Chapter

Perceptions, Attitudes, and Interests of Architects in the Use of Engineered Wood Products for Construction: A Review

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Abstract

Increased use of engineered wood products (EWPs) and thus decreasing share of non-biobased materials such as concrete reduces the impact of buildings on the climate by mitigating the primary energy use and greenhouse gas emissions in construction. A construction project includes many parameters, where the selection of construction material is one of the crucial decisions with its numerous criteria e.g. cost, strength, environmental impact. Furthermore, this complicated process includes different parties such as architects, engineers, contractors. Architects are among the key decision-makers in material selection, and their perceptions influence what they propose and hence an increase in wood construction. In literature, many studies have been conducted on the technological, ecological, economic aspects of EWPs, while limited studies are focusing on EWPs for construction from stakeholders' perspective. In this chapter, architects' attitudes towards the use of EWPs in buildings were scrutinized.

Keywords: Engineered wood products, construction, architects, attitude

1. Introduction

By its very nature, one cubic meter of wood stores almost a ton of CO_2, so wood reduces the carbon footprint of the construction industry while evaluating the entire life cycle from raw material to production, use, and recycling, and timber buildings play an important role in supporting to the sustainable bioeconomy [1, 2].

Studies indicate that increasing the use of EWPs in the construction sector has environmental benefits, as wood is a renewable and lightweight material [3, 4], where utilization of EWPs instead of conventional building materials e.g. concrete or steel, the total fossil fuel footprint of building construction can be diminished to a considerable extent through environmental-friendly-material replacement [5, 6]. Also, based on some estimates, substituting concrete with wood could lessen the energy used by construction processes by 40%, while greenhouse gas emissions could be reduced by 35% [7, 8]. Extensive use of EWPs may have helped make the transition towards more carbon-free production of building materials [9, 10].

A construction project involves a large number of participants with various roles, goals, and concerns [11] as in the case of high-rise timber buildings e.g. Mjøstårnet (Norway, 2019) (**Figure 1**), HoHo (Austria, 2020) (**Figure 2**). Besides, the building material selection process includes many parameters,

e.g. cost, structural performance, environmental friendliness, fire performance, availability, and speed of construction [12, 13]. Moreover, the material selection procedure is a complex non-linear process involving various actors such as contractors, structural designers, developers, and architects [14–16].

Among these parties involved, architects play a critical role in material selection [17, 18], their perceptions influence their choice of material in the structural frame [13, 15, 19, 20]. Perhaps more importantly, architects' perceptions could lead to an increase in the use of EWP for construction [19, 21].

In the literature, many studies have been carried out on the ecological, technological, economic, and social aspects of engineered wood products and various technical solutions in buildings [22]; while there is a relatively limited number of studies concentrating on the EWPs for construction from the stakeholders' perspective (e.g. [11, 16, 20–25]).

This chapter presented a comprehensive overview of the perceptions, attitudes, and interests of architects in the use of EWPs together with their perceived benefits and barriers for construction. This study gathered, mapped out, and systematized scattered and multifaceted knowledge on architects' attitudes towards EWPs employment in buildings, and chronologically presented them in an accessible and manageable discourse. Notably, the chapter also revealed how this perception has changed over time.

Figure 1.
Mjøstårnet (Norway, 2019) (Source: Wikipedia).

Figure 2.
HoHo (Austria, 2020) (Source: Wikipedia).

An increasing emphasis on the climate impact of building materials in the construction sector should therefore increase the likelihood that future EWPs will be favored to a greater extent. In this sense, attempts to increase the awareness of architects about EWPs will have a positive effect, e.g. regarding the economic aspects. In this study, wood or timber refers to engineered timber products such as cross-laminated timber, laminated veneer lumber, glue-laminated timber/glulam.

2. Studies on architects' attitudes towards the use of EWPs for construction and discussion

In the literature, several studies from different countries such as Australia, America, Sweden are concentrating on wood as a structural material in the buildings from architects' perspective through questionnaires and/or interviews (e.g. [13, 20, 23, 24, 26, 27]).

Among the studies, Truskett undertook surveys and interviews with architects in Victoria (Australia) to explore factors influencing the specification of wood products [28]. The findings showed that while the vast majority (90%) of those surveyed 'always or mostly' used structural timber for residential purposes, only 20% frequently used structural timber for non-residential applications. According

to the architects, timber as a structural and finishing material has strong aesthetic appeal, but the factors such as maintenance and durability, professional networks, industry practice, information, and environmental issues hamper its general use.

Kozak and Cohen focused on the construction material selection of architects (n = 594 out of 3,986) and structural engineers (n = 384 out of 1,822) for non-residential buildings through an online survey in the United States and Canada [26]. The results showed that steel and concrete continue to be the most common material in non-residential applications, whereas wood governs the construction market for elderly housing and is also frequently employed in religious buildings, restaurants, and commercial/residential combinations. It was also pointed out that as the building height increases, the use of wood decreases. However, the attitudes of architects were encouraging towards the use of timber-frame if they had previously specified it.

In 2004, Wagner and Hansen scrutinized material preferences among architects and engineers in America and Chile by a cross-cultural comparison to establish a procedure for choosing a customer group of a company and then classifying its demands and needs [27]. They stated that American architects did not give much weight to issues concerning cost and ecological properties of the building material when deciding on wood construction, whereas other considerations e.g. dimensional stability were thought to have more potential for development when compared with competing materials like steel. Similarly, surveyed architects from Chile were not interested in the environmental features of the wood. Besides this, both sample groups of architects had a positive attitude towards the aesthetical properties of wood, and they perceived uniform quality as an essential asset. It was also noticed that fire-related issues received less concern among the architects than the relevant literature suggests [26].

O'Connor et al. studied architects' and engineers' perceptions regarding the use of wood in the North American non-residential construction sector through an extensive mail survey applied to a series of specifier's focus groups [15]. This research identified several perceived challenges for wood utilization in construction: building code concerning fire safety; cost-competitiveness with steel especially in terms of complicated structures or structures with a longer span; design performance related to strength, durability, stiffness, and lack of established practices. They also proposed short- and long-term recommendations for addressing these obstacles.

The research of Bayne and Taylor also examined the barriers to the use of wood in Australian non-residential buildings to understand the reasons behind the common use of non-wood products e.g., concrete and steel [29]. They aimed to identify the reasons for the lack of confidence in specifying wood as a structural material in these buildings. As a result of interviews with 34 architects, engineers, building designers, and project managers, a range of strengths and weaknesses regarding the structural application of wood to non-residential use were underlined. Findings suggested that aesthetics, easy construction, and adaptability of design and fire performance were evaluated as advantages, while cost and speed of erection were taken as the most common obstacles by the specifiers. It was also concluded that the use of wood was found more suitable and promising by the architects for smaller building types such as housing for the elderly, schools, public buildings, and churches.

In 2008, Roos et al. presented perceptions of 23 Swedish architects and structural engineers about the material selection process, which also included a comparison of wood with other materials, the effects of main stakeholders, and the relation of wood construction with professional roles and knowledge [30]. Both architects and engineers were interested in using wood but perceived it as complicated. This study as a prospect highlighted the issues such as clear demonstration

of business-sound wood compared with concrete and steel; functional information flows from the construction industry to wood sector; expression of smart solutions enabling flexibility and appropriate span lengths from an architectural standpoint; putting emphasis on aesthetic and visual aspects of timber-frame, and importance of providing more information about environmental benefits of wood by suppliers.

Bysheim and Nyrud investigated Norwegian architects' perceptions regarding the use of wood as a structural material in urban construction via a questionnaire to measure attitudes towards the physical, mechanical, and fire-related properties of wood [31]. They found that many architects show a tendency to use structural timber, but few are planning to do so. They were also positive; fire and aesthetically related properties, costs of using structural timber compared to substitutes, and the energy-related properties of the material, the physical and mechanical properties of timber-frame. They felt qualified to specify timber-frame in buildings but did not perceive the choice of using structural timber as being entirely up to them. The architects had positive attitudes towards timber-frame in residential buildings but were negative towards use in other building types. Additionally, they were positive to utilize in buildings up to 3-story. The architects had little experience with timber-frame in other building types other than residential ones. Most of the respondents strongly agreed that other architects would have a positive tendency to them employing timber-frame, whereas contractors and real estate developers were perceived as negative towards the use of timber-frame.

Robichaud et al. explored the challenges to the use of wood in the North American non-residential construction sector [32]. This study aimed to examine the possible role of communication in this emerging market among architects through a survey (n = 165 out of 5,000). The results showed that generally, the architects assessed wood to be a 'sincere' but 'unexciting' structural material. When compared to concrete and steel, wood was perceived as the most environmentally friendly material. However, wood was rated with the lowest score in terms of durability, fire-resistant, structural performance, and contribution to the high building value. In the recommendation part of the study, the issue of better communication on the part of wood producers and product information was highlighted.

The research of Roos et al. analyzed architects' and structural engineers' attitudes and perceived factors that hinder or facilitate the specification of wood construction in Sweden [20]. The main finding of this research was that the material preference of architects and structural engineers is affected by attitudes concerning the properties of wood and beliefs about the control and ease of building in wood. Wood was generally perceived as a suitable building material. Issues about decay, instability, and sound transmission were assessed as negative aspects, while the features of strength, environmental friendliness, simple handling, and suitability for use along with industrial methods were taken as advantages of wood. Besides this, developers and contractors were perceived as the most influential parties by both Swedish architects and structural engineers in the material selection process.

The result suggests that if the following measures are taken into consideration, perceived obstacles could be lessened: (i) developing clearer business concepts for timber-based transparent and affordable construction approaches that decrease the uncertainty, (ii) creating prefabrication methods for wood to reduce the risk factor in the construction, (iii) developing education and training in building design and construction in wood, (iv) providing information about the environmental performance of wood as a building material, (v) improving the 'professional status' of wood via interesting design, (vi) supporting architects and engineers in pursuing wood construction and developing a dialogue among all the related professions.

Hemström et al. assessed Swedish architects' perceptions, attitudes, and interest towards steel-, concrete-, and timber-frames in multi-story buildings through

a web-based questionnaire (n = 412 out of 3,600) [11]. The results indicated that concrete was found the most favorable frame material for multi-story construction mainly because of its performance of engineering-based issues e.g., stability and fire safety that was considered critical for the selection of frame material. The general attitude towards, and interest in, timber-frame utilization was positive and related to its perceived environmental features. Differing from findings in North America [15], this study showed that costs and time to construct a building are not perceived as major barriers to the use of wood among architects in Sweden. Contradictory to the perception of wood being a less suitable multi-story frame material than concrete and steel, the interest in the use of wood frames was large. Contrary to Norwegian findings [16], the overall attitude towards the use of wood frames in residential buildings presented here was not different from the attitude towards the wood in non-residential buildings. Besides this, the results showed that contractors, structural engineers, and building commissioners have a great influence on the choice of frame material.

In 2014, Xia investigated the reasons as perceived obstacles for comparatively limited use of the timber-frame in multi-story non-residential buildings (compared to low-rise housing) among industry professionals - also including architects - in Australia by a questionnaire survey (n = 74 out of 176) [13]. The results indicated five main groups of identified obstacles: (1) lack of support in official regulations, (2) lack of interest in the industry, (3) lack of experience in professionals, (4) perception of drawbacks, and inadequate knowledge about merits of timber-frame utilization. This study also made several recommendations concerning more supportive legislation by the governmental side to stimulate the use of wood in multi-story building construction, industry training to raise the awareness and knowledge of the technological improvements regarding EWPs, the attitudes of developers and investors as the most influential decision-makers towards increasing the awareness of timber-frame advantages.

Viluma and Bratuškins conducted research among architects and other stakeholders in Latvia to find out the main barriers to using wood for buildings through 38 interviews and questionnaires [33]. There were 73 answers from 85 registered persons of which 36 were architects, 25 were students and lecturers, as well as representatives from timber production and media. In this study, the main motivating factors and seven main barriers to the selection of wood constructions were identified. Research results showed that architects' attitude towards timber-frame, in general, is positive, but they thought that due to the Latvian Fire Safety Regulation, it is not easy to find solutions for wood construction. Additionally, the architects emphasized the *stereotypes, legislation,* and *the specialist's qualification* as the main barriers, while the architecture students opted for the lack of knowledge, lack of experience, and lack of information as the main obstacles out of seven given possibilities. Two of the seven barriers formulated - *stereotypes* and *legislation* - were not stated in other research, however, these are the most mentioned barriers in the Latvian case.

Conroy et al. investigated familiarity, use, and perceptions of EWPs among the AIA-certified architects across Washington, Oregon, and California through an online questionnaire (n = 533 out of 3,469) [18]. The results indicated that durability, fire resistance, and strength were assessed as weaknesses of engineered wood products, unlike other studies such as [16, 29] that found architects saw wood fire performance as a strength. The architects from Washington and Oregon projected the use of wood in the construction industry to develop more in the next five years compared to steel and concrete. To boost the use of wood as a construction material for the structure and building enclosure in non-residential buildings, it was

recommended that the forest products industry enhances its internet presence, developing interdisciplinary communication strategies.

As one of the most recent studies, Kuzman et al. attempted to better understand the specification process of EWPs and to provide an updated overview of the perceived identity of these materials among architects in Slovenia, Austria, France, Sweden, Croatia, and Bosnia, and Herzegovina [34]. The results indicated that generally, participating architects have a positive attitude towards wood utilization in all countries. Thermally modified wood was perceived as positive, whereas the architects were unfamiliar with more recently introduced wood modification methods e.g., acetylation, furfurylation (which are not well known). Their findings suggested that the opportunities for wood to gain a greater market share will grow.

Markström et al. probed Swedish architects' perception of the use of EWPs in buildings and the parameters which positively influence the preference of these products via a survey questionnaire [24]. Findings highlighted that in general, and as per the more recent study by [34], the perception of EWPs is positive among Swedish architects, and most of them think that their use will increase in the future. They also added that other decision-makers with greater influence over the material selection, such as contractors, developers choose other materials. A lack of knowledge, as well as uncertainties about the quality over time, were other common reasons for not preferring EWPs. The results also indicated that environmental concerns and aesthetic appearance are the main reasons to select these materials for the architects involved in building projects. It was stated that knowledge, familiarity, and architects' attitude play a role in increasing the use of EWPs.

Therefore, it can be said that perceived positive aspects of EWPs have markedly changed from earlier studies in 1997. By that year, in one of the studies by [28] entitled *'Factors influencing architects in their specification of timber and timber products'*, architects perceived EWPs positively, mostly due to a strong image of their aesthetic appeal. However, later studies showed that according to the architects, EWPs had numerous perceived positive aspects besides their aesthetic quality as seen in **Table 1**. Among these positive aspects, *environmental performance* (e.g. [11, 20, 30, 32]), *energy efficiency* (e.g. [11, 16, 29]) and *speed of erection* (e.g. [30]) were the highlights. On the other hand, *durability, fire resistance,* and *strength* were assessed as the most critical barriers to EWPs in the last two decades of research among architects (e.g. [15, 18, 20 26, 32]). In general, in the light of the above-mentioned studies, it can be stated that architects adopted positive attitudes towards the use of EWPs in construction.

In terms of the major benefits and barriers to using EWPS for construction, similar findings were identified in different studies such as [11, 24, 32]. Architects mostly had a positive attitude towards aesthetic quality (e.g. [24, 31]) and environmental performance (e.g. [18, 26]) of EWPs.

Also, in Bayne and Taylor's study on the barriers to the use of EWPs, it was found that the use of timber is more suitable for smaller buildings such as housing development [29]. Similarly, Bysheim and Nyrud found that architects took a positive attitude towards the use of timber as frame material in three-story houses [31].

Some other studies among architects such as [11, 18, 24, 32] highlighted *ecological characteristics* of EWPs such as low climate impact and environmental friendliness.

In studies conducted among architects in the USA [18, 32] and those in Sweden [30], *fire safety issues* were considered as one of the most important obstacles to the widespread use of timber frame structures. On the other hand, exceptionally, fire performance was assessed as a positive consideration for the structural application of timber for non-residential purposes by [29].

Study by (chronologically)	Target groups	Main perceived benefits of EWPs	Main perceived barriers to EWPs
[24]	architects in Sweden	• aesthetics • low impact on the environment • speed of construction	• lack of knowledge
[18]	architects in the US West Coast	• ease of use • aesthetics • cost • environmental friendliness	• durability • fire resistance • structural performance
[33]	stakeholders (including architects) in Latvia		• stereotypes • legislation • lack of knowledge
[13]	industry professionals (including architects) in Australia		• maintenance costs • fire resistance • limited awareness of emerging technologies
[11]	architects in Sweden	• sustainability • ease of renovation and demolition • ease of recycling	
[20]	architects and structural engineers in Sweden	• strength • environmental friendliness • simple handling • compatibility with industrial methods	• durability • instability • sound insulation
[32]	architects in North America	• environmental friendliness	• durability • fire resistance • structural performance
[31]	architects in Norway	• aesthetics • fire resistance • cost • physical and mechanical properties	
[30]	architects and building engineers in Sweden	• lightweight • aesthetics • good indoor climate • environmental friendliness	• fire resistance • sound insulation • form stability • insecure supply • unsuitability for large-span-structure
[29]	architects, engineers, building designers, and project managers in Australia	• aesthetics • ease of use • adaptability of design • fire resistance	• structural performance • cost

Study by (chronologically)	Target groups	Main perceived benefits of EWPs	Main perceived barriers to EWPs
[27]	architects and engineers in the US and Chile	• warmness • consistent material with a unique texture	
[26]	architects and structural engineers in the US and Canada	• warmness • functionality • cost • environmental friendliness	• fire resistance • durability • inconsistent price • insecure supply

Table 1.
Studies on architects' attitudes towards the use of EWPs for construction.

As many studies (e.g. [13, 33]) reported, *more experience with concrete construction* compared to timber was recognized as the main disadvantage of EWPs for construction. Additionally, *knowledge gaps or lack of expertise* in timber construction were underlined as weaknesses in the studies by [30, 35]. Although *lack of cost competitiveness* was generally seen as one of the major barriers to the use of EWPs (e.g. [15, 29]), Roos et al. pointed out that while some architects surveyed claim that EWPs are cost-effective when applied correctly, others fear high costs due to perceived risk factors in timber construction [30].

Besides, according to the participants in the study by Xia et al., *lack of developer interest* was the strongest obstacle to the use of EWPs [13]. Regarding this, the surveyed architects may not be able to perceive their impact on the choice of frame material as strongly as building contractors or clients. This issue may support the relatively low perceived influence of Swedish architects [11, 30], while it may differ from the findings by O'Connor et al. that architects played the most critical role in the multidisciplinary material selection process [15].

Overall, architects' perceptions of EWPs' engineering performance can deter them from employing EWPs for construction. Such a change can be driven by an increase in examples of promising timber building applications. e.g. high-rise buildings (over 8-story), and so the general attitude of architects towards EWPs will be more positive in terms of engineering-based features such as sound insulation, fire safety, durability, and structural performance.

Future scenarios for wooden buildings could improve if there is a new trend towards greater importance of environmental factors in the choice of structural material facilitated by policies, which can make a difference in the demands of customers and the tendencies of contractors.

Moreover, architects can play an important role as prime marketers in increasing EWPs for construction, but it seems that more initiatives are required to enhance their familiarity since the lack of experience and level of knowledge may prevent architects from proposing timber in their projects.

3. Conclusions and recommendations

The aim of this chapter was to understand the architects' perceptions, attitudes, and interests in the use of EWPs for construction. In doing so, this research attempted to identify perceived major benefits and barriers to EWPs utilization.

Overall, architects mostly had a positive attitude towards the use of EWPs. Among EWPs' positive aspects, aesthetic quality, environmental performance, energy efficiency, and speed of erection were the highlights. Durability, fire resistance, and strength were assessed as the most critical barriers to the common use of EWPs. These were followed by a lack of cost competitiveness, knowledge gaps or lack of expertise, and lack of developer interest.

In this sense, the following recommendations may help to overcome identified barriers by improving overall attitudes towards EWPs for construction:

(1) providing architecture students with more education and inspiration at university, more information about wood-based products, better design aids, and more design examples (2) supporting architects in timber construction by creating a sharing environment with members of these professions (3) developing more active participation in EWP-based problem solving and better interdisciplinary communication strategies among timber suppliers, the timber construction industry and the architectural community (4) developing business-oriented approaches for timber compared to traditional materials e.g. concrete in construction (5) developing effective timber prefabrication methods to reduce the risk factor in construction (6) Enhance the collaboration of different stakeholders such as government, client, designer, contractor, and supplier by issuing more supportive regulations and guidelines to increase the use of EWPs for construction.

It is believed that this chapter will help to deepen the understanding of various considerations shaping the decision-making process in the use of EWPs for construction.

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References

[1] Tolppanen J, Karjalainen M, Lahtela T, Viljakainen M. Suomalainen puukerrostalo: rakenteet, suunnittelu ja rakentaminen. Helsinki: Opetushallitus: Puuinfo. 2013.

[2] Aaltonen JA. Viewpoints of Residential Multi-Story Construction Industry's Productivity, Environmental Regulations and Future in Finland, MSc Thesis, Forest Economics and Marketing Faculty of Agriculture and Forestry, University of Helsinki, May 2019.

[3] Gustavsson L, Joelsson A, Sathre R. Life cycle primary energy use and carbon emission of an eight-storey wood-framed apartment building. Energy and Buildings. 2010;42:230-242.

[4] Høibø O, Hansen E, Nybakk E. Building material preferences with a focus on wood in urban housing: Durability and environmental impacts. Canadian Journal of Forest Research. 2015;45:1617-1627.

[5] Milaj K, Sinha A, Miller TH, Tokarczyk J.A. Environmental utility of wood substitution in commercial buildings using life-cycle analysis. Wood and Fiber Science. 2017;49: 338-358.

[6] Hurmekoski E, Myllyviita T, Seppälä J, Heinonen T, Kilpeläinen A, Pukkala T, Mattila T, Hetemäki L. Impact of structural changes in wood-using industries on net carbon emissions in Finland. Journal of Industrial Ecology. 2020;24:899-912.

[7] Herczeg M, McKinnon D, Milios L, Bakas I, Klaassens E, Svatikova K, Widerberg O. Resource Efficiency in the Building Sector. Final Report, Prepared for European Commission by ECORYS and Copenhagen Resource Institute, Rotterdam, the Netherlands. 2014.

[8] Kylkilahti E, Berghäll S, Autio M, Nurminen J, Toivonen R, Lähtinen K, Vihemäki H, Franzini F, Toppinen A. A consumer-driven bioeconomy in housing? Combining consumption style with students' perceptions of the use of wood in multi-storey buildings, Ambio. 2020;49:1943-1957.

[9] Hildebrandt J, Hagemann N, Thrän D. The contribution of wood-based construction materials for leveraging a low carbon building sector in Europe. Sustainable Cities and Society. 2017;34:405-418.

[10] Viholainen N, Kylkilahti E, Autio M, Toppinen A. A home made of wood: Consumer experiences of wooden building materials. International Journal of Consumer Studies. 2020;00:1-10.

[11] Hemström K, Mahapatra K, Gustavsson L. Perceptions, Attitudes and Interest of Swedish Architects towards the Use of Wood Frames in Multi-storey Buildings. Resources, Conservation and Recycling. 2011;55:1013-1021.

[12] Castro-Lacouture D, Sefair JA, Flórez L, Medaglia AL. Optimization Model for the Selection of Materials Using a LEED-Based Green Building Rating System in Colombia. Building and Environment. 2009;44:6:1162-1170.

[13] Xia B, O'Neill T, Zuo J, Skitmore M, Chen Q, Perceived Obstacles to Multi-storey Timber Frame Construction an Australian Study, Architectural Science Review.2014;57:3:169-176, 2014.

[14] Emmitt S. Architectural Technology. London: Blackwell Science. 2002.

[15] O'Connor J, Kozak R, Gaston C, Fell D. Timber Use in Non-residential Buildings: Opportunities and Barriers. Forest Products Journal. 2004;5:3:19-28.

[16] Bysheim K, Nyrud, AQ. Using A Predictive Model to Analyse Architects'

Intention of Using Wood in Urban Construction. Forest Products Journal. 2009;59:7/8:65-74.

[17] Gosselin A, Blanchet P, Lehoux N, Cimon Y. Main Motivations and Barriers for Using Wood in Multi-Story and Non-Residential Construction Projects, "Wood for large buildings," BioResources. 2017;12:1:546-570.

[18] Conroy K, Riggio M, Knowles C. Familiarity, Use, and Perceptions of Wood Building Products: A Survey Among Architects on the United States West Coast, BioProducts Business. 2018.

[19] Mahapatra K, Gustavsson L. Multi-storey Timber Buildings: Breaking Industry Path Dependency. Building Research and Information. 2008;36:6: 638-648.

[20] Roos A. Woxblom, L. and McCluskey, D. The Influence of Architects and Structural Engineers on Timber in Construction - Perceptions and Roles. Silva Fennica. 2010;44:5:871-884.

[21] Bregulla JR, Grantham R, Johansson HE, Enjily V. 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. 2003.

[22] Toivonen R, Lähtinen K. 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. 2019.

[23] Mallo MFL, Espinoza O. Awareness, Perceptions and Willingness to Adopt Cross-laminated Timber by the Architecture Community in the United States. Journal of Cleaner Production. 201;94:198-210.

[24] Markström E, Kuzman MK, Bystedt A, Sandberg D, Fredriksson M. Swedish Architects View of Engineered Wood Products in Buildings. Journal of Cleaner Production. 2018;181:33-41.

[25] Markström E, Kuzman MK, Bystedt A, Sandberg D. Use of Wood Products in Multi-storey Residential Buildings: Views of Swedish Actors and Suggested Measures for an Increased Use, Wood Material Science & Engineering. 2019;14:6:404-419.

[26] Kozak RA, Cohen DH. Architects and Structural Engineers: An Examination of Wood Design and Use in Non-residential Construction. Forest Products Journal. 1999;49:4.

[27] Wagner ER, Hansen EN. A method for Identifying and Assessing Key Customer Group Needs. Industrial Marketing Management. 2004;33:643-655.

[28] Truskett B. Factors Influencing Architects in their Specification of Timber and Timber Products. Market research report no. 1. University of Tasmania. March 1997.

[29] Bayne K, Taylor S. 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. 2006.

[30] Roos A, Woxblom L, McCluskey D. Architects', and building engineers', and stakeholders' perceptions to wood in construction: results from a qualitative study. In: Delbeck G EB, Hoen H-F, editors. Proc of the biennal meeting of the Scandinavian society of forest economics. Norway: Scandinavian Forest Economics. 2008;184-94.

[31] Bysheim K, Nyrud AQ. Architects' Perceptions of Structural Timber in Urban Construction, Conference COST E53, 29-30 October 2008, Delft, The Netherlands. 2008.

[32] Robichaud F, Kozak R, Richelieu A. Wood Use in Nonresidential Construction: A Case for Communication with Architects. Forest Products Journal. 2009;59:1-2:57-65.

[33] Viluma A, Bratuškins U. Barriers for Use of Wood in Architecture: The Latvian Case. Architecture and Urban Planning. 2107;13:43-47.

[34] Kuzman MK, Sandberg D, Haviarova E. Architects´ Perception of EWPs and Modified Wood in Contemporary Timber Architecture, 2018 World Conference on Timber Engineering (WTCE 2018), August 20-23, Seoul, Republic of Korea. 2018.

[35] Bengtson A. Framing Technological Development in a Concrete context - The Use of Timber in the Swedish Construction Industry. Ph.D. Dissertation, Department of Business Studies, Uppsala University, Sweden. 2003.