Accepted manuscript of the article published in the I**nternational Journal of Building Pathology and Adaptation**
https://doi.org/10.1108/IJBPA-04-2021-0059

Finnish Architects' Attitudes Towards Multi-Storey Timber Residential Buildings

Abstract

Material selection is a complex process that includes different actors, e.g. developers, engineers, and architects. Architects are one of the key decision-makers and hence their perceptions influence what they propose as construction materials, thereby impacting a more sustainable built environment. To date, the literature is lacking studies that specifically provide a comprehensive understanding of architects' perceptions of wood construction. As such, this research aims to understand Finnish architects' attitudes towards the use of timber as a structural material in multi-storey (over 2-storeys high) residential construction. A web-based questionnaire was distributed among architects. The 147 received responses highlighted that: (1) respondents perceived the most important advantages of wood as a lightweight, ecological, and local material; (2) wood construction (compared to concrete) included perceived concerns about it being more costly and needing more complex engineering; (3) respondents had a favourable overall attitude towards the use of wood particularly in low-rise residential construction, while their perception of tall housing, including timber ones, was mostly negative. This paper aids in the understanding of the use of timber in residential construction in Finland from the architect's perceived motivations and barriers. The findings confirmed some results reported in other countries, e.g. Sweden and the USA.

Keywords: Residential buildings, multi-storey buildings, timber/wood, Finnish architects, attitude.

1. Introduction

Similar to other countries, Finland has been influenced by global urbanisation (United Nations, 2018): by 2050, nearly 90% of the population will be living in urban areas. More than 80% of Finns already live in urban environments, and in the future the increasing number of business and working-age populations will continue to increase in Finland's major cities, thereby expanding the number of urban residents (Suomala, 2019).

In this sense, high-rise buildings can be a sustainable solution to combat rapid population growth and reduce urban sprawl, due to their compact land use and density characteristics (Ali and Al-Kodmany, 2012; Gunel and Ilgın, 2014; Ilgın, 2018; Ilgın et al., 2021; Ilgın, 2021a; Ilgın, 2021b). Moreover, numerous proposed high-rise residential projects might be an indication that building higher has been gradually gaining popularity in Finland (e.g. 35-storeys high Keski-Pasila 5, 33-storeys high Redi Kalasatama 3 in Helsinki region (CTBUH, 2021). However, it remains to be seen whether this urbanisation and densification trend will continue in the wake of the COVID 19 pandemic, when residents' housing priorities may have shifted. For example, people may favour low-density urban housing and new communities far from the city centers in a post-pandemic environment (Batty, 2020).

Due to its positive environmental properties such as low carbon emissions during processing and significant carbon storage in use, wood construction stands out as one of our best allies in resolving the climate crisis. The use of wood also supports the Finnish government's bioeconomic strategy for a carbon-neutral society in 2035 and addresses European climate policy (Wood Building Programme, 2020). Moreover, from an architectural point of view, timber buildings are thought to have the potential to generate a more pleasant, warm, and natural environment (Ramage et al., 2017; Thomas and Ding, 2018). Further, wood in indoor settings has been shown to improve the well-being of residents regarding living comfort, emotional state, psychological health, and indoor environmental quality (Rice et al., 2006; Tsunetsugu et al., 2007; Gold and Rubik, 2009).

Multi-storey wood construction has been developed and promoted in Finland since the 1990s (Lazarevic et al., 2017). Despite these efforts, the large forest resources, and strong wood construction culture in Finland (Riala and IIola, 2014; Jussila and Lähtinen, 2019), the Finnish market share of timber multi-storey (over 2-storeys high) apartment buildings has remained very low at 10% by 2015 (Toppinen et al., 2018). In this context, multi-storey construction could be the biggest opportunity for growth in wood construction in Finland.

The selection of construction materials consists of numerous criteria e.g. cost, strength, durability, environmental impact, speed of erection, availability, and delivery time (Castro-Lacouture et al., 2009; Hemström et. al, 2011; Xia et al., 2014; Kayan, 2017; Zuhaib et al., 2017). Furthermore, the material selection process is a complicated process including different parties, e.g. developers, architects, engineers, contractors, specifiers, and end-users (Emmitt, 2001; Emmitt, 2002; O'Connor et al., 2004; Bysheim and Nyrud, 2008).

Since architects have been one of the key decision-makers for material selection (Roos et al., 2010; Gosselin et. al, 2017; Conroy et al., 2018), their perceptions influence what they propose as construction material (O'Connor et al., 2004; Mahapatra and Gustavsson, 2008; Roos et al., 2010; Hemström et al., 2011; Xia et al., 2014). Additionally, the perceptions of architects may manipulate an increase in the specification of wood in construction (Bengtson, 2003; Bregulla et al., 2003; O'Connor et al., 2004; Mahapatra and Gustavsson, 2008). On the other hand, architects' intermediation plays an important role in the transition to low-carbon buildings (Fischer and Guy, 2009). These issues highlight the importance of the focus on architects regarding the use of wood in multi-storey construction. However, to date, there are few studies in this area, while there are no studies examining the role of architects and their views on the use of wood in multi-storey construction in the Finnish context (Vihemäki et al, 2020).

Overall, the objective of this research was to gain an overview of Finnish architects' perceptions regarding the use of wood in residential buildings via a survey questionnaire. To understand the drivers and barriers for the design and construction of timber residential projects in Finland, the following research questions were identified:

- What are Finnish architects' motivations to specify wood?
- What is Finnish architects' understanding of the benefits, disbenefits, and barriers of wood construction? (especially compared to concrete construction, which is the most common structure)
- How are timber residential buildings perceived by architects in Finland, and is there a difference in perception between low-rise, mid-rise, and tall buildings?

This study will assist to identify the motivations and barriers perceived by the Finnish architecture community for timber residential construction. In this paper, 'low-rise building', 'multi-storey building', 'mid-rise building', and 'tall building' are defined as a building with 1-2-storeys, over 2-storeys, 3-8-storeys, and over 8-storeys, respectively.

2. Literature review and theoretical framework

2.1 The selection of construction material

Material selection is one of the crucial phases of architectural design that affects the quality of the built environment (Ogunkah and Yang, 2012; Sharma, 2018). Almost all projects have various constraints that affect the material selection process, such as budget and time limitations (Cristóbal et al., 2018). Research shows that most professionals who specify materials prefer materials they are familiar with, especially in time-sensitive projects (e.g. Emmitt and Yeomans, 2008).

While construction costs appear to be prominent among the major determining factors in material selection and construction technology (Tykkä et al., 2010; Akadiri, 2018; Adebisi et al., 2018), recent studies show that this is changing, and the construction industry is moving towards focusing on total life cycle costs (e.g. Backes et al, 2021). In this sense, one of the biggest obstacles to choosing wooden products is the perception that they involve higher costs due to the need for more frequent maintenance and/or shorter life cycles (Riala and IIola, 2014). Despite the growing environmental awareness among stakeholders, there is a reluctance to pay extra costs to reduce the environmental burden of construction. However, this might be different for architects as they do not have easy access to different product costs and they have an aesthetic-oriented rather than a cost-oriented approach like other stakeholders (Markström et al., 2018).

2.2 Considerations affecting human behaviour

Ajzen's theory of planned behaviour (1985; 1991; 2001) describes the probability of certain behaviours among individuals, of which perceived behavioural control is one of the two main parameters. This depends on both internal factors (e.g. knowledge, experience, and skills) and external factors (e.g. availability of time and opportunities). Similarly, in the construction industry, experience greatly influences material selection, and adequate knowledge together with education about wooden construction also plays an important role in this process (Bysheim and Nyrud, 2009; Roos et al., 2010; Mallo and Espinoza, 2015).

As the second main parameter, intention in Ajzen's theory depends on the individual's attitude towards behaviour and subjective norms. However, in the construction industry, subjective norms do not have a significant impact on material selection. However an individual's attitude does, but to a lesser extent than perceived behavioural control (Bysheim and Nyrud, 2009). Related to the tall timber buildings and material selection, for example, it was reported that Swedish architects had a positive attitude towards timber frames in multi-storey buildings, especially due to their environmental performance, but their attitudes towards concrete and steel were even more positive (Hemström et al., 2011).

2.3 Innovation diffusion in the construction industry

Innovation diffusion is an important concept in the theory of planned behaviour. Since some engineered wood products may be new to architects, the theory of innovation diffusion can clarify architects' views on the use of these products and of factors that may influence the likelihood of increased use (Markström et al., 2018). According to the theory, the adoption rate depends on how individuals perceive innovation in terms of various parameters such as utility, compatibility, and complexity. In the context of construction innovation, critical parameters are cost, time, technical performance, environmental impact, safety (Slaughter, 2000). When it comes to material selection, the innovation-decision process usually begins when a particular problem cannot be resolved with the materials for which the specifier already has personal experience (Emmitt and Yeomans, 2008).

In the early stages of innovation diffusion, external drivers e.g. financial issues, demand, and environmental concern can help as in Sweden (Lindgren and Emmitt, 2017), but more competitive systems and increased recognition can reduce these positive effects later. On the other hand, it is unclear whether requests from organizations, governmental authorities, and regulations for the use of timber frames or other promotional initiatives have a positive impact on the diffusion. For example, in Finland, there is a perception among construction companies that such actions contribute to unfair competition for timber and result in a dislike for timber among some of these actors (Riala and Ilola, 2014).

Elements of success and obstacles for innovation diffusion of new wood products were reported by Roos et al. (2010). Among them, solid leadership; the skill of the people engaged; the determination to innovate among all parties involved, and communicating with the market at various times can be considered elements of success. On the other hand, uncertainty and lack of information flow were identified as the major obstacles. In addition, other issues such as lack of legal support, lack of industry interest, lack of experienced professionals, and limited awareness of the advantages of timber framing were cited as critical obstacles to the innovation diffusion of timber framing into multi-storey buildings (Xia et al., 2014).

2.4 Perception of architects to use wood as a building material

Many studies have been conducted about the technological, ecological, social, and economic aspects of wood in construction and various types of building solutions (Toivonen and Lähtinen, 2019). However, a limited number of studies are concentrating on wood as a structural material in residential buildings from the architect's perspective (e.g. Mallo and Espinoza, 2015; Markström et al., 2018). These few studies are all questionnaire- and/or interview-based non-Finnish studies (e.g. Swedish, American origin), and most have been done in the last decade.

On the other hand, there are also some studies on this subject for non-residential buildings (e.g. O'Connor et al., 2004; Bayne and Taylor, 2006; Xia et al., 2014). The following overview was based on studies involving the perception of architects regarding the use of wood as a structural material that also included residential buildings; a summary of all studies is provided in Table 1.

Among the limited number of studies conducted in the last 20 years, architects' perceived motivations and barriers of the use of wood were presented (e.g. Roos et al., 2008; Bysheim and Nyrud, 2008; Roos et al., 2010; Hemström et al., 2011; Mallo and Espinoza, 2015; Viluma and Bratuškins, 2017; Conroy et al., 2018; Markström et al., 2018). Those studies reporting on the perceived benefits and motivations of wood, environmental attributes were recognized as the biggest advantage by the majority of respondents in the studies [i.e. low environmental/climatic impact, environmental performance, or environmental friendliness (Roos et al., 2010; Mallo and Espinoza, 2015; Markström et al., 2018)]. This was followed by its aesthetics properties (e.g. Roos et al., 2008; Markström et al., 2018), ease of use (e.g. Conroy et al., 2018), and speed of erection (e.g. Markström et al., 2018). Other timber construction benefits highlighted by the majority of respondents in a Swedish study were ease of renovating/demolishing and ease of recycling (Hemström et al., 2011).

Wood's structural characteristics including structural performance, strength, form stability, or capacity of large span, remained as unclear issues, where some studies reported them as benefits (e.g. Roos et al., 2010; Mallo and Espinoza, 2015), and some studies reported them as perceived disbenefits of wood (e.g. Roos et al., 2008; Conroy et al., 2018). Similarly, regarding cost-based issues such as maintenance cost or initial capital cost, the US West Coast architect respondents perceived them as an advantage (Conroy et al., 2018), while most surveyed American architects in the study of Mallo and Espinoza (2015) regarded wood construction's structural characteristics as a disadvantage. However, it is unclear why these contradictory views exist; though it might be explained by different contexts, and/or experience and knowledge of respondents with wood construction as previously described. Additionally, the observed positive views are more recent and may reflect increased knowledge, experience but also increased diffusion of timber construction.

On the other hand, apart from the Norwegian study (Bysheim and Nyrud, 2008), architect respondents generally regarded fire-related properties of wood as a limitation to specification (e.g. Roos et al., 2008; Mallo and Espinoza, 2015; Conroy et al., 2018). Moreover, its sound insulation performance was considered as an obstacle to its use in Swedish studies by the majority of respondents (Roos et al., 2008; Roos et al., 2010). Additionally, decay/durability issues were also perceived as a weakness of wood construction (Roos et al., 2010; Conroy et al., 2018). Furthermore, lack of knowledge (e.g. Markström et al., 2018), regulatory code compatibility (Mallo and Espinoza, 2015), insecure supply (Roos et al., 2008) as well as legislative issues and stereotypes (associated with widely known public belief such as its combustive characteristics) (Viluma and Bratuškins, 2017), were reported as barriers to the use of wood in residential construction.

Based on the literature above, architects generally seem to have a positive or encouraging attitude towards the use of wood, however, there are also clear perceived barriers surrounding its use for residential construction - see summary Table 1. Notably, in the past few years there has been increased discussion about the merits of wood construction particularly in terms of climate issues, also reflected in the different findings and focus of the more recent research (e.g. Markström et al., 2018; Conroy et al., 2018; Sotayo et al., 2020).

3. Research method

This study was conducted through a literature survey mainly including international peer-reviewed journals and similar research projects (see section 3.1). Furthermore, the literature survey informed the generation of the web-based survey questionnaire designed to gather information on architects' perceptions, attitudes, and interest in the use of wood in multi-storey (over 2-storeys high) residential buildings.

Questionnaire items were created taking into consideration previous wood product perception research (e.g. Mallo and Espinoza, 2015; Markström et al., 2018) and expressed equally in positive and negative formats to minimize any bias. In this study's questionnaire, 5-point Likert-type scales, multiple-choice, and open answer options were provided. On a Likert-type scale, the 'I don't know' option was given in the required section (perceived benefits of wood compared to concrete) to prevent the participants from giving false information about the question and to distinguish between those who were unsure of the question and those who gave definite answers.

In this research, an online survey was selected since it offers to reach out to a wider population, limits data entry errors, and a cost-effective approach often employed in market research

(Lavrakas, 2008). In advance of the finalization of the questionnaire, a pilot study was conducted with 25 architect respondents from both academia and professional life. Their comments and feedback then helped construct the final questionnaire. While the survey was conducted in Finnish, it should be noted that some questions may be interpreted differently by different participants, as the pilot study showed. Although this source of error cannot be entirely eliminated, productive discussions with the participants both during and after the pilot study aimed to minimise the incidence of it occuring.

The target population of the survey included architects in Finland, regardless of their experience of timber and/or tall building design, hence the survey questionnaire was administered in the Finnish language. On October 14, 2020, e-mails through the internal system of SAFA were sent to 3000 SAFA members, of which 2000 are reported as active members by the relevant responsible contact (Pia Selroos / Senior Advisor) of the Finnish Association of Architects. This was followed by three reminder e-mails, 12 days, 2 weeks, and 4 weeks after the initial e-mail. Further invitations to participate in social media were made. The responses were handled anonymously, and no personally identifiable data was collected or used in the analysis stage. The invitation letter of the survey mainly contained information on the purpose and the sections of the questionnaire (together with informed consent), a short introductory part, and contact details for more information.

In this study, Azjen's theory of planned behaviour, as cited in section 2.2, was used to establish the conceptual framework for identifying Finnish architects' attitudes towards timber and timber residential buildings. According to the theory, the tendency of architects to use or propose timber as a building material varies according to attitude, subjective norms and perceived behavioural control. Attitudes here can be associated with architects' summary evaluation of an object obtained through quality dimensions, e.g. good-bad, harmful-useful, and pleasant-intolerable, so attitude can be interpreted as architects' point of view regarding reliability, suitability, and technical performance of wood. Subjective norms can be associated with architects' expectations of normative responses from other architects or critical players in the construction industry when dealing with timber use. On the other hand, perceived behavioural control includes perceived factors that enable or hinder the decision to recommend the use of wood in construction. In the light of the above-mentioned issues, the questionnaire consisting of the following 4 parts was generated (see also Table 2):

The first part - (Part A) background information - covered the respondents' experience related to the surveyed subjects. They were asked how many years of experience they had in designing, planning, or detailing residential buildings, tall residential buildings (over 8-storeys), timber buildings, and multi-storey (over 2-storeys) timber residential buildings. There were five options offered for all the questions in this part: none, (0-1), (over 1 - 5), (over 5 - 10), 10+.

In Part B, the respondents were asked to indicate the perceived benefits of wood compared to concrete, which is the most used structural material in housing construction in Finland, regarding different parameters (e.g. speed of construction, aesthetics, climate impact). A Likert-type scale was used [from 1 (highly positive) to 5 (highly negative)].

In Part C, the respondents were asked to rate on a Likert-type scale (as Part B) about their perceptions of tall concrete residential buildings, and tall, mid-rise, and low-rise timber residential buildings.

Finally, in Part D, the respondents were asked questions with free comment boxes about the main barriers regarding the use of wood in residential buildings. Additionally, architects' main motivations behind the use of wood in residential projects were probed, especially compared to tall residential buildings.

4. Findings

4.1 Architects' questionnaire - overview

In this study, the response rate was just over 7% (147 responses out of 2000 active SAFA members). This is low, however, other similar studies reported response rates from architects between 7% to 22.7% (O'Connor et al., 2004; Gaston, 2014; Mallo and Espinoza, 2015; Markström et al., 2018). The reasons for lower participation in the survey are unknown; this might include e.g. survey fatigue, a non-attractive survey subject, or the length and complexity of the questions (Fan and Yan, 2010). It was also reported by SAFA (Pia Selroos / Senior Advisor) that these are typical response rates obtained in recent survey studies such as the questionnaire concerning COVID-19 situation in architectural offices and remote working (160 and 109 responses, respectively).

More than half (56%) of 147 respondents were experienced designers with 10 years or more experience in designing, planning, and/or detailing residential buildings, while in terms of tall residential buildings, the majority (59%) had no experience in designing them. Regarding the design, planning, and/or detailing of timber buildings, the majority (35% or 51 architects) of the participants reported 10 years or more of experience, whereas 52% of the respondents stated that they had no experience in designing, planning, and/or detailing multi-storey (over 2-storeys high) timber residential buildings.

4.2. Architects' questionnaire: Perceived benefits of wood compared to concrete

Figure 1 highlights the perceived benefits of wood's characteristics in residential construction compared to concrete as reported by the Finnish architect respondents, in the following order of importance (the total occurrence of 'strongly agree' and 'agree' options): (1) lightweight (92%), (2) ecology (86%), (3) local material (83%), and (4) climate impact (82%). Its secondary perceived advantages were as follows: (5) coziness (78%), (6) ease of recyclability (75%), (7) warm insulation performance (74%), and (8) dry construction method (i.e. specialist method of interior construction with industrially prefabricated elements, which does not require any additional drying time) (70%).

However, the following characteristics were considered as disadvantages compared to concrete (the total occurrence of 'strongly disagree', 'disagree', and 'neutral' options): (1) cost-competitiveness (74%), (2) sound insulation performance (68%), (3) long-term durability (for ex. facades) (65%), (4) structural performance (59%), and (5) fire safety performance (58%).

Note that for all the timber construction benefits offered in the study, the "I do not know" option had low occurrences compared to other options. Additionally, as can be inferred from the comments shared in the free comment box, several architect respondents raised their concerns regarding the structural performance and fire safety performance of wood construction.

4.3 Perception of tall residential concrete buildings, and tall, mid-rise, and low-rise timber residential buildings

Surveyed architects' attitudes towards tall concrete buildings were negative (the total occurrence of 'highly negative' and 'negative' options) (37%) to neutral (34%), with a minority of respondents having a favourable perception (the total occurrence of 'highly positive' and 'positive' options) (28%) - see Figure 2. Interestingly, there was almost no difference in the perception of the participants about tall timber buildings compared to concrete: 36% negative perception to 29% neutral and 30% positive. However, as the number of floors decreases to mid-rise storey heights, this trend turned more positive, with 71% of respondents having favourable perceptions of timber construction. Moreover, when it comes to the use of timber in low-rise residential buildings, the architects' attitudes were predominantly positive and in favour of the use of timber (94%) - see Figure 2. This might indicate that while timber construction is perceived positively in low- to mid-rise housing blocks, the negative perception of tall buildings more generally might influence the perception of tall timber buildings.

4.4 The main barriers and motivations regarding the use of wood in residential buildings and the difference in perception of tall residential buildings

Based on the open answers *(58 responses)* in this part of the survey, the obstacles preventing Finnish architects from specifying wood were listed below in order of importance:

- Lack of demand from the client/building contractor (32 responses)
- Familiarity with concrete construction and lack of expertise in wood construction (16 responses)
- Lack of cost-competitiveness (6 responses)
- Fire safety issues (4 responses)

Note: Some answers addressed more than one obstacle.

The latter two perceived obstacles, i.e. cost-competitiveness and fire safety were also considered as disadvantages wood compared to concrete as reported in other parts of the survey (Section 3.3). Furthermore, its positive environmental attributes such as its smaller carbon footprint, ecological properties, climate-friendliness were assessed as the main motivations behind the use of wood in residential projects among the respondents in the open answers (which was also consistent with Section 3.3). Moreover, the surveyed architects commented about the lack of a need for tall residential buildings in Finland, which also supported the results in Figure 2.

5. Discussion

The findings of this study regarding the main motivations and barriers to the use of wood in residential construction confirmed some of the results reported in other countries such as the USA and Sweden, such as environmental attributes, lightness, fire safety issues, lack of cost-competitiveness (e.g. Conroy et al., 2018; Markström et al., 2018; Mallo and Espinoza, 2015), as summarised in Table 3.

Additionally, in the non-residential building study by Bayne and Taylor (2006) in Australia, wood was perceived to be more suitable for smaller building types such as housing according to the architect respondents. In the Norwegian study on architects' perceptions concerning the use of wood as a structural material, architects were positive about wood utilization in residential buildings up to 3-storeys (Bysheim and Nyrud, 2008). Similarly, the responding Finnish architects had a favourable overall attitude towards low-rise and mid-rise timber housing, which was indicated by previous studies also (e.g. Roos et al., 2008).

In the case of tall buildings, the introduction of wood did not turn the participants' perspective into a positive one, and the architects questioned the need for tall buildings in Finland alltogether. However, no comparison could be made with other studies on this topic in different countries since no similar studies about the perception of tall timber buildings were found at the time of writing.

The positive attitude by Finnish architects for low-rise residential buildings was mostly related to the environmental attributes of wood, e.g. climate impact, ecological properties. These findings verified findings of other similar studies such as Hemström et al. (2011), Markström et al. (2018), and Conroy et al. (2018). Additionally, Roos et al. (2008) confirmed our results in terms of lightness and coziness, while Hemström et al. (2011) supported our findings of ease of recycling and ease of demolition as advantages of timber structures. Among the 20 dimensions provided for the respondents in Figure 1, warm insulation performance and dry construction were not mentioned in other studies. These characteristics were reported as perceived benefits of wood compared to concrete in this study (74% and 70% of responses respectively).

Based on the perceptions of the Finnish participants, fire safety issues were considered as one of the most important disadvantages preventing the common use of timber structures. This was also found in the study among the American architects (Conroy et al., 2018) and Swedish architects (Roos et al., 2008).

Our findings of the perceived familiarity with concrete construction and lack of expertise in wood construction were seen as a major barrier of specifying timber in residential construction; this was also reported in several studies (e.g. Viluma and Bratuškins, 2017). Additionally, our findings on this issue, especially pertaining to the knowledge gaps or lack of expertise in wood construction, confirmed those of Roos et al. (2008).

Lack of cost-competitiveness was identified as one of the most significant obstacles to the use of wood, which resembled the findings in the study of Mallo and Espinoza (2015). However, the earlier findings by Roos et al. (2008) showed some different views on this subject. That study indicated that some respondent architects claimed that, if correctly applied, wood was cost-effective, while other respondents feared high costs owing to perceived risk factors in wood construction.

Finally, this study highlighted that lack of demand from the client/building contractor was the strongest barrier to the use of wood as also emphasized by Xia et al. (2014) - they noted the lack of developer interest. Regarding this obstacle, the architects responding to Xia's survey might not perceive their impact on the choice of frame material as strong compared to the building contractor or client. The relatively low perceived influence of Finnish architects over timber construction choice was also reported in the case of Swedish architects (Roos et al., 2008; Hemström et al., 2011), though North American findings indicated that the material selection was a multi-disciplinary process but mostly determined by architects (O'Connor et al., 2004).

Despite the general attitude and interest of the Finnish surveyed architects to use wood does not necessarily lead to an increase of wood in multi-storey (over 2-storeys high) residential construction. Finnish architect's perceptions of the engineering performance of wood may deter them from putting it forward. Clients, especially in the public sphere, could have an important role to play here in driving the specification of wood to make this happen.

Similarly, future scenarios for timber buildings could improve given the increased significance of environmental aspects in the choice of structural materials that are facilitated by environmental performance policies that underpin client demand and building contractors' decision-making. Additionally, Finnish architects can be ideal promoters for the increased use of wood in residential construction, if their knowledge of engineering and financial aspects is improved, as the lack of experience and level of knowledge may cause architects to bypass timber specification in favour of current prevalent concrete structures. Moreover, one of the biggest challenges in adapting to new materials is the lack of regulation in the construction market in Finland. This is reflected by even leading architecture offices avoiding making large-scale software investments. Elsewhere, this lack of knowledge of wood construction was a strong barrier for aspiring designers to enter the market, thereby slowing down the possible innovative progression of the overall architectural community dealing with timber construction (Sun, 2016).

6. Conclusions and recommendations

The study aimed to understand Finnish architects' attitudes towards the use of timber as a construction material for residential buildings. In doing so, this study made an attempt to identify perceived benefits of wood compared to concrete, perceived motivations and barriers to the use of wood in residential construction as well as architects' views of tall timber residential buildings in Finland.

Regarding the profile of surveyed Finnish architects, most had 10 years or more of experience in designing, planning, and/or detailing residential buildings and timber buildings but the majority had no such experience in multi-storey or tall timber residential buildings.

The most important perceived benefits of wood compared to concrete were that it is a lightweight, ecological, local, and climatically low impact material. Furthermore, these positive environmental attributes were underlined as the main motivations behind the wood utilisation in residential projects among the respondents.

On the other hand, aspects regarding cost-competitiveness, sound insulation, long-term durability, and fire safety performance of wood were considered as disadvantages compared to concrete construction. Moreover, lack of demand from the client/building contractor, and familiarity with concrete construction, and lack of expertise in wood construction together with cost competitiveness and fire safety performance, were highlighted as the biggest obstacles to the use of structural timber among architects.

Participants had a positive general attitude towards low-rise (1-2-storeys) and mid-rise (3-8-storeys) timber housing, while mostly a negative attitude towards tall residential buildings (over 8-storeys), whether they were concrete or timber.

Given the long and dominant tradition and practice of concrete in Finnish residential buildings, it is believed that the following recommendations can improve attitudes towards timber construction and can help to overcome perceived barriers: (1) provide architects with assistance and industry training (e.g. workshops and seminars) regarding wood structures to increase the awareness and knowledge of the technological innovations related to wood products in the building sector and to address perceived difficulties in meeting legislative code requirements; (2) try to change the attitudes of clients and contractors as the ultimate decision-makers through professional bodies by increasing the awareness of the advantages of timber; (3) the government to issue more supportive legislation and regulations to increase the utilisation of wood as a structural material in multi-storey construction.

This study contributes to the understanding of the different factors influencing the decision-making process of timber construction in Finnish residential contexts. The main limitation of this study was the comparatively small sample of architect respondents and a follow-up study of a larger sample and more extensive questions would be beneficial to gain further understanding of the perceived barriers and benefits of timber in Finnish housing construction. Another important issue for future research is the interaction of different factors such as knowledge, perceived risks, economic factors, etc. when choosing construction materials. These relationships and the respective strengths of each aspect can be studied in more detail in both quantitative and qualitative studies.

Future studies of the potential diffusion of multi-storey (over 2-storeys high) residential buildings can scrutinize the attitudes and interest of contractors, structural engineers, and building commissioners towards the use of more wood in Finland since they have a great influence on the choice of structural material. Future works could also include how architects' educational background and participation in continuing education affects their perceptions of the use of wood, and how their familiarity affects their specification of wood as a structural material in Finland.

References

Adebisi, E. O., Stephen, O. O., & Alao, O. O. (2018). Assessment of factors influencing the failure and abandonment of multi-storey building projects in nigeria. International Journal of Building Pathology and Adaptation, 36(2), 210-231. DOI: 10.1108/IJBPA-10-2017-0048

Ajzen, I. (1985). From Intentions to Actions: A Theory of Planned Behavior. In: Kuhl J., Beckmann J. (eds) Action Control. SSSP Springer Series in Social Psychology. Springer, Berlin, Heidelberg. DOI: 10.1007/978-3-642-69746-3_2

Ajzen, I. (1991). The theory of planned behavior, Organizational Behavior and Human Decision. Processes, 50(2), 179-211. DOI: 10.1016/0749-5978(91)90020-T

Ajzen, I. (2001). Nature and operations of attitudes. Annual Review of Psychology, 52, 27-58. DOI: 10.1146/annurev.psych.52.1.27

Akadiri, P. O. (2018). Investigating Factors Influencing Building Materials Selection in Nigerian Construction Industry. American Journal of Civil Engineering and Architecture, 6, 154-157. DOI:10.12691/AJCEA-6-4-4

Ali, M. M., and Al-Kodmany, K. (2012). Tall Buildings and Urban Habitat of the 21st Century: A Global Perspective. Buildings, 2(4), 384-423. DOI: 10.3390/buildings2040384

Backes, J. G., and Traverso, M. (2021). Application of Life Cycle Sustainability Assessment in the Construction Sector: A Systematic Literature Review. Processes, 9(7), 1248.

DOI: 10.3390/pr9071248

Batty, M. (2020). The Coronavirus crisis: What will the post-pandemic city look like?. Environment and Planning B: Urban Analytics and City Science, 47(4), 547-552. DOI: 10.1177/2399808320926912

Bayne, K., and Taylor, S. (2006). Attitudes to the Use of Wood as a Structural Material in Non-residential Building Applications: Opportunities for Growth. Australian Government: Forest and Wood Products Research and Development Corporation. Available online: https://www.fwpa.com.au/images/marketaccess/PN05.1020.pdf (accessed October 08, 2021).

Bengtson, A. (2003). Framing Technological Development in a Concrete context - The Use of Timber in the Swedish Construction Industry, PhD Dissertation, Department of Business Studies, Faculty of Social Sciences, Uppsala University, Uppsala, Sweden.

Bregulla, J. R., Grantham, R., Johansson, H. E., & Enjily, V. (2003). Barriers to the enhanced use of wood in Europe: particular attention to the regulatory barriers. Report prepared by Building Research Establishment (BRE) as a part of the "Roadmap 2010" programme of the European Confederation of Woodworking Industries, CEI-Bois, Brussels. 19 p. Available online: http://www.roadmap2010.eu/ about/PDFs/Reports/BRE_Report.pdf (accessed October 08, 2021).

Bysheim, K., and Nyrud, A. Q. (2008). Architects' Perceptions of Structural Timber in Urban Construction, Conference COST E53, 29-30 October 2008, Delft, The Netherlands.

Bysheim, K., and Nyrud, A. Q. (2009). Using a predictive model to analyze architects' intentions of using wood in urban construction. Forest Products Journal, 59(7/8), 65-74.

Castro-Lacouture, D., Sefair, J. A., Flórez, L., & Medaglia, A. L. (2009). Optimization model for the selection of materials using a LEED-based green building rating system in Colombia. Building and Environment, 44(6), 1162-1170. DOI: 10.1016/j.buildenv.2008.08.009

Conroy, K., Riggio, M., & Knowles, C. (2018). Familiarity, use, and perceptions of wood building products: A survey among architects on the United States West Coast. BioProducts Business, 3(10), 118-135.

Cristóbal, J. R. S., Carral, L., Diaz, E., Fraguela, J. A., & Iglesias, G. (2018). Complexity and Project Management: A General Overview. Complexity, 2018. DOI: 10.1155/2018/4891286

CTBUH. (2021). Council on Tall Buildings and Urban Habitat. Illinois Institute of Technology, S.R. Crown Hall, 3360 South State Street, Chicago, Illinois, USA. Available online: www.ctbuh.org (accessed October 08, 2021).

Emmitt, S. (2001). Observing the Act of Specification. Design Studies, 22, 397-408.

Emmitt, S. (2002). Architectural Technology. London: Blackwell Science.

Emmitt, S., and Yeomans, D. T. (2008). Specifying Buildings: A Design Management Perspective, second ed. Elsevier Butterworth-Heinemann, Amsterdam.

Fan, W., and Yan, Z. (2010). Factors Affecting Response Rates of the Web Survey: A Systematic Review. Computers in Human Behaviour, 26(2), 132-139. DOI: 10.1016/j.chb.2009.10.015

Fischer, J., and Guy, S. (2009). Re-interpreting Regulations: Architects as Intermediaries for Low-carbon Buildings. Urban Studies, 46(12), 2577-2594. DOI: 10.1177/0042098009344228

Gaston, C. W. (2014). Visual Wood Product Trends in North American Nonresidential Buildings. Forest Products Journal, 64(3-4), 107-115. DOI: 10.13073/FPJ-D-13-00077

Gold, S., and Rubik, F. (2009). Consumer attitudes towards timber as a construction material and towards timber frame houses – selected findings of a representative survey among the German population. Journal of Cleaner Production, 17(2), 303-309. DOI: 10.1016/j.jclepro.2008.07.001

Gosselin, A., Blanchet, P., Lehoux, N., & Cimon, Y. (2017). Main Motivations and Barriers for Using Wood in Multi-story and Nonresidential Construction Projects. BioResources, 12(1), 546-570.

Günel, M. H., and Ilgın, H. E. (2014). Tall buildings: Structural systems and aerodynamic form. London: Routledge.

Hemström, K., Mahapatra, K., & Gustavsson, L. (2011). Perceptions, Attitudes and Interest of Swedish Architects towards the Use of Wood Frames in Multi-storey Buildings. Resources, Conservation and Recycling, 55, 1013-1021. DOI: 10.1016/j.resconrec.2011.05.012

Ilgın, H. E. (2018). Potentials and Limitations of Supertall Building Structural Systems: Guiding for Architects, PhD dissertation, Department of Architecture, Middle East Technical University, Ankara, Turkey.

Ilgın, H. E., Ay, B. Ö., & Gunel, M. H. (2021). A study on main architectural and structural design considerations of contemporary supertall buildings. Architectural Science Review, 64(3), 212-224. DOI: 10.1080/00038628.2020.1753010

Ilgın, H. E. (2021a). Space Efficiency in Contemporary Supertall Office Buildings. Journal of Architectural Engineering, 27(3). DOI: 10.1061/(ASCE)AE.1943-5568.0000486

Ilgın, H. E. (2021b). Space Efficiency in Contemporary Supertall Residential Buildings. Architecture, 1(1), 25-37. DOI: 10.3390/architecture1010004

Jussila, J., and Lähtinen, K. (2019). Effects of institutional practices on delays in construction - Views of Finnish homebuilder families. Housing Studies, 35, 1167-1193. DOI: 10.1080/02673037.2019.1651831

Kayan, B. A. (2017). Green maintenance for heritage buildings: Paint repair appraisal. International Journal of Building Pathology and Adaptation, 35(1), 63-89. DOI: 10.1108/IJBPA-05-2016-0011

Lavrakas, P. J. (2008). Encyclopedia of survey research methods (Vols. 1-0). Thousand Oaks, CA: Sage Publications, Inc. DOI: 10.4135/9781412963947

Lazarevic, M., Mäenpää, D., Ovaska, I., Peck, P., Rodhe, H., Temmes, A., & Thidell, Å. (2017). Renewal of Forest Based Manufacturing Towards a Sustainable Circular Bioeconomy. Reports of the Finnish Environment Institute 13/2017, Helsinki. Available online: http://hdl.handle.net/10138/186080 (accessed October 08, 2021).

Lindgren, J., and Emmitt, S. (2017). Diffusion of a systematic innovation: a longitudinal case study of a Swedish multi-storey timber housebuilding system. Construction Innovation, 17(1), 25-44. DOI: 10.1108/CI-11-2015-0061

Mahapatra, K., and Gustavsson, L. (2008). Multi-storey timber buildings: breaking industry path dependency. Building Research & Information, 36(6), 638-648. DOI: 10.1080/09613210802386123

Mallo, M. F. L., and Espinoza, O. (2015). Awareness, Perceptions and Willingness to Adopt Cross-laminated Timber by the Architecture Community in the United States. Journal of Cleaner Production, 94, 198-210. DOI: 10.1016/j.jclepro.2015.01.090

Markström, E., Kuzman, M. K., Bystedt, A., Sandberg, D., & Fredriksson, M. (2018). Swedish Architects View of Engineered Wood Products in Buildings. Journal of Cleaner Production, 181, 33-41. DOI: 10.1016/j.jclepro.2018.01.216

O'Connor, J., Kozak, R., Gaston, C., & Fell, D. (2004). Wood Use in Non-residential Buildings: Opportunities and Barriers. Forest Products Journal, 54(3), 19-28.

Ogunkah, I., and Yang, J. (2012). Investigating Factors Affecting Material Selection: The Impacts on Green Vernacular Building Materials in the Design-Decision Making Process. Buildings, 2(1), 1-32. DOI: 10.3390/buildings2010001

Ramage, M. H., Burridge, H., Busse-Wicher, M., Fereday, G., Reynolds, T., Shah, D. U., Wu, G., Yu, L., Fleming, P., Densley-Tingley, D., Allwood, J., Dupree, P., Linden, P. F., & Scherman, O. (2017). The wood from the trees: The Use of Timber in Construction. Renewable and Sustainable Energy Reviews, 68(1), 333-359. DOI: 10.1016/j.rser.2016.09.107

Riala, M., and Ilola, L. (2014). Multi-storey Timber Construction and Bioeconomy - Barriers and Opportunities. Scandinavian Journal of Forest Research, 29(4), 367-377. DOI: 10.1080/02827581.2014.926980

Rice, J., Kozak, R. A., Meitner, M. J., & Cohen, D. H. (2006). Appearance Wood Products and Psychological Well-Being. Wood and Fiber Science, 38(4), 644-659.

Roos, A., Woxblom, L., & McCluskey, D. (2008). Architects', and Building Engineers', and Stakeholders' Perceptions to Wood in Construction - Results from a Qualitative study, Scandinavian Forest Economics: Proceedings of the Biennial Meeting of the Scandinavian Society of Forest Economics, 42, 184-94. DOI: 10.22004/ag.econ.198817

Roos, A., Woxblom, L., & McCluskey, D. (2010). The Influence of Architects and Structural Engineers on Timber in Construction - Perceptions and Roles. Silva Fennica, 44(5), 871-884.

DOI: 10.14214/sf.126

Sharma, A. (2018). Green Building Materials and Designs: A Study. International Journal of Sustainable Building Technology, 1(1).

Slaughter, E. S. (2000). Implementation of construction innovations. Building Research & Information, 28(1), 2-17. DOI: 10.1080/096132100369055

Sotayo, A., Bradley, D., Bather, M., Sareh, P., Oudjene, M., El-Houjeyri, I., Harte, M. A., Mehra, S., O'Ceallaigh, C., Haller, P., Namari, S., Makradi, A., Belouettar, S., Bouhala, L., Deneufbourg, F., & Guan, Z. (2020). Review of state of the art of dowel laminated timber members and densified wood materials as sustainable engineered wood products for construction and building applications. Developments in the Built Environment, 1, 1-11. DOI: 10.1016/j.dibe.2019.100004

Sun, J. (2016). Mid-rise Timber Construction in Finland A Study on Material, Technology and Market Maturity, MSc Thesis, Civil Engineering, Helsinki Metropolia University of Applied Sciences, Helsinki, Finland.

Suomala, T. (2019). Understanding the Perceptions of Urban Citizens Concerning a Forest-based Bioeconomy, MSc Thesis, Department of Forest Sciences, Faculty of Agriculture and Forestry, University of Helsinki, Helsinki, Finland.

Thomas, D., and Ding, G. (2018). Comparing the Performance of Brick and Timber in Residential Buildings - The Case of Australia. Energy and Buildings, 159, 136-147.

DOI: 10.1016/j.enbuild.2017.10.094

Toivonen, R., and Lähtinen, K. (2019). Sustainability - A Literature Review on Concealed Opportunities for Global Market Diffusion for the Cross- Laminated Timber (CLT) in the Urbanizing Society; The Manuscript for Bioproducts Business; IUFRO: Curitiba, Brazil.

Toppinen, A., Röhr, A., Pätäri, S., Lähtinen, K., & Toivonen, R. (2018). The future of wooden multistory construction in the forest bioeconomy - A Delphi study from Finland and Sweden. Journal of Forest Economics, 31, 3-10. DOI: 10.1016/j.jfe.2017.05.001

Tsunetsugu, Y., Miyazaki, Y., & Sato, H. (2007). Physiological Effects in Humans Induced by the Visual Stimulation of Room Interiors with different Wood Quantities. Journal of Wood Science, 53, 11-16. DOI: 10.1007/s10086-006-0812-5

Tykkä, S., McCluskey, D., Nord, T., Ollonqvist, P., Hugosson, M., Roos, A., Ukrainski, K., Nyrud, A. Q., & Bajric, F. (2010). Development of timber framed firms in the construction sector - Is EU policy one source of their innovation?. Forest Policy and Economics, 12(3), 199-206. DOI: 10.1016/j.forpol.2009.10.003

United Nations. (2018). World Urbanization Prospects 2018, Department of Economic and Social Affairs, Population Dynamics. Available online: https://population.un.org/wup/ (accessed October 08, 2021).

Vihemäki, H., Toppinen, A., & Toivonen, R. (2020). Intermediaries to accelerate the diffusion of wooden multi-storey construction in Finland. Environmental Innovation and Societal Transitions, 36, 433-448. DOI: 10.1016/j.eist.2020.04.002

Viluma, A., and Bratuškins, U. (2017). Barriers for Use of Wood in Architecture: The Latvian Case. Architecture and Urban Planning, 13, 43-47. DOI: 10.1515/aup-2017-0006

Wood Building Programme. (2020). Finnish Ministry of Environment, Available online: https://ym.fi/en/wood-building (accessed October 08, 2021).

Xia, B., O'Neill, T., Zuo, J., Skitmore, M., & Chen, Q. (2014). Perceived Obstacles to Multi-storey Timber Frame Construction an Australian Study. Architectural Science Review, 57(3), 169-176. DOI: 10.1080/00038628.2014.912198

Zuhaib, S., Manton, R., Hajdukiewicz, M., Keane, M. M., & Goggins, J. (2017). Attitudes and approaches of irish retrofit industry professionals towards achieving nearly zero-energy buildings. International Journal of Building Pathology and Adaptation, 35(1), 16-40. DOI: 10.1108/IJBPA-07-2016-0015