (2018) point out that consumers should have a larger role in the business ecosystem. Instead of acting only as passive buyers, consumers can, for example, affect the business ecosystem through word-of-mouth, or can even create content in the case of many online applications (Joo and Shin 2018).

The business ecosystem concept has not been accepted without appraisal. Criticism has been mainly caused by the use of several, somewhat overlapping 'ecosystem' concepts in the literature, namely innovation, knowledge, platform, service, entrepreneurial, and digital ecosystems. Several studies have aimed to compare the differences between these concepts and to standardize their meanings and use to reduce confusion (see e.g. Clarysse et al. 2014; Valkokari 2015; Aarikka-Stenroos and Ritala 2017; de Vasconcelos Gomes et al. 2018; Scaringella and Radziwon 2018; Aksenova et al. 2019; Gupta et al. 2019;).

While the business ecosystem concept has been mostly applied to the high-tech sector, with examples such as Apple and IBM, the concept has since also gained interest in other sectors (Moore 2006). Examples of business ecosystem studies presented in Table 1 indicate that the concept has been adopted by a diverse set of industries, including sea shipping and oil and gas production, along with sustainability-oriented recycling and low-carbon transportation. Studies on business ecosystems have so far been scarce in the construction sector context, with a few exceptions. In their study, Jiang et al. (2016) concentrated on the Chinese prefabricated housing sector, visualizing the business ecosystem with its major

Table 1. Examples of fields in which the business ecosystem concept has been studied during recent years.

Year of publication	Authors	Title	Field
2014	Lu et al.	Business ecosystem and stakeholders' role transformation: Evidence from Chinese emerging electric vehicle industry	Electric vehicle industry
2015	Overholm	Collectively created opportunities in emerging ecosystems: The case of solar service ventures	Solar service industry
2017	Hsieh et al.	Governing a sustainable business ecosystem in Taiwan's circular economy: The story of spring pool glass	Glass recycling industry
2018	Ma et al.	Co-evolution between urban sustainability and business ecosystem innovation: Evidence from the sharing mobility sector in Shanghai	Electric vehicles, sharing economy
2019	Eriksson et al.	Projects in the business ecosystems: The case of short sea shipping and logistics	Sea shipping projects
2020	Masucci et al.	Removing bottleneck in business ecosystems: The strategic role of outbound open innovation	Oil and gas production

participants (property developers and contractors). Aksenova et al. (2019) studied the adoption of building information modelling in the Finnish architecture, engineering, and construction industries, and found that the business ecosystem concept is useful for understanding the value networks involved.

However, this study, namely Articles I and II, follow in the footsteps of Pulkka et al. (2016), whose study on the business ecosystem in the construction industry indicates that the concept is not only applicable in construction projects, but that operating according to the principles of a business ecosystem is positively connected to value creation in construction networks. They based their study on Thomas and Autio's (2014) three business ecosystem characteristics, namely i) a network of participants (i.e. specialization, complementariness, and co-evolution), ii) a governance system (i.e. authority structure, membership control, and task coordination), and iii) shared logic (i.e. legitimacy, trust, and mutual awareness). Similarly to the innovative cases studied by Pulkka et al. (2016), WMC projects involve innovativeness and working with novel aspects in a collaborative manner (see e.g. Gosselin et al. 2018), creating an interesting setting for the business ecosystem concept to be applied, as presented below.

Table 2. List of actors in construction projects (Clough, 2015; Klee, 2015).

Role	Description
Owner / Client / Employer	- Recognizes the need for the construction and initiates the construction project. - Pays for the design and construction; owns or operates the finished product. - Public (e.g. municipality) or private (e.g. individual, corporation)
Regulators	- Apply professional expertise in e.g. zoning, building permits, health and safety, and environmental issues
Architect-Engineer	- Designs the project, i.e. acts as the primary designer
Engineers and other consultants	- Called upon by the primary designer - Possess specific expertise required for the design (e.g. civil engineer, lighting consultant)
Construction manager	- Enters a contract with the owner and provides the owner with different services, e.g. planning, scheduling and designing the project - Construction management can be performed by design firms, contractors or professional construction managers
Prime/general contractor	- Manages and coordinates the entire construction project - Is in a contract with the owner and enters into contracts with subcontractors
Subcontractor/ specialty contractor	- Performs specialty work, such as electrical work or plumbing - Contracts with the prime contractor (subcontract)
Sub-subcontractor	- Performs work on behalf of the subcontractor - Contracts with the subcontractor
Material supplier	- Provides materials or products to the project
End-users	- End-users of the building

All construction projects include a **network of participants**, who aim to produce complex products that require collaboration and interaction between several specialized participants (see Table 2) with complementary skills to create a functioning product (e.g Håkansson and Ingemansson 2013; Pulkka et al. 2016). However, deeper collaboration in projects is made difficult by inputs from the participants usually taking place only at certain phases of the project (Gann and Salter 2000). On the other hand, for example Giesekam et al. (2016) and Uusitalo and Lavikka (2020) argue that collaboration should begin early on and extend throughout the project, to be able to leverage the knowledge of all stakeholders collaboratively. The temporary nature of the projects and the changing roster of actors hamper the ability to learn from project to project, while incremental knowledge development would be important for the adoption of low-carbon building materials (see e.g. Giesekam et al. 2016).

Furthermore, while end-users should be seen as business ecosystem participants (Moore 2006), for example Bygballe and Ingemansson (2014) have found that construction companies value internal networks higher than external ones, which may have a negative effect on learning and innovation. End-user consideration and gaining understanding on their experiences may increase satisfaction levels towards novel housing, which is essential for acceptance (Mlecnik et al. 2012). End-user involvement and perceptions are described further in Chapter 2.2.

A business ecosystem with its participants requires a solid **governance system**. The authority structure of a construction project is usually contract-based, with membership control being implemented mainly through the use of various procurement methods (Pulkka et al. 2016, see also Clough 2015, ch.1, p.1 and Gosselin et al. 2017). Traditionally, the procurement methods used in construction projects favour low cost and speed, while improved communication and learning call for procurement that encourages team integration, partnering, and risk sharing (Blayse and Manley 2004). When the participants have been chosen and contracts written, task coordination — both contractual, but also informal — during the project ensures that the various participants are aware of their particular tasks (Pulkka et al. 2016).

Finally, it is important for participants to have a **shared logic** to guide the interaction and create a feeling of togetherness. This logic is created on trust between the participants as well as through mutual awareness, but also through legitimacy, i.e. being compliant with regulations and societal norms along with sharing a common perspective on what the ecosystem is for (Pulkka et al. 2016). For example, Kadefors (2004) mentions workshops held at the beginning of construction projects as a means to agree on common objectives and working methods and to create trust. Additionally, Wandahl et al. (2011) suggests that sharing an interest for providing end-users with appealing and usable products may help the network establish closer collaboration and increased competitiveness as the end-users are one of the main aspects the network partners have in common.

End-user views and experiences on wooden living — towards involvement

Developing solutions that are not only profitable for business, but also meaningful to people, requires the involvement of potential end-users (Baldassarre et al. 2017). End-user involvement has been found to benefit the end-user, for example, by increasing feelings of ownership (Eriksson et al. 2015). Understanding end-user preferences and apprehensions is

important for construction professionals to be able to provide housing that meets the needs and desires of end-users (Høibø et al. 2015).

In this thesis, I use the concept of end-user to consider the terms 'homeowner', '(future) resident', 'consumer', and 'citizen', which are used in the articles (I, III, and IV). In articles I and III, 'end-users' are individuals and family members who purchased an apartment from a wooden building (homeowner) and were about to move into their new home (future resident), and finally live in their home (resident) while consuming the wooden material (consumer). The 'end-users' in article IV represent individuals from the general public (citizen) and how they perceive wood as a construction material. Therefore, the 'end-user' refers to both individuals who provide their perceptions on wooden construction and individuals who have purchased a wooden home and have gained experience with living in it. 'End-user' was chosen as the overarching term, as it provides a clear and neutral way for describing the variety of people using the building, be they apartment building residents or public building users, tenants, or owners, future or current users.

Previous studies have shown that end-users have both concerns and positive perceptions when it comes to wood material use in multistorey buildings (see Table 3). 'Soft' aspects, such as naturalness and environmental friendliness, along with a pleasant and healthy living environment, are properties of wooden living that end-users appreciate. Concurrently, end-users consider fire safety, a high maintenance need, and unsuitability in urban areas to be downfalls of wooden materials.

In their study, Gold and Rubik (2009) found that despite the 'soft' criteria being deemed important, they are not enough to trigger interest towards wood material use in construction. However, all buildings, regardless of the used materials, should fulfil the very basic requirements set, for example, for durability, fire protection and resale value. Research also indicates that end-users who are more familiar and knowledgeable of wood use in housing and WMC in particular have fewer negative perceptions concerning WMC, which suggests that increasing knowledge among the public is important for the positive market development of WMC (e.g. Larasatie et al. 2018; Kylkilahti et al. 2020).

Notably, end-users are not homogeneous in their views. For example, Lähtinen et al. (2019) found that Finnish consumers can be divided into two groups based on their views concerning the benefits of wood as a construction material. These groups are "Technology and environment believers" and "Aesthetic and well-being believers". Moreover, young

Table 3. Examples of end-user perceptions on WMC based on existing literarure (e.g. Gold and Rubik, 2009; Hu et al., 2016; Høibø et al., 2015, 2018; Karjalainen, 2002; Kremer and Symmons, 2016; Larasatie et al., 2018; Rametsteiner et al., 2007; Schauerte, 2010).

Positive associations	Doubts and concerns
Cosy and pleasant living environment	Risk of fire
Aesthetically pleasing	Poor durability, requires upkeep, high maintenance costs
Good indoor air quality, healthy, enhances well-being	Poor structural soundness (esp. in earthquakes), prone to decay and pests
Natural	Poor sound insulation
Modern, liked design	Old-fashioned, poor suitability in urban areas
Versatile	High initial price and unstable value
Eco-friendly, renewable, less pollution	Contributes to deforestation

people have stronger environmental values compared to older generations, and may thus be considered the most suitable target group for urban wooden housing (Høibø et al. 2015). Compared to the categories presented by Lähtinen et al. (2019), Kylkilahti et al. (2020) found that young people appreciate either aesthetic qualities or well-being, or the environment and longevity, which further indicates differences between end-user perceptions, for example, between different age groups (see also e.g. Kremer and Symmons 2016). These differences should be taken into consideration when communicating with end-users and creating specific messages (e.g. Kremer and Symmons 2016; Lähtinen et al. 2019).

While initial perceptions provide some understanding to the aspects of wood that end-users appreciate and what may affect their purchase behaviour, they are only a part of the story. Homes are to be lived in and "consumed", including engaging with the materials (see e.g. Klaufus and van der Horst 2009). Moving into a new home involves learning and interacting with the materials and systems, and the residents may share and solve possible problems through social interactions in the community (Baborska-Narozny et al. 2014). In their collection of resident experiences from Finnish wooden multistorey buildings, Karjalainen (2002, 2017) found that people appreciated similar issues as those presented in other studies, such as cosiness, good indoor climate, and building architecture. Contrary to perceptions, however, residents considered building fire safety to be good due to the presence of fire-safety equipment, namely sprinklers. The residents also believed that e.g. sound insulation properties could be improved.

This study seeks to add and deepen these findings by examining the perceptions and experiences of homeowners (Article III), along with how the homeowners are included in the design and construction phases of a project (Article I). Purchasing a home is a large investment (e.g. Savolainen 2009), and ultimately it is the homeowners who bear the financial risks related to new technologies. For example, in the housing company model applied in Finnish apartment blocks and row houses, the homebuyers purchase an apartment within a building, i.e. repairing and preserving the good quality of the building as a whole is important for maintaining the value of individual apartments (Lujanen 2010). An unknown novelty, such as WMC, may thus represent a risky investment that homebuyers may want to avoid. Homeowners are not only 'building managers', but also individuals with their own behaviours, which is why it is important to consider how they use all the aspects of their homes (Stevenson and Rijal 2010).

Several communication alternatives have been recognized with building end-users. End-user involvement can occur throughout a project (Eriksson et al. 2015) via platforms such as resident meetings and workshops (Pemsel et al. 2010). Additionally, for example post-occupancy evaluation has been studied in connection to novelties in the construction sector (e.g. energy-efficient housing), aiming to provide professionals feedback concerning the functioning of the housing and developing best possible solutions for end-users (Brown 2016). End-users may be involved in many ways, and companies should supervise how knowledge sharing evolves between the end-users and professionals (Heiskanen et al. 2010).

However, end-users are rarely involved in residential apartment building construction projects (Vischer 2008). For example, end-users in Finland are typically only able to influence the interior materials of the apartments they have purchased (Autio and Autio 2013). The final end-users of residential apartment buildings are not known until the later stages of a project, and efforts to involve the public through participatory process sessions during the early stages are considered to only generate concerns instead of ideas (Florencia et al. 2018). Even if end-users can be identified, building professionals believe that deeper end-user involvement will slow down the project and increase its costs (Autio and Autio

2013). Also, a lack of expert knowledge makes the involvement problematic, especially when developing innovations (Goodman et al. 2017).

Indirect measures of end-user consideration are thus mostly favoured, such as using generalized information possessed by architects and other consultants, compared to directly involving the end-users (Kim et al. 2016). Due to the above-mentioned problems in end-user involvement, along with the current low number of wooden multistorey buildings — especially owner-occupied ones — the construction industry benefits from gaining understanding on how the general public perceives WMC (Article IV).

METHODS AND DATA

The philosophical background of this study lies in interpretivism (see e.g. Eriksson and Kovalainen 2008, p.19), exploring and interpreting the perceptions and experiences of WMC project members and end-users in everyday contexts and in an in-depth manner (Moisander et al. 2020). Inductive reasoning was used to draw insights from empirical data (Eriksson and Kovalainen 2008, p. 22). Yet it should be remembered that researchers seldom function in a vacuum and their work is to a certain degree also constantly affected by theoretical underpinnings, i.e. using also deductive reasoning (Eriksson and Kovalainen 2008, p. 22–23; Braun and Clarke 2017).

The data were collected from case construction projects using semi-structured interviews (Articles I–III) and from a cross-country online citizen panel using an open-ended survey question (Article IV). Qualitative methods were chosen, as they can reveal subtleties and

Table 4. Data and methods used in the original articles.

Article	I	II	III	IV
Country	Finland	Finland	Finland	Austria, Denmark, Finland, Germany, Norway, Sweden, UK
Data	Semi-structured interviews in Case I building project; incl. company representatives (n=12), a municipality representative (n=1) and future residents (n=7)	Semi-structured interviews with actors involved in three case building projects (Cases I-3) (n=23)	Semi-structured interviews with homeowners in Case I (n=13)	Open-ended question in an online panel survey (n= 6 633)
Analysis	Thematization	Thematization	Thematization	Qualitative Content Analysis

complexities that may go unnoticed if using quantitative means (see e.g. Anderson 2010). Furthermore, they can shed light on how people (e.g. project participants and end-users) think and act in their everyday lives, and what meanings people attach to things (e.g. wooden housing materials) (see Taylor et al. 2015, p. 17–21). Table 4 presents an overview of the data collection and analysis methods used in each article. The data collection and analysis methods are further discussed in the chapters below.

Interviews with project actors and future residents

Case descriptions

Articles I–III analyse empirical data collected using semi-structured interviews from three Finnish WMC case projects. Articles I and III study Case I from two different aspects, namely the collaboration of the business ecosystem actors and end-user involvement, and end-user perceptions/experiences, respectively. Article II broadens the business ecosystem view by complementing the data from Case I with two additional Finnish WMC cases (Case 2 and 3). Details of the cases are presented in Table 5.

The case projects were chosen because they introduced a new technology and/or project role, and the key actors were willing to collaborate with the research project. Cases 1 and 2 were, at the time, rare examples of WMC projects with owner-occupied flats and a private developer in charge. Moreover, the timing of Case 1 enabled including homeowners both before the move and after one year of habitation within the research timeframe. Due to these reasons, the two-storey residential building in Case 1 was regarded suitable for the study, even though it does not represent a taller building per se. Case 3 represents a public project, which is more common in WMC projects, yet the building itself is a pioneering case designed

Table 5. Details of the case buildings and data collection.

	Case 1	**Case 2**	**Case 3**
Building	Two-storey residential building with 14 apartments	Three-storey residential building with 27 apartments	Twelve-storey student housing building
Developer	Private	Private	Public
Residents	Owners, renters	Owners, renters	Students
Year of data collection	2017	2019	2019
Construction phase during data collection	Finished; end-users were about to move in	Finished; end-users were about to move in	Planning phase; waiting for construction permit approval from the city
Interviews with	Project participants, end-users	Project participants	Project participants
Considered in original article	I, II and III	II	II

to have 12 floors.

Wood is the main structural material used in all the case project buildings. In Case 1, the decision to use wood was made by the main contractor company, who is a wood element manufacturer. Their agenda is to occasionally test their new products in actual construction projects, which is why they take up the role as a main contractor in addition to being the material supplier. In Cases 2 and 3, the use of wood as a structural material was determined by the local municipalities' land zoning decisions.

Data collection — semi-structured interviews

Qualitative semi-structured interviews were chosen to gain in-depth insights on the functioning of the projects and on the homeowner views. The semi-structured interview guide enables the interviewer to consider the discussion topics, which were decided upon beforehand based on the research problem, but it also leaves room for the interviewer and interviewee to interact, possibly bringing up new interesting topics broader than those originally intended (Edwards and Holland 2013; Kvale and Brinkmann, 2015 p. 33–34). While the interview may, to some extent, be affected by the presence of the interviewer and his/her skills and biases, the possibility of the interviewer guiding and redirecting the interview can also be seen as a benefit (Andersson 2010).

Interviews with the project actors in Cases 1–3 were designed to elicit information concerning the practices in the design and construction phases of the construction projects and how the future residents were considered by the actors (Case 1). Case 1 was the first studied project, which is why a wider set of actors was interviewed during the project compared to Case 2 and 3 projects. The latter two case projects were analysed using a simplified setting by focusing on the key players in the core business ecosystem using snowball sampling. Therefore, municipality representatives or real estate agents, for example, were not considered relevant bodies to be interviewed in Cases 2 and 3.

Interviews with the homeowners (Case 1) were conducted in two rounds. The first round was made when the building was being finalized and the homeowners had purchased the apartments. These interviews focused on why they had chosen the apartment, how they felt about the purchasing process and were they able to express their needs and wishes, what their expectations towards their new homes were, and how they perceived wooden materials (in general and in construction). The second interview round was conducted when the homeowners had been living in their new homes for one year. Thus, the second round enabled analysing the experiences the homeowners had gained about living with wood.

The interviews were mainly conducted face-to-face. Some interviewees were only reachable via phone due to scheduling issues, and one interviewee in Case 3 wanted to provide their answers via email. The interviews were recorded and transcribed in full.

Data analysis — thematization

Thematic analysis was used to analyse the interview data. As described by Clarke and Braun (2017), thematic analysis is an experimental tool used to identify, analyse, and interpret themes arising from qualitative data; it aims to grasp the thoughts, feelings, and actions of the interviewees. As a first analysis step, the interview recordings were listened to and the transcriptions were read several times to familiarize the researchers with the data (Clarke and Braun 2017). In the next step, an initial categorization was generated based on recurring topics, descriptive category names were created for each topic, and interview quotes dealing

with the topic were collected under each category. These categories were further grouped under overarching themes. For example, recurring topics from the project actor interviews included 'lack of feedback' and 'novel solution resulting in new skills and experience', which were grouped under the theme 'learning'.

Additionally, when analysing data for articles II and III, the topics and themes were tabulated to compare the findings. In article II, data collected from the three WMC case projects were analysed in a tabular form, where each case had their own column, while the topics and themes were the same for all projects. This enabled identifying similarities and differences between projects. The same procedure was conducted for the data used in article III: the initial end-user perceptions before moving into their new homes were compared with the experiences after one year of habitation to detect any changes. This was first conducted separately for each individual interviewee, after which the tables were combined to consider all interviewees and their responses to arising topics and themes in one table.

The analysis process was iterative; a team of researchers reviewed the themes several times to ensure that they were representative of the data. Most of the topics and themes brought up in the interviews were recurring, indicating that the data were saturated.

Citizen responses to open-ended survey question

Data collection — open-ended responses

An online survey panel was used to elicit information on citizen housing material preferences highlighting WMC. Online panels are a cost-effective and quick means to collect large, representative samples, yet they may be biased due to participants needing internet access and due to the risk of generating low-quality data through unmotivated respondents (e.g. Hays et al. 2015; Chandler et al. 2019). Data were collected from seven countries: Austria, Denmark, Finland, Germany, Norway, Sweden, and the UK. These countries differ in building traditions regarding wood use in construction, as well as in forest resources and the importance of their forest industry.

The complete survey consisted of 35 multiple-choice questions and one open-ended question, which is considered in this study. For the open-ended question, the panellists were asked to answer the question: "How do you perceive wood as a construction material? Respond in 2–3 sentences." The question was aimed to provide respondents with a low threshold to describe their feelings and opinions, not their level of knowledge. Out of the 7 007 collected responses, 6 633 open-ended responses were analysable, while the remaining responses were empty or otherwise nonsensical. The responses, which were provided in the native language of each country, were translated into English by the bilingual researchers in the team and cross-checked by co-authoring researchers to reduce the number of errors.

Data analysis — qualitative content analysis

The collected dataset of 6 633 responses was analysed using qualitative content analysis (QCA). QCA is used to interpret qualitative material concerning social and personal meanings (Schreier 2012, p.20). However, while most other qualitative data analysis methods aim to open up data, discover new information, and thus involve producing more data, QCA focuses on selected aspects and reduces data in two ways: by limiting the analysis to aspects

that are relevant to the research question and by classifying specific information in the data to a more abstract level in the coding framework (Schreier 2012, p. 7–8). The main difference between content and thematic analyses is that the former enables data quantification by counting the frequency that each theme is mentioned (Vaismoradi et al. 2013).

A coding framework is developed in the QCA method to analyse the data. First, 20 random responses from each country (a total of 140 responses) were analysed to identify recurring topics such as "wood requires maintenance". These topics were grouped under subcategories, such as "Durability", which represent the recurring topics. Further, the subcategories were grouped under overarching major categories such as "Physical aspects". Additional categories were also created to allow noting the country and the tone of the response (namely positive/no concern or negative/concern). This preliminary framework was developed based on comments from the co-authors and then piloted on 700 randomly chosen responses, after which final modifications were made to ensure that the framework was satisfactory.

The finalized coding framework was applied to the 6 633 open-ended responses. Each response was segmented into units, which could be labelled with one of the subcategories. For example, a response stating: "Wood is beautiful, but bad for the environment" consists of two units: i) wood is beautiful, and 2) but bad for the environment. After applying the framework to all the responses, tabulations could be performed to see how many times each subcategory and major category was mentioned. Cross-tabulations could also be done, for example, to examine tone was used for each category, along with detecting differences between countries.

Trustworthiness of the research

As pointed out by Schreier (2012, p. 27–28): "In qualitative research, the quantitative criterion of objectivity does not apply", which makes the reliability assessment different from that in quantitative research. Furthermore, the validity of qualitative research is affected by its interpretative nature, i.e. different meanings can be drawn from the same research material, yet all interpretations can be equally valid (Eriksson and Kovalainen 2008; Shcreier 2012). Therefore, instead of using reliability and validity, other criteria, namely credibility, transferability, dependability, confirmability, and reflexivity have been suggested to be used, particularly when assessing qualitative research and proving its trustworthiness (Eriksson and Kovalainen 2012; Nowell et al. 2017; Korstjens and Moser 2018;).

Research credibility was established by analysing and interpreting the collected data among the group of participating researchers (i.e. investigator triangulation), along with conducting several iterations of rereading, interpreting, and discussing the data and revising the themes (i.e. persistent observation) (Korstjens and Moser 2018). Secondly, the data from the case construction projects represents the views of project actors in various companies and positions (articles I and II), as well as in projects taking place at different locations and during different times (article II). Such procedures can be considered 'data triangulation', which also increases the credibility of the research findings (Korstjens and Moser 2018). The QCA method used in article IV also enables testing the credibility (reliability in the QCA literature) of the coding framework in a numerical manner by assessing how consistently the data are coded using the same framework as in the original coding round (see: Schreier 2012, pg. 167). The data were coded identically in 93% of the cases, indicating that the framework is 93% reliable. The credibility could have been further improved by using different data

collection methods, i.e. methods for triangulation, such as focus group discussions or diaries kept by the end-users.

Regarding transferability, the case projects, along with the interviewees and respondents, were aimed to be described in a manner enabling other researchers to assess whether previous findings are transferrable to their settings (Korstjens and Moser 2018) while maintaining the anonymity of individual people. Furthermore, as described by Eriksson and Kovalainen (2012), transferability also refers to the similarity of research findings and other, already existing research. This dissertation provides novel insights into the studied topics, yet similarities with existing studies were also found, indicating clear connections and thus transferability between our results and previous ones. The dependability of the research was ensured by documenting the research process and results in a thorough and transparent manner, and confirmability was ensured by presenting several quotations from the interviews and the open-ended responses in the original articles to back up the data interpretations.

Finally, considering reflexivity, researchers should acknowledge their personal biases, preferences, and preconceptions that may affect the research process (Korstjens and Moser 2018). Critical reflection on the effects of each individual researcher is not considered relevant in a thesis summary in a research endeavour such as this one, in which several researchers have taken part in collecting, analysing, and interpreting the data. Reflecting on my own effects in the process, with no background in the field of wooden multistorey construction, construction project networks, and end-user perceptions, the consequential lack of preconceptions and biases may have increased my objectivity while conducting the research. As an interviewer, being the same nationality and speaking the same language as the interviewees has quite possibly facilitated the creation of rapport during the interviews. Yet, a more seasoned interviewer may have been able to establish an even more open setting for the interview and detect ques or topics that could have been discussed deeper than what occurred. However, no major biases, preferences, or preconceptions were recognized during the analysis, also benefitting from the expertise from a large research group.

RESULTS

Collaboration and end-user involvement in WMC project business ecosystem

Article I employed the business ecosystem lens for empirically studying a Finnish WMC project, providing insights on how to develop collaboration and end-user involvement in such novel settings. Thus, article I contributes to business ecosystem literature by providing a new context (WMC) and examining the end-user role in the WMC business ecosystem. The case project was studied during the design and construction phases, until the project was being finalized and homeowners were about to move into their new homes. The results are summarized in Table 6 in connection to the business ecosystem characteristics of Pulkka et al. (2016) and Thomas and Autio (2014).

The case project had been initiated by a wooden element producer that had also adopted the roles of the main developer and constructor of the project, with the aim of gaining research and development knowledge of their novel wooden intermediate flooring solution. The developer formed the centre of the business ecosystem, acting as the keystone and surrounding itself with specialized, complementary actors (e.g. designers). Procurement was conducted using tendering and co-operation contracts with companies the developer was

Table 6. Enablers and barriers for collaboration and end-user involvement in WMC projects through the business ecosystem lens, as detected in article I.

Business ecosystem characteristic	Enablers and barriers for collaboration and end-user involvement in WMC projects
Network of participants	+ Long-standing collaboration with trustworthy actors and mutual learning of novel wooden solutions - End-users not perceived as active actors: views and concerns on material choice neglected
Governance system	+ Keystone player orchestrates the ecosystem and shares information on wooden materials - Lack of keystone's leadership skills and limited feedback of how novel design solutions function in practice
Shared logic	+/- Lack of clarity concerning project goal, yet similar higher aim to produce high quality - Lack of actor and end-user interaction and awareness of wood as a sustainable material

familiar with. This familiarity and trust formed between the actors through a common history strengthened the collaboration and future projects.

The novel wooden flooring element underlined the need for collaboration and efficient communication; the actors were working together, for example, to match design plans and find the best plumbing solutions on-site. Actors who had previously worked with the developer were more likely to have experience with working with wood, while more occasional partners regarded the project as a learning opportunity. Certain actors who were not directly affected by the structural material, such as the company excavating the foundations, found the project to be like any other.

However, the new role of the keystone as the developer/main constructor forced the company to work outside of their comfort zone, which became evident as challenges in leadership, namely as lacking communication concerning the overall project aim (i.e. testing of the flooring element) and issues with managing the project schedule. Furthermore, feedback processes appeared to be absent, both between the site and the design team concerning the implementation of the design plans on-site, and between the hub and the entire ecosystem concerning the overall progress of the project.

The other actors did not recognize the end-users as focal to the project but rather considered them to lie on the outskirts of the ecosystem during the design and construction phases of the building. End-users became involved in the project after they had bought the apartment and were given the opportunity to personalize their apartments from a selection of materials, kitchen cabinets for example. The project actors did not consider it feasible to involve the end-users in the design phase, as they were not known at the time. The architect was seen to be in charge of creating solutions that most end-users would appreciate, yet it was the real estate agent who actually communicated with the future residents when selling the apartments.

The end-users had chosen the apartments mainly based on their newness, location, affordability, and functional layout. The wooden material had not been extensively marketed or discussed when selling the apartments, and while the future residents considered wood to

be an advantage (e.g. clean, natural, and healthy), concerns and lack of knowledge were also voiced. The interviewed end-users implied their interest towards being able to influence the design process to some extent along with being updated on the construction progress of their future homes. In the end however, the project participants apparently shared a similar vision with the future residents: high-quality and affordable living. Sustainability of the wooden material was rarely mentioned by the project actors and end-users.

Shared business ecosystem logic and benefits of collaboration in WMC projects

Article II contributes further to the understanding of the network structure, shared logic and benefits of collaboration in WMC business ecosystems by studying the roles and experiences of actors in three Finnish WMC projects.

The studied ecosystems were formed around keystones (Case 1 and 2: the main developer/constructor; Case 3: customer & consultant) that governed the project, as illustrated in Figure 3. Most of the designers, contractors and material suppliers surrounding the keystones had previous experience working with the keystone as well as many of the other actors, and the possibility to work with familiar partners seemed to benefit the collaboration. These actors did not consider the roles of the municipality or end-users to be central to the project. It was revealed, however, that the municipality did act as an important gatekeeper through providing the plots based on competition (Cases 2 and 3). Furthermore, due to the novelty of the wooden materials and methods, further communication with the municipalities was actually required compared to more traditional projects.

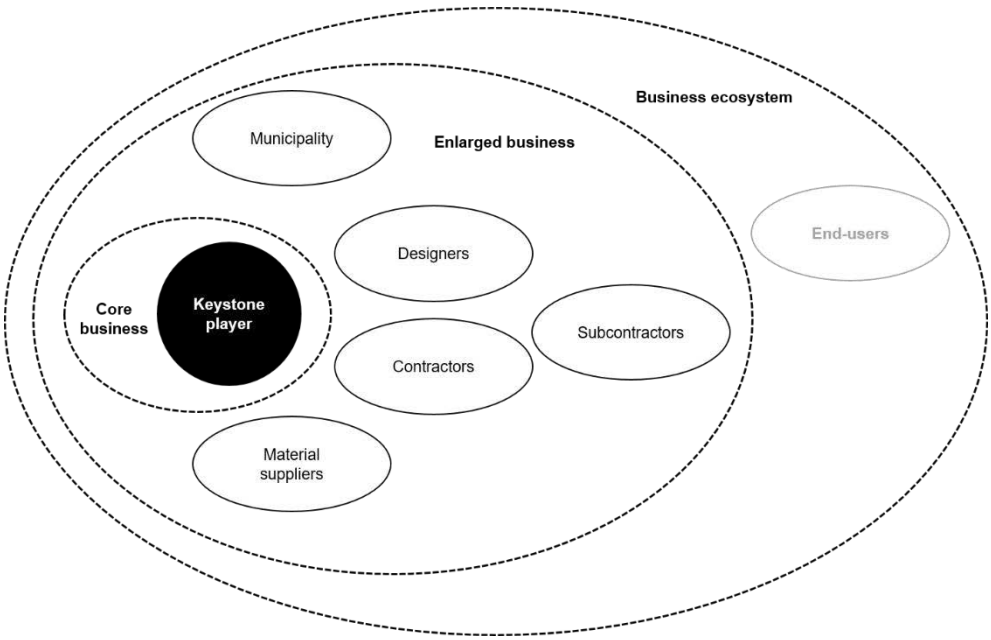

Figure 3. A simplified illustration combining the business ecosystem networks of the studied case projects. The business ecosystem layers are adapted from Moore (1993) and Heikkilä and Kuivaniemi (2012).

Efficient communication and sharing of information between all actors were regarded as important for smooth functioning and for creating a complex product — a building. The interviewees further mentioned that communicating and working together had become easier with time, as the actors had become more familiar with each other. This had also created mutual trust, ensuring that all actors fulfil their duties as agreed while concurrently nurturing flexibility, i.e. working beyond contractual boundaries and thinking about the 'greater good' of the ecosystem.

These benefits gained while working with familiar partners had not gone unnoticed by the keystones: instead of using the more common recruitment method of tendering, all three had taken on actors based on previous experiences of working together. This was considered especially important in the WMC case, which is still a separate niche in the construction industry. Co-evolving with trustworthy partners project by project was regarded to facilitate gaining knowledge of WMC, although other ongoing projects were indicated to reduce the time available for deepening this collaboration.

On the other hand, the keystones had not succeeded in sharing the larger goals they had determined for their projects. Keystones typically disseminate their goals in kick-off meetings, whereas such meetings were not held in the studied cases, all actors were not present, or the goals were not clearly presented in the meeting. Therefore, most actors seemed unaware of the larger goals intended by the keystones, namely testing new products (Case 1), learning about WMC (Case 2) and creating a durable and healthy building (Case 3). However, financial targets and high-quality construction were shared elementary-level goals.

When asked what benefits the project and collaboration had brought to the actors themselves or to other actors in the project, many interviewees mentioned WMC-related aspects: gained experience and knowledge, R&D possibilities, and visibility created specifically by the novelty of WMC and in working with well-known, large partners. Financial benefits and future business opportunities were also mentioned, yet it was also pointed out that profit margins are not substantial with such experimental projects.

Homeowner perceptions and experiences towards the wooden materials of their homes

Article III analysed how homeowners perceive the wood material before moving into their new wooden homes and how they experience and incorporate the wooden material of their homes into their daily lives during the first year of habitation. The results of the article provide deeper understanding of end-user perceptions and experiences compared with existing research, which tend to focus on a single point in time. Furthermore, the qualitative interviews enabled bringing more depth into the topic compared to e.g. using survey data. The case building and its end-users, studied in article III, are the same as those in article I, which considered end-user involvement, while article III particularly examines end-user perceptions and experiences with living with wooden living.

All interviewed future residents had perceptions to share about wood material use in construction purposes (see Table 7). Positive views included softness, cosiness, naturalness, and healthiness. The perceptions were sometimes connected to fond memories and to the Finnish tradition of using wood in many applications, respecting the country's nature and artisanship. Wood was also regarded as renewable and easy to recycle if not excessively treated, yet its environmental sustainability was rarely mentioned unless the matter was brought up by the interviewer. Apprehensions were mostly related to moisture and fire-safety

risks, although residents seemed to rationalize their feelings, connecting such issues to all construction materials. The naturalness and softness, which were mostly regarded in a positive manner, were also connected to concerns towards durability and structural stability, especially in taller building applications. However, the interviewees also regarded taller wooden buildings as "a new trend" and "a Finnish innovation".

During the first year of habitation, the residents had begun accustoming to the wooden material despite mentioning that living in the building did not differ from living in any other building. While wood was not visible within the apartments, its presence could be experienced in other ways, namely through practicality. The soft, echoless soundscape and the ease of attaching pictures to the walls were appreciated properties, while the heavy fire door, vibrating floors, and difficulty in cleaning the novel wood-based wall material were considered annoyances. Additionally, the 'liveliness' of wood was an inconvenience, i.e. the swelling and shrinking of the material due to changes in air humidity, which e.g. prevented doors from closing. Residents with more knowledge and experience of wood material use in buildings seemed more tolerant of such surprises.

Residents had yet to see how the wooden material endures when more time passes, but wood was thought to require more upkeep than other materials, especially in parts exposed to the elements, such as the wooden staircases and the façade. While naturalness of the wood material was considered healthy and to enable recycling, treating the material was considered necessary to increase its durability.

Table 7. Examples of consumer perceptions and experiences of wood use as a building material found during the two interview rounds.

Properties of wooden building material	Perceptions before moving in	Experiences after habitation (1 year)
Aesthetics and well-being	Natural, soft, beautiful Finnish tradition Good indoor air quality	Soft, inviting, homely (No issues mentioned with indoor air quality)
Practical	Easy to work with, versatile No echo Liveable	Easy to drill the walls Pleasant, echoless soundscape Swelling/shrinking of wood material, floor vibrates easily
Technical and ecological	Sensitive to moisture Risk of fire, but prevention exists (e.g. sprinklers) Surface treatments may enhance durability Ecological material	Visible fire prevention: a heavy and noisy fire door Treating wooden surfaces may increase durability but hinder recyclability Wooden façade and staircase need maintenance in the future

Citizen perceptions towards wood material use in construction

Article IV studied how citizens in seven countries — Austria, Denmark, Finland, Germany, Norway, Sweden, and the UK — perceive wood as a construction material. The article contributes to understanding end-user perceptions of wood as a building material by providing breadth and a geographically larger scope to the topic, along with enabling end-users to describe their views more freely through an open-ended question than in quantitative survey responses.

Based on responses, the perceptions towards wood as a construction material could be categorized into five major groups. 'Social aspects' (39%) and 'physical properties' (31%) were mentioned most often. 'Environmental aspects' (14%) and 'other aspects' (13%, namely naturalness and sustainability) generated a modest number of descriptions. 'Economic aspects' were mentioned by a minute portion of respondents (3%).

When respondents mentioned social aspects, they did it mostly in a positive manner. The beautiful appearance of wood material and its ability to create a pleasant and cosy atmosphere were the most frequently described aspects throughout the study. Additionally, wood was believed to improve indoor air quality, although a few respondents also regarded it as unsafe and risky concerning moisture and fire-related issues. Wood use in construction was considered traditional, especially in Finland and Norway, and it was described as suitable for many construction applications ranging from floors, window trims, and trusses to detached homes and even multistorey applications. Some respondents, however, considered wood to be visually unpleasant and to only be suitable for certain applications, such as cottages, sheds, and fences.

The physical properties of wood were regarded as both suitable and unsuitable for construction purposes. The high maintenance need was seen as problematic and inevitable, especially in outdoor applications such as the façade, and its endurance towards moisture, fire, and natural events (e.g. pests and storms) was regarded as poor. On the other hand, respondents also described wood as a durable and sturdy material along with being easy to work with and repair. Sound and thermal insulation were mentioned a few times, in both positive and apprehensive tones.

Renewability, recyclability, and general environmental friendliness were considered positive aspects of wood, yet some respondents stated the opposite. Carbon storage and low emissions were only rarely mentioned. The methods for procuring the wooden raw material were regarded as problematic: wood use was approved, as long as the used timber is sourced from responsibly managed forests and the balance between planting and harvesting is ensured. Deforestation and harming wildlife were not approved. On the other hand, using domestic raw materials was supported.

Regarding affordability, wood was described as both an affordable and cheap material, as well as an expensive one. Affordability, when further described, was connected to local material sourcing and thus to reduced transportation costs and good thermal insulation properties, reducing the need for heating. Expensiveness, on the other hand, was connected to the maintenance need.

Other aspects included respondents describing wood as 'natural'. The word can be considered to have a rather positive connotation and is often connected to positively perceived aspects, such as health, renewability, breathability, recyclability, and a pleasant atmosphere. Negative tones were also present, and in such cases, naturalness was connected to doubts about wood's ability to hold its form and its higher need for maintenance.

Table 8. The five aspects mentioned most frequently by respondents concerning wood as a construction material.

Aspect	Examples from the data
Ambient lifestyle	Beautiful, cosy
Trendiness	Future, suitable for x application (e.g. cottages), unwanted
Naturalness	Natural material, lively
Durability	Requires maintenance, durable
Work easability	Easy to work with, easily modifiable

Similarities and differences were also observed between countries. Aspects such as visual appearance, cosiness, and the naturalness of wood materials were appreciated in all studied countries, while durability and need of maintenance create concerns (Table 8). The UK stood out with the highest number of concerned responses, with respondents being particularly concerned whether wood can endure the country's wet climate. Norwegian respondents were most approving, describing wood as a sturdy material that is easy to work with.

Furthermore, Finnish, Norwegian, and Swedish respondents indicated their approval towards locally sourced timber for building materials, while citizens in Austria, Denmark, Germany, and the UK were concerned about detrimental forest management practices and sourcing timber for construction purposes. Norwegian and Finnish citizens described wood as a traditional material and believed wood to fit in the landscapes of the countries. Conversely, Austrian, Danish, German, and UK citizens were more likely to regard wood as untrendy or unacceptable in construction.

DISCUSSION AND CONCLUSIONS

Contribution and implications

This dissertation contributes to business ecosystem research by examining the business ecosystems behind WMC projects – a context to which the approach had previously not been applied to. Using business ecosystem characteristics, namely the network of participants, the governance system, and shared logic (Thomas and Autio 2014; Pulkka et al. 2016) as a lens, this study specifically examined the collaboration occurring in the currently novel setting of wooden residential building production. The business ecosystem lens was also used to examine end-user involvement in WMC projects, thus also contributing to business ecosystem research from the end-user inclusion viewpoint. Furthermore, this dissertation adds breadth to the existing understanding of end-user perceptions concerning wood as a construction material by using a large cross-cultural dataset and extends the analysis from general opinions to homeowner experiences of wooden living, thereby bringing more depth into existing research knowledge. By applying qualitative methods, end-users were given more freedom to express their perceptions and experiences in their own words, compared to

previous studies concentrating more on survey-based outputs (such as e.g. Larasatie et al. 2018, Kylkilahti et al. 2020).

Through the business ecosystem lens, it was possible to detect points for improvement in the functioning of WMC projects, but also current practices that support collaboration and learning about building with wood, which should therefore be nurtured. The results indicate that similar to any other construction project, collaboration between specialized, complementing participants is a necessity for a WMC project to succeed in creating a functioning product (see e.g. Håkansson and Ingemansson 2013). However, the novelty of using wooden materials and related new building methods requires deeper collaboration and communication both within the projects as well as between projects, for the business ecosystem to effectively co-evolve capabilities and develop WMC-related knowledge (see also Pulkka et al. 2016).

The business ecosystem keystone has an essential role in facilitating collaboration and co-evolution among the participants and in governing the business ecosystem (de Meyer and Williamson 2020). Instead of choosing project participants solely based on costs, the keystones in the studied case projects had made a conscious decision to surround themselves with trustworthy and capable actors they were familiar with, and with whom they could develop WMC-related practices from project to project. Hence, long-term collaboration was apparently sought after, thus benefitting learning and knowledge accumulation in WMC (e.g. Giesekam et al. 2016).

On the other hand, the project-level analysis showed that the keystones also struggled with certain issues. The project actors may be less aware of the overarching goal (e.g. testing new wooden solutions) defined by the keystone, and the feeling of working collaboratively with novel solutions had not reached all actors in the studied projects. Also, some actors felt that their work was not affected by the material choice. Additionally, feedback processes on how the novel design solutions work in practice seemed to be missing. While these hindrances were stated to be common in the construction industry culture, they were most visible when the keystone was a young company and new in its role as a project leader. Therefore, although young, small companies can apparently be more agile than incumbents and more used to taking risks (see e.g. Jones et al. 2016), they may lack leadership skills required for efficient collaboration in a WMC setting.

Frequent meetings or workshops (Kadefors 2004), arranged by the keystone and taking place throughout the project from start to finish, may be beneficial for seeing that the goal is clearly communicated, feedback is shared, and the abilities of all participants are considered in the collaboration (see also e.g. Giesekam et al. 2016; Uusitalo and Lavikka 2020). Tight time restrictions caused by other ongoing projects and the physical distance between participants should, however, be acknowledged.

Common to residential building production (Vischer 2008), end-users were not considered active participants of the business ecosystem during the design and construction phases, but were rather left at the outskirts to take their role as homeowners in the following life cycle phase of the building (i.e. living and use). To some extent, the end-users were able to influence the materials in their new homes (see also Autio and Autio 2013), but deeper involvement was arguably problematic mainly because the future residents were not identified until later on in the process, as also found e.g. by Franzini et al. (2018). While the project participants and end-users apparently shared a similar ultimate goal — high-quality and affordable housing —, both ecosystem collaboration and the end-users could have benefitted more if this goal had been more clearly shared and elevated to also incorporate the

use phase of the wood material. Yet wood properties were not extensively discussed with the future residents or marketed to them.

Homeowner experiences revealed the importance of the daily practicality of the wooden material. While issues, such as the soft soundscape and the ease with which shelfs could be mounted onto the walls were appreciated (see also Karjalainen et al. 2002, 2017), the heavy fire door and the 'liveliness' of the wood were found to be annoying and even surprising. Such experiences and surprises go to show that end-users have grown accustomed to materials, such as concrete, as an urban material (Høibø et al. 2015), and while it also has aspects that affect daily living, such as the cold and hard feeling end-users described, they have come to terms with such properties. Over time this may also happen with wood. As said, quality is also important to the end-users and it should be met regardless of the used material, as also argued by Gold and Rubik (2009). This was also visible when the homeowners demanded fire and moisture safety from all materials, not only from wood, whereas previous studies have indicated high end-user concerns towards wood material's flammability (e.g. Gold and Rubik 2009; Larasatie et al. 2018).

Even though end-users may not be able to affect the structural materials of their homes but can mainly only choose from existing alternatives for their apartments (Mark-Herbert et al. 2018), the construction material does affect the daily lives of people along with their trust in construction quality — especially when considering homeowners as building managers (Lujanen 2010; Stevenson and Rija, 2010). Communicating with end-users may lessen their worries and increase their appreciation towards WMC, which may result in more positive word-of-mouth (Joo and Shin 2018) and advocating in favour of WMC, for example. Moreover, feedback from the end-users can be used when designing future projects (see also e.g. Lessing and Brege 2015), which benefits the whole business ecosystem, including future end-users. However, due to the long lifetime of the product, i.e. the residential building, the ecosystem should apparently not be portrayed as a stagnant system including the keystone and the participants of the design and construction phases, but as an ecosystem that evolves throughout the life cycle of the building, with the homeowners taking the role of the keystone during the use phase (see also Heikkilä and Kuivaniemi 2012).

As WMC is still rare and hence few residents have experiences with it, it is also necessary to recognize the prevailing environment around WMC among citizens and to pre-emptively deal with issues both in building design and when informing the general public. Resonating with previous research (e.g. Larasatie et al. 2018), citizens were found to appreciate the aesthetic qualities of wood and the ambiance it creates, yet concerns also exist and are related to, for example, durability and weathering of the façade. Concerns towards durability may be connected to the large and long-term investment that housing represents (Savolainen 2009) and to retaining economic value, even though economic aspects were rarely mentioned directly by the citizens or homeowners.

On the other hand, the qualitative nature of this study enabled citizens to describe their perceptions in more detail, revealing interesting nuances compared to previous studies. For example, the naturalness of wood was seen to associate with environmental friendliness and healthiness, but also with a need for treatment and maintenance, indicating that individual aspects can carry several meanings. Moreover, the country comparison together with the homeowner interviews suggests that the tradition and memories of using wood in Finland, along with the easy access to domestic raw materials, have a positive connection to end-user approval of wood use in construction. As pointed out for example by Høibø et al. (2015), such information can be valuable for professionals in charge of decision-making concerning building materials, such as developers and contractors (Roos et al. 2010).

In the end, while WMC is often advocated as an environmentally friendly solution compared to existing construction materials and methods, practicality seemed to ultimately weigh more for both the project actors and end-users. For the project actor, the benefits of working in WMC projects were related to, for example, new skills and experience, as well as reference value, whereas the benefits of using wood for the end-users were related to the pleasant and healthy living environment that wood is believed to create. Environmental aspects, such as lowered carbon emissions, were only rarely mentioned as a benefit of wood materials, but sustainability can e.g. be considered to include requirements on the quality, durability, and longevity of the building (see also Häyrinen et al. 2020). These benefits and requirements should be taken into consideration when increasing the knowledge and acceptance concerning WMC, both among construction industry professionals and end-users of the buildings.

Limitations and further research

While this study sheds light on the functioning of a business ecosystem in the WMC context, along with end-user perceptions and experiences, relatively little is still known of the matter. The small case projects and the short timeframe during which the data were collected create their limitations. Furthermore, several actors had to be left out of the business ecosystem inspection. For example, Franzini et al. (2018) acknowledge the "gatekeeper" role of municipalities in urban development and in deciding on construction materials. Regarding the end-users, had the homes been in a taller wooden building or the citizens been asked specifically about WMC, their views may have been different, which is why it would be beneficial for future research to also consider this aspect.

As WMC activity levels are increasing, opportunities for studying WMC business ecosystems and end-users are improved in current and future research. For example, examining a longer time period both from the business ecosystem and end-user viewpoints would be beneficial for deepening the understanding of project-to-project collaboration and how homeowner experiences develop over time. Moreover, this would facilitate understanding the static and dynamic views of construction project business ecosystems. Various data sources, such as meeting minutes (see e.g. Gosselin et al. 2017) and group interviews, could enrich the data and bring actors together.

Conclusions

The objective of this dissertation was to examine the collaboration taking place in residential WMC projects that use a business ecosystem approach, and to deepen the understanding concerning end-user perceptions and experiences of WMC and of end-user involvement in the business ecosystems.

The business ecosystem concept provides a useful lens for assessing effective and ineffective practices of collaboration when working with novel wooden materials in a construction project setting. The ecosystem keystone, such as the developer, has an important role in enabling efficient collaboration. Long-term commitment with trusted partners instead of the more traditional price-based tendering and temporality seemed to benefit the accumulation of WMC-related skills and knowledge among participants from project to project. On the other hand, a lack of feedback processes, end-user involvement, and a shared

goal hampered effective collaboration and learning, and should therefore be paid attention to.

Supporting previous studies, the end-users appeared to appreciate the softer aspects of wood, such as a pleasant and healthy living environment, while durability and maintenance needs were questioned. Yet the qualitative method applied revealed that aspects described by end-users can be multifaceted, e.g. naturalness can be connected to healthiness, but also to a high need of maintenance. Furthermore, the everyday practicality related to the wooden material, such as an echoless soundscape and a heavy fire door, were revealed after experiencing wooden living. The 'liveliness' of the wooden material also seemed to come as a surprise to some of the homeowners.

These findings underline a need for business ecosystem participants to increase their communication with end-users concerning the qualities of novel wooden materials and their everyday usability, along with incorporating the feedback of end-users into the development of future WMC projects. Furthermore, due to the long lifetime of the product, the business ecosystem should not be seen as static, i.e. only including the project actors involved during design and construction, but as a dynamically evolving ecosystem where the end-users' role becomes more prominent when moving into the living and use phase of the building.

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