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Log Construction Practices and Future Outlook: Perspectives of Finnish Experts

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Abstract: This paper analyzed practices and future outlooks of log construction from the perspective of Finnish experts through interviews. Key findings highlighted that: (1) interviewed experts emphasized the environmental benefits of log construction; (2) moving log buildings from one place to another was considered a natural way to reuse logs, but several challenges regarding wet areas and incompatibility of different producer profiles were reported; (3) single-material construction of log was stated to have many advantages such as ease of application during erection and relatively long service life; (4) log structures were mostly associated with health, safety, coziness, beauty, and warmth; (5) increasing trend in the use of log construction in large-scale public projects was reported; (6) experts stated that the use of logs in high-rise buildings in Finland is underdeveloped, but hybrid applications using engineered wood products can provide a solution to this issue; (7) modern log cities can be designed with proper solutions, paying attention to several issues e.g., large glass-faced facades; (8) cost competitiveness, familiarity, fire safety, and facade cladding were assessed among the biggest challenges of log construction; (9) issues such as increasing number of contractors specializing in log buildings, robotics in production automation, digitization of manufacturing control were on the future agenda of log construction. It is thought that this study will support the use of logs by contributing to log structures that will be diversified and developed in the Finnish construction market.

Keywords: wood/timber; log; log construction; experts; Finland

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1. Introduction

The construction industry is one of the largest sources of greenhouse gas emissions, especially from large and high-rise building projects [1–3]; these emissions are one of the biggest contributors to the climate crisis and account for around 40% of energy-related CO_2 emissions worldwide [4–6]. In this sense, the construction industry is looking for ecological and sustainable solutions more than ever before, as the climate crisis has significantly impacted building codes and standards [7,8].

In line with European Union's 2050 targets, the goal, according to Finland's 2019 government program, is to be carbon neutral by 2035 and carbon negative soon after [9,10]. The construction industry has an important role to play in achieving Finland's climate targets, as buildings and construction account for around 30% of Finland's greenhouse gas emissions and around 40% of energy consumption [11]. The two main methods used in the construction industry today to reduce environmental impacts are (a) the use of environmentally friendly materials and (b) optimizing energy consumption throughout the building's service life [12].

Regarding the first method above, as an environmentally friendly material, timber is associated with lower carbon construction and lower embodied energy consumption compared to non-timbered buildings [13,14]. Wood, which can be used in place of other construction materials to minimize greenhouse gas emissions, also has the distinguishing feature of storing a large amount of carbon in the building [15–17]. In addition to being a

building material, timber can be reused as a raw material for other structures or burned for energy after its service life as a last resort [18,19].

The use of wood has been improved as a result of Finland's climate policy goals, making it increasingly versatile in large construction projects [20]. Additionally, forest sustainability efforts have been made to increase the use and processing value of wood [21,22]. With increasing environmental awareness and the development of low carbon footprint construction methods, wood is used in many challenging and demanding projects such as tall buildings [23–25]. The oldest and most traditional form of wood used is logs. Today in Finland, wood is used in many different applications, from multi-story apartments to additional floor construction, from high-rise buildings to facade renovation [26,27].

Used primarily for wall construction, log is a thick building material traditionally made from solid wood by hand, turned on a planer or lathe, and carved into circular, square, or other shapes [28]. Log, which can be of round or rectangular cross-section, can be made from a piece of wood or two or more pieces glued together. Logs are usually made from spruce or pine. A log house or log building is a structure built with horizontal logs interlocked with notches at the corners (Figure 1).

(**a**) (**b**)

Figure 1. A log house (Pinus sylvestris/Scotch pine), Ikaalinen, Finland; (**a**) general view from outside; (**b**) a corner detail (Photos courtesy of Jenni Vilkman).

Especially considering carbon neutrality, it is worth mentioning the thermal insulation capacity of log structures. In a solid log wall, logs provide both structure and insulation. The R-value for wood ranges between around 1.40 per inch for most softwoods and 0.70 for most hardwoods [29]. The extent of a log building's interaction with its environment is largely dependent on the climate. Due to the log's heat storage capacity, its large mass can result in better overall energy efficiency in some climates than others. Logs act as 'thermal batteries' and, under the right conditions, can store heat during the day and slowly release it at night. Additionally, in an environment such as Canada, where outdoor temperatures fluctuate throughout the day, thermal mass can help naturally manage temperature fluctuations. Moreover, several studies have shown that log houses provide up to 15% energy efficiency compared to timber-framed houses when considering annual purchased heating and cooling energy needs [30].

Although the Finnish word 'hirsi' is translated into English word as 'log', it does not exactly correspond to the meaning of the word 'hirsi'. English word 'log' also refers to a cut piece of a tree trunk, but in Finnish, 'hirsi' simply means a tooled tree trunk used in construction, often wall construction. Therefore, in this study, the word 'log' is used to mean a building material such as brick or concrete [28].

There have been many studies on the experimental effects of wood in various fields (e.g., [31–34]), but there are limited studies on log construction in the literature [35]. Among prominent studies, Ilgın and Karjalainen [36] studied Finnish massive wood construction from past, present, and future prospects. In their study, it was emphasized that the entire tradition of wooden construction in Finland is based on the use of logs, and industrial log construction in Finland has become increasingly popular in the last decade. Similarly, in the study of Häkkänen et al. [37], it was stated that the log structure, which has an important place in the history of Finnish summer cottages, is also used in most of the newly built holiday homes. In their study, advantages of log construction were noted, such as breathability, and moisture balance. Lakkala et al. [38] holistically analyzed the log building as a phenomenon in the Finnish context and the perceptions of the log as an architectural material using a semi-structured interview among 18 Finnish laypersons. The results showed that logs were perceived as a current and trendy material, and stereotypes about logs, such as rurality or traditionalism, had changed. Luusua et al. [35] examined 15 construction professionals' perceptions of log and log building through semi-structured interviews in Finland; their results mainly highlighted that (a) log was seen not only as a traditional material but also as a contemporary material due to trends in international architecture, ecology and environmentalism, and human health; (b) the images related to log construction were very strong; (c) log as a material was undergoing a rapid shift in perception due to the introduction of industrial log and computer-controlled manufacturing methods. Vares et al. [39] discussed conventional solutions for carbon-neutral construction in arctic conditions by using a Finnish log house as a case study. The results demonstrated that the operational energy demand could be met with the use of solar photovoltaic collectors, ground source energy, and wind energy supply. Schramel [40] compared the development of jointing techniques in log construction in different countries in Europe and East Asia. The results mainly showed that climatic conditions and availability of wood primarily influenced the development and use of log construction as a building method, and similar solutions, although developed independently in many regions, were obtained for different missions. Jokelainen [41] attempted to develop log construction training networks in the Nordic and Baltic countries within the scope of the Prolog project, mainly funded by the Nordplus Horizontal Programme. Jokelainen's report highlighted the following barriers: an unspecified education system for the official location of log construction, different contextual approaches, lack of coordination, and lack of cooperation among trainers. Heikkilä [42] focused on the modern application of the traditional log construction technique from a historical perspective of Finland. The result highlighted that today, logs were re-evaluated as a natural and genuine Finnish material, and it was necessary to develop their architectural expression for log houses to return to the construction of single-family homes. Overall, there is a large gap in knowledge regarding log experiences as a specific subset of wood [35].

The literature to date lacks a broad understanding of log construction practices and the future outlook in Finland, including from the perspectives of experts. This study aims to provide an overview of the future of log construction and highlight the potential of log structures in the light of the following main themes: (1) ecological features of log construction; (2) reuse of logs; (3) single-material construction; (4) perception of log construction; (5) public and large-scale log construction; (6) high-rise log construction; (7) log use in cities; (8) challenges of log construction; and (9) development and future of log construction. It is important to know the practices of log-building techniques with potential for the future and to find out in which direction the techniques currently used are evolving.

This study mainly seeks answers to the following questions: (i) what are the possibilities of log to meet Finland's climate targets? (ii) how has the perception related to log construction changed? (iii) what is the current state of log construction practices in Finland?, and (iv) what are the possibilities, needs, and trends in the future? Since increasing the use of wood, such as in log buildings, is key in tackling the climate crisis, it

is critical to understand its current applications, potentials, areas for improvement, and, therefore, future projections. In this sense, it is believed that this study will promote the use of logs by contributing to log buildings that will be diversified and developed in the Finnish construction market.

In this paper, timber or wood refers to engineered wood products, e.g., cross-laminated timber (CLT—a prefabricated multi-layer engineered wood product, manufactured from at least three layers of boards by gluing their surfaces together with an adhesive under pressure), and glue-laminated timber (glulam) (GL—made by gluing together several graded timber laminations with their grain parallel to the longitudinal axis of the section).

The remainder of this paper is structured as follows: First, log construction in Finland is described. This is followed by a description of the materials and methods used. After this section, the results based on the expert interviews on log construction in Finland and a comprehensive discussion section are provided. Finally, conclusions are presented along with future research needs and research limitations.

2. Log Construction in Finland

Log structure, in which the load-bearing walls are made of logs, is a construction method traditionally practiced in the northern coniferous region for over a thousand years. Similarly, Finland has a long history of timber construction, largely based on log construction. Logs are often arranged horizontally and joined by special corner joints. Due to the abundance of forest resources, the horizontal log technique has been used for over a thousand years in Finland. Logs have become a natural building material, resulting in simple rectangular architectural spaces with scale uniformity relative to the log's length in Finland (Figure 2). Additionally, the slightly sloped simple ridge roof is a typical element of traditional Finnish log houses.

Figure 2. A traditional log cottage in northern Finland (Photo courtesy of Lotta Häkkänen).

Although the log technique has been used in Finland for thousands of years, it was only in the early 1900s that log construction began to gain recognition as a new industrial building material [43]. However, in the early stages of industrialization, logs turned into a material used only in the construction of sauna buildings and summer cottages [44].

In the Finnish wood construction industry, until the 1930s, before the market dominance of American lightweight framing, the most used application for residential buildings was log construction [45]. With the American-style urbanization and industrialization at that time, different construction solutions were sought in the housing sector, including prefabricated solutions. Still, single-family homes were built using solid wood logs harvested directly from the forest area [46].

During the Second World War, when there was a shortage of construction materials in the 1940s, the demand for fast and affordable mass housing construction using prefabricated elements was triggered. By the 1950s, log construction was revived in Finland with the development of industrial production techniques. Logs, which were mostly used in the construction of holiday homes/summer cottages in those years, became popular again due to the easy accessibility of raw wood material and its nail-free structure.

In the following period, concrete, which emerged on the construction scene in the late 1960s with the modernist movement in Finland as well as in the world, became a widely used material in many medium and large-scale structures. In the 1970s and 80s, log house factories improved their production technologies in terms of high quality, precise measurement, and technical functionality; this made Finland a country that could export around 60% of the industrial log houses it produced.

In the early 2000s, log structure, which was mostly used in the construction of saunas and holiday homes, later started to be used in single-family homes. Today, it has become popular in single-family homes, summer cottages (Figure 3), and sauna buildings. Moreover, log construction is now used in one out of every four single-family homes in Finland [47] (Figure 4).

Figure 3. A modern single-family home with log construction in Finland. (Photo courtesy of Lotta Häkkänen).

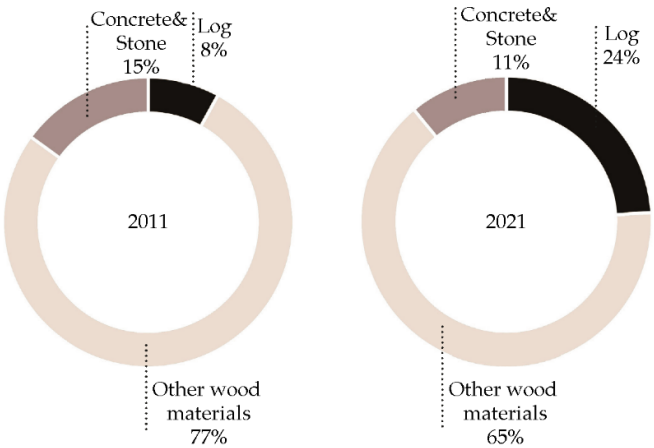

Figure 4. The percentages of frame materials of Finnish single-family homes in 2011 and 2021 [48].

In addition, the perception that log structures have an unexplored potential for architectural expression, especially in the last decade, has changed the perspective of professionals in a positive way [49]. Today, logs are produced industrially in factories from glued laminated wood using sophisticated woodworking machinery. Laminated log is produced by gluing kiln-dried dimensioned pine and spruce timber together in two or more pieces. Due to kiln drying and gluing processes, twisting, and cracking problems, which are also problems in traditional logs, have been prevented, and logs that are glued with cross seams are called 'non-settling' logs [50]. Furthermore, nowadays, log construction has begun to find a place for itself in large-scale projects such as school campuses (Figure 5) and multi-story apartments (Figure 6) as well as small houses.

Figure 5. Pudasjärvi log school campus (Pinus sylvestris/Scotch pine), Pudasjärvi, Finland: (**a**) general view from outside; (**b**) corner detail from inside; (**c**) corner detail from outside (Photos by Hüseyin Emre Ilgın).

Figure 6. A four-story log apartment building (Pinus sylvestris/Scotch pine), Pudasjärvi, Finland (Photo by Hüseyin Emre Ilgın).

3. Materials and Methods

This research was conducted through a literature review and expert interviews [51] to deepen the study (Table 1). Finnish experts from different fields, such as industry and academia, were extensively selected for the interviews to bring together as many different views as possible and to get the broadest possible picture. The main aim of the interviews was to provide new perspectives and insights to shed light on the current state, development, and future outlook of log construction in Finland.

Table 1. Interviewees by their position/title, and organization type.

	Interviewee 1	Interviewee 2	Interviewee 3	Interviewee 4	Interviewee 5	Interviewee 6
Position/title	Technical director	Professor	Manager	Lecturer	Program Manager	Business Director
Organization type	Municipality	University	Construction industry	University	Ministry of Environment	Manufacturer of single-family homes

In this paper, in-depth interviews were used as a data collection method to collect qualitative information about log construction from various key stakeholders. The major advantage of in-depth interviews is that they provide much more detailed information than what is available through other data collection methods, such as surveys; they also may provide a more relaxed atmosphere in which to gather information—people may feel more comfortable having a conversation with you about their program as opposed to filling out a survey [52]. Additionally, semi-structured interviews were conducted as the ideal method, where the procedure allowed interaction between interviewer and interviewee, and thematically organized questions served as a basis for conversation. Moreover, in these interviews, different perspectives inspire the creation of new topics beyond those originally explored [53–55]. The progress of the interview depends on the emergence of the main themes.

Interviews were organized via e-mail and conducted via online video conferencing. The program used made it possible to record interviews, which facilitated the analysis of interview results. After the interviews, the video recordings were meticulously reviewed, and the results of the interviews were transcribed and sent to the interviewees via e-mail for further review and completion.

The selection of interviewees was done by purposeful sampling. The two main criteria for respondent selection were as follows: experts must possess adequate knowledge of log building, and experts should have firsthand experience on log building projects or have closely monitored the development of log construction; they were selected among the leading institutions and organizations of academia, public institutions, and the wood industry, with their knowledge and experience in Finnish log construction. Thus, a balanced sample of interviewees was obtained among experts from different backgrounds. This provided a broad view of how Finnish experts view the state of the art and future of logs as a construction material.

In addition, it is worth noting that Pudasjärvi, a small Finnish town and municipality, is located in the province of Oulu. This town is home to a log campus, one of the world's largest wooden buildings, as well as the world's largest log house factory, Kontiotuote. The interviewees were people who have a direct link to this important campus project or who are involved in other pioneering research projects related to log construction. Additionally, industry experts were included to gain a more complete view of the subject. In this sense, a specialist from the single-family housing sector was involved, as there have been significant developments in terms of log construction recently.

The thematic analysis method was chosen because it is the most common form of analysis in qualitative research [56]; it is a method for identifying, examining, and recording themes within data. Themes are patterns among datasets that are crucial to describing a phenomenon and associated with a particular research question, and these themes become categories for further analysis. The analysis includes writing field notes, reviewing transcripts, and coding interviews. The five stages of thematic analysis include: (i) becoming familiar with data and exploring recurring themes; (ii) coding the transcripts according to the aims of the study and emerging themes; (iii) comparing codes between interviews and re-coding; (iv) grouping themes into broader categories by creating a conceptual framework; and (v) summarizing and synthesizing data into charts to illustrate themes through representative citations [57].

All concepts, features and dimensions, themes, and categories are combined and analyzed through a framework based on thematic matrices. Trends in literature research also play a role in establishing themes. This matrix format allows for easier pattern matching and comparisons between interviewees; these themes and theme-related questions are provided in Tables 2 and 3, and Appendices A and B, respectively. Additionally, interview questions have been prepared by taking into account the knowledge and experience of the experts interviewed on issues related to log construction. Questions asked in Appendix A were used during interviews with experts from academia and public authorities, and questions in Appendix B were used during interviews with experts from industry and production.

Given that the participant's native language was Finnish, the interviews were conducted in Finnish, audio recorded, and eventually transcribed in a software program. The validity of the Finnish-to-English translation was given meticulous attention. Rigorous comparisons were made between the translated version and the original version to ensure accuracy and consistency.

In this study, the authors analyzed the data. Since the number of interviewees was manageable, the analyzes were made manually, without using any numbering system for the answers, by going through the answers, highlighting, and classifying the points emphasized by the interviewed experts. Classification of the obtained data is an important part of the analysis [58]. In assessing the reliability of the results, it should also be noted that the opinions are geared toward presenting a comprehensive picture of the future through fact-based forecasting.

Responses were classified under the identified recurring themes: (1) ecological features of log construction; (2) reuse of logs; (3) single-material construction; (4) perception of log construction; (5) public and large-scale log construction; (6) high-rise log construction; (7) log use in cities; (8) challenges of log construction; and (9) development and future of

log construction. The identities of the interviewees and the results of the interviews were kept anonymous and confidential.

Table 2. The main themes, addressee, and main purpose of the interview questions (Appendix A).

Main Themes		Corresponding Sub-Sections	Addressee	Main Purpose
Topics	**Sub-Topics**			
Ecology	Challenges arising from the climate crisis	Sections 4.1 and 4.2	Experts from academia and public authorities	Identifying experts' views and outlook
	Challenges of reuse and ways to increase reuse			
Development of log construction	Current trend and focus direction	Sections 4.3 and 4.4		
	Impact of increased wood use			
	Main drivers for successful applications			
	Effects of new projects			
Public log construction	Ways to popularize public projects	Sections 4.5–4.9		
	Challenges			
	Innovations to increase usage			
	Main drivers for urban areas			
	Large-scale & tall building projects			

Table 3. The main themes, addressee, and main purpose of the interview questions (Appendix B).

Main themes		Corresponding Sub-Sections	Addressee	Main Purpose
Topics	**Sub-Topics**			
Ecology	Challenges arising from the climate crisis	Sections 4.1 and 4.2	Experts from Industry and manufacture	Identifying experts' views and outlook
	Customers' attitudes towards environmental issues			
Development of log construction	Current trend and focus direction	Sections 4.3 and 4.4		
	Impact of increased wood use			
	Factors in the growing popularity of single-family homes			
	Effects of new projects			
Public log construction	Important developments for urban use	Sections 4.5–4.9		
	Innovations to increase usage			
	Main drivers for urban areas			
	Large-scale & tall building projects			
	Challenges and possibilities for tall building projects			

4. Results

As noted in the previous section, the results of the interviews were divided into themes that provide a representative understanding of the current state, development, and future of log construction in Finland. Themes occurred in more than one context in the interviews, regardless of whether the question addressed a particular theme or who the interviewee was. Interview results were presented according to the following classes: (i) ecological features of log construction; (ii) reuse of logs; (iii) single-material construction; (iv) perception of log construction; (v) public and large-scale log construction; (vi) high-rise log construction; (vii) log use in cities; (viii) challenges of log construction; and (ix) development and future of log construction as given in Tables 2 and 3.

4.1. Ecological Features of Log Construction

Responses from interviewees highlighted that log buildings act as a carbon store and therefore have a significant effect on the Finnish construction industry in terms of environmental impact and carbon emission. It was pointed out that the carbon footprint of the building industry affects the materials used in construction. Logs can be used in response to the challenges posed by the climate crisis and Finland's goal of becoming carbon neutral by 2035.

Moreover, the interviewees' answers emphasized that, however, the criticality of the construction industry, different economic factors, and sometimes operational aspects that play a role in various material options prevent it from turning into a completely objective assessment. For example, although there are many studies about the ecology of wooden construction, it is difficult to find completely objective data since the background of various studies is largely based on industrial interests.

It was emphasized that when using wood, it is necessary to consider how much forest can be cut, and it is not easy to completely replace materials with higher carbon footprints with wood. When comparing the annual growth of trunk wood in the world's forests and the rate of deforestation for the annual consumption of concrete in the building industry, wood cannot completely replace concrete.

However, according to recent reports on the Finnish forests, a position was taken on increasing the log construction and whether the forests should be allowed to grow older. It was also mentioned that trees are mainly used to build trunks, but log waste, such as stumps and branches release carbon dioxide when they decompose.

According to the sectoral experiences of the interviewees, especially on the single-family home side, it was reported that there had been a shift in the low energy demand of buildings and the renewable energy used. Currently, the construction of wood and log is growing in popularity in Finland, but awareness of carbon footprint and its calculation methods for buildings continues to grow. In this context, the experts interviewed stated that energy consumption and material-related carbon play an important role during the use of buildings, and the necessary calculation methods should be developed.

It was mentioned that the construction industry should consider that wood as a material produces suitable technical functions, as in concrete or steel structures. It was also stressed that by improving the cooperation and communication between designers from different fields, the benefits of log construction, such as carbon storage, would stand out for both the designer and the builder.

From the point of view of municipalities, it was stated that public constructions are of great importance in terms of carbon neutrality. Pudasjärvi, for example, has set an example for the public in log construction and has encouraged other municipalities to undertake log construction opportunities (Figure 5). It was also mentioned that good experience with log construction has contributed to the new objectives of log construction, and guidance at the municipal level is of great importance for log construction in the region.

The experts interviewed noted that buyers of single-family log homes today are more conscious of the ecological properties of logs and how logs work as long-term carbon stores, so many people are very willing to choose a log house and pay more for

it. Due to the ecological values of the log, it is possible to construct, for example, carbon-negative buildings.

It is foreseen that buyers of single-family log homes are likely to be interested in ecological ones, and this market will continue to grow in the future. The ecological nature of the log is one of the most important log triumph cards, which concerns not only the market but also its homeland, customers in different parts of the world, and ecology. It was emphasized that the importance of using certified timber for sustainable forest management and, therefore, sustainable production could be achieved by following the origin of the wood.

4.2. Reuse of Logs

In the answers of the interviewees, it was stated that moving log buildings from one place to another is a natural way to reuse logs in Finland, which has a long tradition of log construction. It was emphasized that the building should be designed as part of the structural solutions at the planning stage for demountability and transformation flexibility in the reuse of the structure. The experts interviewed mentioned that log construction technology could extend the life of buildings by moving them to another location, thus reducing their carbon footprint. However, it was noted that many improvements are still needed to ensure that the structures can be easily disassembled for reuse without any damage, as was the case with the butterfly-fastener-CLT construction in Norway.

In terms of reuse, it was reported that the wet areas of the buildings and the log profiles of different manufacturers do not fit together without process, which causes difficulties. However, the Finnish Building Inspection Association is in the process of developing guidelines for log houses, procedures for building inspection, and practices, so that awareness of the problems and their solutions will increase.

It was mentioned that the promotion of building materials is related to the reuse of EU regulations and various working environments and practicality issues, and as with many other structures, the suitability of building materials is highlighted, while the challenges related to reuse arise in the next process. Although the reusable logs are not CE marked, the need to develop a separate use procedure for them was underlined during the interviews. In terms of reuse, it was noted that the legislation currently does not fully support the use of recycled materials, but improvements will be made in this regard. It was also stated that these developments would be related not only to usage processes but also to how to obtain reused log products suitable for new buildings.

Experts' answers pointed out that recently, there has been controversy over the promotion of wood and log construction, the adequacy of wood resources, and the increase of logs. In addition, the high number of cuts causes the carbon stocks of forests to decrease for a certain period, which requires optimization of the material used. It was argued here that the aim should not only be to create a perspective to increase carbon storage, but also to replace traditional construction materials with wood to achieve the lowest possible carbon footprint.

Possible reuse of wood as part of the building planning and construction process, removing and reinstalling its components, and how solid wood can be reused in a building with minor modifications several decades later. In addition, attention was drawn to the importance of using traditional mechanical connections and fastening methods such as quilting.

4.3. Single-Material Construction

Responses from interviewees with single-material construction highlighted that various new products have entered the Finnish building market. In the market, around 90% of new single-family homes are made of rigid-framed timber houses or logs. It was reported that the possibilities of using logs have expanded, and most of the increase in the use of wood has been directed to different types of construction and usage patterns, where wood

is the only material in the building wall. The use of logs is often justified by the fact that it is possible to make functionally good single-material, massive and layerless structures.

The experts interviewed reported that log buildings, which are very simple in structure and implemented by gluing, have positive properties in terms of fault tolerance and indoor air quality. In addition, the monotony of the log, the absence of layers where moisture can condense, and its breathable structure make it a technically moisture-safe structure as it equalizes the humidity of the indoor air.

It was stated that moisture-causing mold and fungus and ultraviolet rays of the sun are risk factors that reduce the service life of wood and that the service life of the log can exceed 200 years due to its single-material structure. In addition, it was emphasized that the life of buildings could be extended due to the flexibility of the transformation of buildings.

4.4. Perception of Log Construction

According to the responses from interviewees, the popularity of log architecture is partly based on people's positive perceptions. Additionally, its reputation as a healthy and safe material for mold problems has played an important role in increasing its demand. It was also stated that the ecological value of the log, which is perceived as cozy, beautiful, and warm as a material, is becoming more and more trendy every day. The traditionality of the log, whose main material is natural solid wood, has always been appreciated in Finland, although its structural functionality is not always fully understood.

It was considered by the experts that the housing fairs where many log houses are exhibited and the successful updating of the perception in accordance with the urban architecture is of great importance in the positive perception of log houses. In addition, with the development of their architectural features, the perception regarding the applicability of logs in buildings for leisure use changed, and log houses became applicable as a strong alternative to many traditional solutions, such as stone houses.

Experts surveyed noted that log construction has become popular among single-family homes; they considered that log houses are becoming widespread in densely populated areas as well as in sparsely populated areas due to their ready-made solutions. It was also stated that the use of logs, especially in large public buildings such as school campuses, has contributed significantly to the popularity of the log and its position in the construction industry by enabling the public to experience such structures.

In Finland, where forest resources are predominantly used in the pulp industry, it was emphasized that as people's sensitivity to environmental problems increases, they consider in which areas they want to use forest resources more; this contributed to the strengthening of the perception of log construction, triggering the awareness that wood can be transformed into high-value end products.

4.5. Public and Large-Scale Log Construction

As mentioned in the previous section, good experiences with log construction were highlighted in Finland, which can encourage public use of log buildings. It was reported that the perceptions of people who have experienced log construction in public buildings, such as Pudasjärvi, changed positively. Here, the important support of awareness and natural willingness among people was stressed rather than forced manipulation by the relevant authorities to increase log construction.

In the answers of the interviewees, it was noted that although there is already great interest in the use of logs in municipal-based projects such as schools, the recent global situation has severely limited the activities of construction companies. It was also stated that log construction practitioners are small-scale and have turnkey contracts in the residential sector rather than large public construction projects, such big projects have more complex and high-demand facilities that require a construction firm.

Additionally, it was pointed out that non-settling logs and their ability to increase spans are among the important innovations that boost the use of logs, especially in large public buildings. In this context, it was foreseen that large-scale projects such as public

buildings would be hybrid structures that benefit from the advantages of more than one material instead of a single material.

4.6. High-Rise Log Construction

It was stated that the current perception towards log construction is positive, its demand is increasing, and it is preferred in large-scale public buildings. However, the practice of log use in high-rise construction in Finland is not developed enough.

Interviewed experts also mentioned that the log apartment buildings, recently completed in Pudasjärvi, are implemented as hybrid structures with log exterior walls and concrete load-bearing parts of the frame. Here, it was underlined that the use of logs alone is not sufficient, especially in tall building construction. In this context, the perception that log houses have a structural system consisting only of logs should change.

It was noted that by using the properties of different products, sustainable, large, and well-designed structures could be achievable, as in Norway, where glulam and CLT are used together for tall wooden buildings. Although it is thought that the load-bearing frames of tall buildings can only be made of wood as column-beam in the future, it is argued that the use of logs may allow for additional floors today. Furthermore, non-settling logs are used in almost all houses built with logs today; the issue of deflection becomes much more critical when it comes to the construction of tall buildings, that is, above 8-story.

The design skills, multidisciplinary collaboration, and construction experience required for hybrid apartment projects as a glulam frame with CLT mezzanines and log walls were also highlighted.

4.7. Log Use in Cities

According to the responses from interviewees, all construction materials can be made proper for urban solutions using suitable architecture. Typically log buildings are single structures, and construction materials can be easily deduced from them. It was also stated that, if necessary, log buildings can be closed with wooden curtains, for example, in Finland's old wooden towns, made up of log houses covered with planks and converted into suitable towns.

It was underlined that if the designer architect is competent enough, the logs can be used to make urban-type buildings. The appearance of log houses has been updated to make them more suitable for urban architecture. Although log is a suitable material for facades, there may be difficulties in placing logs on large-glazed facades.

4.8. Challenges of Log Construction

Responses from interviewees highlighted that the benefit of building materials competing with logs is that they have the advantages of cost and familiarity due to their high production rate and long-term use experience. It was considered that in public projects where cost is an important criterion, log could become preferable by emphasizing its ecological advantages. On the other hand, although the current global conditions in Finland cause fluctuations in timber prices, it was believed that this situation would improve in the long run.

Similarly, it was reported that, in the single-family home sector, affordability is key, as the price is a decisive factor for home buyers. In this context, it was projected that the production process and, therefore, price improvement trends are important issues for the future and ensuring this will increase the number of potential customers.

It was also pointed out that developing the wood production chain and end products should be seen as a national mission as it affects the gross domestic product. In this sense, interviewees stated efforts should be made to bring greater decentralization to Finnish woodworking so that the development of the entire production chain will also support smaller companies.

Additionally, if the wood structure value can be considered attractive to forest owners, logs can be converted into wood products with high processing value to increase their size.

The use of wood in construction will certainly increase, as Finland is self-sufficient in raw wood materials and the increasing importance of environmental issues can positively affect the popularity of log construction.

Experts noted that the giant log differs from other types of logs due to its 360 mm height. Traditionally, the size of the logs was determined by the size of the cut trees. It was also stated that the difference between log and CLT construction is that the logs are stacked and CLT is used as larger elements. Currently, glued logs have enabled various sizes for logs that are larger than before. This change in dimensions makes logs more such as CLT than before.

It was underlined that large-scale log construction is suitable for low-rise structures, but its use in tall buildings creates difficulties due to problems such as cladding, and additional fire protection measures. On the other hand, it was also mentioned the fact that fire regulations are constantly being changed most properly for wooden structures and related regulations are developed accordingly.

The challenges of public construction sites, fire safety concerns, and the familiarity of construction with other materials were seen as barriers to the widespread use of logs. On the other hand, it was thought that the carbon footprint calculations, which will be requested with the legislative change, would have a positive effect on the log in the future.

4.9. Development and Future of Log Construction

Views that emerged in the interview included the evolution of log construction, supporting the advancement of wood in use, and promoting the use of wood that takes advantage of the single-material nature of log construction and mass. The log buildings constructed in Pudasjärvi were thought to demonstrate the contribution logs make to architectural aesthetics.

It was stressed that due to the developed log solutions, it is possible to build long spans and various types of structures, and the compatibility of logs with architecture is gradually increasing. It is thought that the skill of constructing logs, which is under the control of only a few companies, will be adapted to the present day with architectural details and the interest of Finns in log structures will be preserved. The share of the log construction industry, whose main area of development is single-family homes, has reportedly increased in public buildings over the past few decades. Further development of new technical solutions and long-cycle adhesives was foreseen in the future.

The widespread use of logs was reportedly enabling more and more contractors to specialize in logs and are encouraged to bid on log construction contracts. It was thought that prejudices against log construction would be overcome with the support of manufacturers who sell not only logs but also log frame structures, especially with the increasing know-how in single-family home log construction.

Finland has been recognized as having an important position in the world in terms of the architecture and structural engineering of log building, industrial log production, and log construction experience. In this context, the necessity of robotics, which is used in production automation and log production in the industry and continues to develop rapidly, was emphasized. In parallel, it was stated that digitalization is a strong part of production control, and for example, geo-information sources of cut logs or data on carbon stocks and carbon footprint can be added to product labels. It was thought that materials that remained anonymous to users could better connect with log building occupants, for example, with location data to be integrated into log tags.

It was reported that log houses, which enter the market with turnkey models and offer convenience to customers with ready-to-move-in solutions, have become a pioneer in the log house market in Finland. Moreover, it was stated that the increase in the popularity of log houses is reflected not only in the single-family home market but also in the large and traditional collections of wooden housebuilders as a new phenomenon. Attention was drawn to the importance of compliance with the relevant legislation in finding a place for logs in the wood market, which currently focuses on 2–4-story compact structures.

It was thought that the circular economy, efficient use of natural resources, and the widespread use of carbon footprints in architecture could be combined with the concept of log construction; in the future, mechanically jointed and glue-free wooden structures would attract the attention of architects and adhesives would become more and more ecological.

Energy efficiency regulations were expected to tighten in the 2020s, which is anticipated to pose challenges for both log construction and other construction sectors. It was also predicted that future low-carbon calculations would cause changes in the wood industry, with regulations focusing on energy forms such as heat pumps.

5. Discussion

Although the participants came from different areas of log construction, their views expressed in the interviews were compatible, supportive, and complementary. Highlights from log construction practices and future outlook in Finland include:

(i) ecological feature of log construction is one of its strongest aspects, which should be emphasized even more;
(ii) in Finland, moving log buildings from one place to another is a natural way to reuse logs. On the other hand, challenges in reusing logs, such as wet areas and incompatibility of different producer log profiles, and the importance of integration into structural solutions in the early stages of the project are important issues;
(iii) single-material construction of the log has many advantages, such as ease of application during construction, use with adhesive, and relatively long service life;
(iv) regarding the perception of log construction in Finns' minds, the positive perception and popularity of log is mostly related to its reputation as a healthy, safe, cozy, beautiful, and warm material;
(v) increase in the number of good practices, changing perceptions of those who experience log construction in public buildings, and the development of non-settling logs used in long spans are boosting the use of logs in large-scale public projects;
(vi) use of logs in high-rise buildings in Finland is underdeveloped, but hybrid solutions using engineered wood products such as CLT and glulam could be exploited;
(vii) cities, where logs are used, can be designed with proper solutions, paying attention to issues, e.g., large glass-faced facades;
(viii) issues regarding cost competitiveness, familiarity, fire safety, and facade cladding can all be considered challenges of log construction;
(ix) further development of new technical solutions, an increasing number of contractors specializing in log buildings, robotics used in production automation, digitization of manufacturing control, geo-information resources used in product labels, and mechanically jointed and glue-free structures are on the agenda of the future of log construction.

The findings of this study regarding ecological attributes, reusing, single-material construction, and challenges confirmed some of the findings reported in other studies in the literature, such as [38,39].

Experts emphasized the environmental features of log construction. Similarly, some Finnish laypersons interviewed in the study of Lakkala et al. [38] underlined the naturalness of log buildings. In the same study, some also defined the log as a natural or organic form of construction. Our findings can also be related to the approach of Vares et al.'s study [39]. In their study, a log building in Finland was used as a case study to examine sustainable and carbon-neutral building alternatives in a cold climate. On the other hand, it may also be worth addressing the general perception of wood products, as logs are a special subset of wood building materials. In many perceptual studies on wood construction in the literature, environmental properties have been considered one of the greatest advantages of timber construction (e.g., [59–62]).

Moving log buildings from one place to another was seen as a natural way to reuse logs, but some difficulties with the reuse of logs, such as incompatibility of different producer profiles, were reported by experts. Similar to our results, Finnish participants surveyed

in Lakkala et al.'s study [38] experienced the reuse of logs salvaged from old, demolished buildings in another building. In the same study, it was also stated that as a part of the Finnish tradition, the log houses were dismantled and moved from one place to another and used within the framework of a new structure. In this context, the effect of cultural history on the recognized qualities of the log was emphasized. According to Vares et al. [39], the log has versatile potential for reuse.

The single-material construction of the log was noted to have many benefits, particularly ease of application during construction and relatively long service life; this was supported by findings from other studies. For example, in the study of Lakkala et al. [38], the general opinion of the Finns was that the log was a durable and long-lasting material. Moreover, the surviving examples of old log buildings showed that log construction has a structural service life of hundreds of years [39].

According to the interview results, log structures were mostly associated with health, safety, coziness, beauty, and warmth. In the study of Lakkala et al. [38], which strongly supported our findings, logs were considered a contemporary and popular building material due to their features regarding warmth and well-being. Similarly, breathability, moisture stabilization, allergy-friendly, and aesthetics were among the advantages of the log construction in Polina's study [63]. On the other hand, Ojanen's work focused on how log construction improves indoor climate conditions [64]. Additionally, Lakkala and Pihlajaniemi [65] underlined the architectural quality of industrial log design within the scope of tectonics.

Responses from experts highlighted the increasing trend in the use of log construction in large-scale public projects. Our finding can be associated with the fact that public service buildings, which are open to public use and visit due to their nature, have a very important role in the diffusion of the positive attributes of the log. For example, people, who experienced the Pudasjärvi log school campus (Figure 5), had positive impressions of the log building, such as warmth, coziness, and acoustic comfort [38].

Interviewed experts stated that the use of logs in tall buildings in Finland is underdeveloped, but hybrid applications using materials such as CLT and glulam can provide a solution to this issue. Considering today's tallest timber construction practices, the potential of hybrid solutions is often exploited [66,67], as is the case with skyscrapers built with other materials, such as a composite of reinforced concrete and steel [68–71]. Similarly, hybrid structures designed from engineered wood products or traditional building materials such as concrete or steel can be used for future log applications in tall buildings.

Experts were of the opinion that logs could be used in cities with suitable architecture. Research projects, such as the 'Modern Log City Project' [49], were undertaken to support this view. Moreover, the stereotype among Finns that logs are primarily a building material in rural rather than urban areas seem to have changed recently [38].

Cost competitiveness, familiarity, fire safety, and facade cladding issues were considered among the biggest challenges of log construction. Similarly, issues such as initial cost, lack of experience and knowledge, and fire resistance were generally perceived as the main disbenefits and barriers in wooden structures (e.g., [72–74]).

Further development of new technical solutions, an increasing number of contractors specializing in log buildings, robotics used in production automation, and digitization of manufacturing control were on the future agenda of log construction in Finland. Our finding resembled the findings of the study of Lakkala et al. [38], in which the need for future development for the logs was underlined. For example, in the opinion of the participants [38], manufacturers should offer much more alternatives for detailing logs, such as alternate cross-section profiles with various bevels and new corner joints. This may require further development of new technical solutions and digitization of the production process.

6. Conclusions

This article has examined log construction practices and future outlook, including from the perspective of Finnish experts, through interviews. In doing so, this paper attempted to identify key themes: (1) ecological features of log construction; (2) reuse of logs; (3) single-material construction; (4) perception of log construction; (5) public and large-scale log construction; (6) high-rise log construction; (7) log use in cities; (8) challenges of log construction; and (9) development and future of log construction. It is believed that this study will promote the use of logs by contributing to log structures that will be diversified and developed in the Finnish construction market.

As a carbon store, log, such as other wood products, contributes to Finland's goal of being carbon neutral by 2035, as it has a significant impact on the Finnish construction sector in terms of environmental impact and carbon emissions. In addition to its ongoing reputation as a healthy, mold-free, environmentally friendly, cozy, and warm material, its use in large-scale public projects has created a positive perception in terms of the harmony of the log with urban architecture. Additionally, the increase in the number of good practices and the non-settling logs used over long spans contribute to this positive perception. Today, log construction has started to find a place for itself in large-scale projects such as school campuses and multi-story apartments, as well as small houses. As with engineered wood products, hybrid solutions could pave the way for tall log construction. Similarly, with appropriate design solutions, the use of logs in urban architecture can be increased. Cost competitiveness, familiarity, fire safety, and cladding are among the issues that need improvement in log construction. A more integrated production and post-production processes with digitalization and technology, and the search for technical solutions that can respond to demanding structures can shape the future of log production.

The results of the study underline the growing interest in log construction and the positive perception of logs in many areas; this is a strong motivation to promote log construction in many parts of Finland, as in the case of Pudasjärvi. As it is known, the world's largest log campus in Pudasjärvi, a small Finnish town, was built at the initiative of the local government to combat mold infection, which has worsened indoor air and caused discomfort to students. It is recommended to realize large-scale public projects for log construction, by developing and disseminating sustainable business models that will be supported both legally and financially by local authorities. In this context, close collaboration between local governments, contractors, suppliers, and other key stakeholders, such as architectural offices, is critical. In addition, it is another important issue to provide the necessary theoretical and practical training in the field of log construction, both in the academy and in the construction industry. Furthermore, policymakers have important duties in the legal and regulatory processes of issues that will determine the future of the log industry, such as robotics used in production automation and the digitalization of production control.

Potential log construction topics to explore may include: the development of bio-based and environmentally friendly adhesives for glued logs, advancement of composite use of logs with other structural materials in demanding applications such as tall building construction, the user or consumer-oriented perceptual studies on the log structure, comparative surveys conducted in other geographies where the log structure is used, development of structural solutions by considering the dismantling of logs intended for reuse and new methods to ensure that log structures can be easily dismantled for reuse without damage and more research about design and implementation dynamics of a modern log city concept.

This study has several limitations. A larger sample group could have been used to collect data in interviews to add a more in-depth dimension to the research. Thus, results that are more suitable for generalization can be obtained. In this context, study results, which are particularly useful for designers, should be considered as insights worthy of further study to validate across a wider population scale. In addition, this study is

geographically and contextually limited to Finland. In other wood-based countries where log building is common, different perspectives may have developed.

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Appendix A. Interview Questions for the Experts from Academia and Public Authorities

Ecology

- How do you see log construction responding to the challenges posed by the climate crisis and Finland's goal of being carbon-neutral by 2035?
- What challenges do you see with the reuse of logs, and how do you see log reuse can be increased?

Development of log construction

- What do you think are the most important development trends in log construction, and what direction do you think log construction is focusing on?
- What kind of effects do you see with the increased use of wood in log construction?
- What do you think are the main reasons for the success of log construction?
- Do you think that the perception of log construction has changed with the new log building projects?

Public log construction

- How to increase the use of logs in public construction in Finland?
- What challenges do you see in the development of public log construction?
- What innovations in industrial log construction are significant for increasing usage in large and public buildings?
- In your opinion, how does log construction correspond to urban construction needs?
- There is a lot of small-scale and low-rise log construction in Finland, so how do you think log construction is suitable for large-scale use as well as high-rise construction?

Appendix B. Interview Questions for the Experts from Industry and Production

Ecology

- How do you see log construction responding to the challenges posed by the climate crisis and Finland's goal of being carbon-neutral by 2035?
- How important do customers consider environmental issues when choosing log buildings?

Development of log construction

- What are the most important development trends in log construction, and where is the focus of product development today?
- What kind of effects do you see with the increased use of wood in log construction?
- The popularity of wood as a building material for single-family homes has been increasing recently. What do you think is the reason for its increasing popularity?

- Do you think that the perception of log construction has changed with the new log building projects?

Public log construction

- Which developments in industrial log construction do you think are essential for urban areas and in terms of enabling log construction in urban site plan areas?
- What innovations in industrial log construction are significant for increasing usage in large and public buildings?
- In your opinion, how does log construction correspond to urban construction needs?
- There is a lot of small-scale and low-rise log construction in Finland, so how do you think log construction is suitable for large-scale use as well as high-rise construction?
- What kind of opportunities or challenges do you see in high-rise construction with log material? Do you think it is technically possible to build an 8-story building with log materials?

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