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Analytical Hierarchical Process as a Multicriteria Decision Tool in Material Selection for Prefabricated Wood Buildings

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Abstract: The popularity of prefabricated wooden buildings is increasing in North America, but choosing suitable materials for these structures can be complicated. This can lead to problems like financial losses, production delays, and lower quality. Therefore, the main goal of this study was to use the Analytical Hierarchy Process (AHP) decision-making tool to rank the criteria for material selection for prefabricated wood buildings in Canada and the United States. The methodology involved surveys experts in the prefabricated wood construction industry from Canada and the United States. The data obtained from the questionnaires utilized for the AHP analysis were modeled using R programming language. The results revealed that for structural materials, the top five subcriteria were safety and security of building occupants (0.234), location, shape, and height of the building (0.218), comfort, satisfaction, and well-being of the building (0.155), occupant health (0.121), and availability of materials (0.098). For selecting envelope materials, the top five subcriteria were comfort, satisfaction, and well-being of the building (0.252), safety and security of building occupants (0.206), location, shape, and height of the building (0.178), occupant health (0.132), and availability of materials (0.078).

Keywords: AHP; construction; multicriteria; technical properties; social benefits

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Citation: Cabral, M.R.; Blanchet, P. Analytical Hierarchical Process as a Multicriteria Decision Tool in Material Selection for Prefabricated Wood Buildings. *Buildings* **2023**, *13*, 2973. https://doi.org/10.3390/buildings13122973

Academic Editors: Jurgita Antucheviciene and S.A. Edalatpanah

Received: 4 November 2023
Revised: 25 November 2023
Accepted: 27 November 2023
Published: 29 November 2023

1. Introduction

As the world population rapidly grows, there is a need for new buildings. The construction industry is the most significant contributor to the global economy, accounting for 13% [1]. In response, prefabricated buildings have become increasingly popular due to their potential to enhance operational efficiency and address labor shortages and low productivity issues. Prefabricated systems such as 2D elements (i.e., walls, trusses, roof, and substructures) or prefabricated buildings as 3D volumetric elements are constructed off-site in a factory and then transported to the site for final installation [2]. This building approach has been widely used in various countries, including Sweden, Japan, Singapore, China, Canada, and the United States. Prefabrication reduces waste generation, energy consumption, and carbon emissions and lowers construction costs [3]. According to the Construction Industry Institute, prefabricated construction can result in up to 10% savings on overall costs and up to 25% on labor costs at the construction site [4]. In addition, it can also reduce logistical costs, as materials can be ordered in bulk, and the transportation of labor and machinery can be minimized [5].

On the other hand, choosing suitable materials is crucial in the construction project as it involves selecting the most appropriate component for a product from a limited number of options based on certain conditions [6]. Choosing the best material for a wall, a module, or an entire building is a complex process that requires consideration of various factors, including function, customer satisfaction, production systems, life cycle, usage, material characteristics, working environment, operation, and costs [7]. However, more studies need to develop a holistic approach to facilitate the selection of the material for prefabricated wood buildings. Multicriteria decision making (MCDM) offers a systematic methodology that simultaneously considers decision criteria (also subcriteria), benefit and cost data, and decision-maker perspectives to determine the best choice among various alternatives [8]. Various tools analyze and validate these criteria and subcriteria, such as the analytic network process, fuzzy set theory, genetic algorithm, and mathematical programming [9,10]. For example, Zakeri et al. [11] proposed a simple ranking process (SRP) to solve complex material selection problems. Peng et al. [12] introduced the sustainability level into MCDM optimization management to analyze prefabricated buildings economically. Ma et al. [13] developed an intelligent building retrofit decision-making model (machine learning algorithms) considering tacit knowledge and climate change.

The analytic hierarchy process methodology (AHP) is an MCDM tool that quantifies and prioritizes criteria and subcriteria. The AHP uses proportion scales to derive ratios from pairwise comparisons [14]. Subramanian and Ramanathan's [15] applications of the AHP have been classified into five major areas of operational research: operational strategy, processes, product design, resource planning, scheduling, project management, and supply chain management. Wang and Yang [16] applied the AHP to aid decision making for outsourcing information systems in companies, evaluating criteria such as economy, resources, strategy, risk, management, and quality. The main contribution of this study was to provide a decision-making tool to select service providers and criteria weighting vectors. In the construction field, Skibniewski and Chao [17] argue that for a tower crane case study, using the AHP could result in technical and economic evaluations of the decision-making process.

The AHP was also used for timber–concrete composite floor systems to select the optimal concept design for multistory buildings. A case study in Vancouver, Canada, used the AHP to create a unified sustainability index by comparing two six-story structural systems in concrete and wood [18]. Depending on the evaluation parameters, Sahlol et al. [19] used the AHP to select the most sustainable building material. Reza et al. [20] applied the AHP to evaluate the sustainability features of flooring systems. The authors asserted that the AHP provides a framework for robust and consistent decision-making practices.

Regarding the effectiveness of the AHP, Jato Espino et al. [21] evaluated 25 MCDMs in terms of their ability to assess many specific cases belonging to 11 different domains in construction. This study showed the predominance of the TOPSIS (Technique for Order of Preference by Similarity to Ideal Solution) and AHP. On the other hand, the authors also asserted that the AHP method stands out clearly from others regarding its usage, either alone or combined, due to its simplicity of application and flexibility for different types of problems. A comparative study of the AHP, ELECTRE, and TOPSIS methods was conducted to select the best location for the industry [22]. The author highlights that because the AHP ensures the analysis of judgment consistency, Saaty's model appears more robust in principle than the other two methods.

Moreover, the ability to quantitatively handle qualitative variables with the AHP was an important observed characteristic. Garbuzova-Schlifter and Madlener [23] argue that the AHP is used to deal with multicriteria problems in real situations. Thanks to these features, it can be adapted to the specificities of each application domain without requiring significant expertise from the decision-maker.

Furthermore, the AHP is widely used to address the problems of MCDM in real-life situations [23–25]. The AHP derives ratio scales from discrete and continuous pairwise comparisons, allowing quantitative and qualitative criteria analysis [14]. Pairwise MCDM tools like the Best Worst Method (BWM) [26], Guilford's method [27], and the AHP [28] play crucial roles in evaluating options and conducting pairwise comparisons within MCDM frameworks. The BWM stands out particularly when dealing with numerous items, as it allows preference strengths to be established. On the other hand, Guilford's method focuses primarily on determining priorities between elements in pairs. In contrast, the AHP sets preferences and quantifies the weight of these preferences. The AHP method necessitates decision makers to systematically incorporate perceptions, experiences, intuitions, and uncertainties, thereby creating priority scales or weights. A distinctive advantage of the AHP over other decision-making methods lies in its focused approach. It guides decision makers to concentrate on one aspect of the problem at a time, simplifying its complexity [29]. Consequently, this characteristic enhances the analytical reasoning capacity of the human brain, enabling more decisive decisions aligned with the overarching objective and more assertive decisions [30,31]. Therefore, the main goal of this study was to use the AHP decision-making tool to rank the criteria for material selection for prefabricated wood buildings in Canada and the United States.

2. Material and Methods

Analytic Hierarchy Process

The AHP is a powerful tool for solving problems that involve fuzziness and are impossible to solve with quantitative methods. It relies on pairwise comparisons and uses experts' judgments to establish priority scales [14]. The AHP involves two main phases. The first phase involves data collection, which is conducted through pairwise comparisons of criteria and subcriteria using a survey. The second phase consists of running the AHP method. For this study, we reviewed the literature to identify the criteria and subcriteria for selecting structural and envelope building materials [32]. Table 1 presents the results of this review, including the criteria and subcriteria, their definitions, and references.

The survey was conducted in two sections. Section A aimed to collect information on the experts' backgrounds, including their areas of expertise, education, and experience related to the subject of study only for the author's analysis. This was crucial to ensure that only experts with relevant knowledge and expertise were included in the weighting analysis, as described earlier. Section B focused on prioritizing criteria and subcriteria for weight allocation. The pairwise comparisons of the questionnaire were constructed according to the criteria and their subcriteria, as shown in Table 1.

The questions and pairwise comparisons were conducted separately: (1) pairwise comparisons for structures and (2) pairwise comparisons for envelopes. For this study, the experts were selected based on the following criteria: (i) professionals who work in the decision-making chain of materials and have knowledge in this field, such as architects, engineers, and project managers; (ii) professionals engaged explicitly in the prefabricated wood construction industry, including 2D systems (i.e., prefab wood systems) and 3D buildings (i.e., prefab wood buildings); and (iii) experts with a minimum of five years of professional experience in the points as mentioned earlier. The selection process involved consulting professional profiles on LinkedIn, resumes, and professional websites. Experts from different United States and Canadian regions were selected to gain a broader insight into the industry. Subsequently, these individuals were contacted via email; sometimes, meetings were conducted via phone and video conferencing to clarify and/or answer questions prior to the questionnaire. In qualitative research, successful groups can function effectively with as few as three individuals or as many as 14 participants [33]. Previous studies on the AHP have utilized four to eleven experts [34]. Therefore, for this study, a group of ten experts was adopted. The questionnaire was individually distributed via email, accompanied by a cover letter explaining its purpose, the researcher's information, participant anonymity, and the confidentiality of the information provided.

Table 1. Summary of criteria and subcriteria to select structural and envelope material.

Criteria	Description	Subcriteria	Description	Reference
Technical properties	The technical properties of materials are defined as properties that describe materials to the best of their ability. They refer to the minimum criteria to meet their functional performance requirements and are crucial in choosing the most suitable building materials.	Mechanical properties	The ability of a material to withstand stress	[35–39]
		Durability	Materials that are weather-resistant	
		Fire performance	The ability of a product to resist fire thanks to its properties and to limit the spread	
		Watertightness	Waterproof materials	
Site condition and logistics	Defined as the conditions of the area or surroundings, including climatic conditions, the delivery of materials, and the types of buildings depending on the construction materials to be chosen.	Ease of use	Materials that are easily integrated/used in systems or buildings	[39–44]
		Availability of materials	Materials that are easily found in the market or an area	
		Location, shape, and height of the building	Materials that are easy to use, regardless of the construction conditions	
Social benefits	The benefits to society for people of the use of certain materials in buildings	Occupant health	Materials that are not hazardous to the occupants	[42,43,45–51]
		Comfort, satisfaction, and well-being of the building	Materials that make the well-being of the occupants possible	
		Safety and security of building occupants	Materials that ensure the safety of the construction, the workers, and the occupants	

No personal identification was requested or stored. The main reason for conducting the research anonymously was to ensure no deceptive persuasion, as anonymity reduces the effect of dominant individuals. Furthermore, anonymity avoids sociopsychological problems and pressure on the interviewees and prevents the refusal to abandon expressed opinions publicly. The research was conducted between 10 February and 10 March 2022. The AHP methodology was conducted following the recommendations of Dong and Saaty [14] and Reza et al. [20] and is described as follows:

Step 1—Construct the matrix:

To determine the appropriate choice at each level of the decision-making hierarchy, it is necessary to understand the respondent's priorities among the compared elements. This involves making multiple pairwise comparisons, using Saaty's AHP scale (Table 2), to determine the relative weights of the features. The scale uses numbers 1, 3, 5, 7, and 9 to indicate the equal, moderate, strong, very strong, and absolute importance of each theme's significance, while intermediate values are represented by 2, 4, 6, and 8.

Table 2. Saaty's AHP scale of importance.

Weight	Definition
1	Equal Importance
3	Moderate Importance
5	Strong Importance
7	Very Strong
9	Absolute Importance
2; 4; 6; 8	Intermediate Values

The pairwise comparison on n criteria yields a matrix A of size (n × n), where each element aij (i, j = 1, 2, . . ., n) denotes the relative importance of i concerning j. The diagonal parts of A are always equal to 1, as a criterion compared to itself has equal importance. The pairwise comparison matrix A can be represented mathematically, as shown in Equation (1).

$$A = \begin{pmatrix} 1 & a_{12} & \ldots & a_{1m} \\ a_{21} & 1 & \ldots & a_{2m} \\ \ldots & \ldots & \ldots & \ldots \\ a_{m1} & a_{m2} & \ldots & 1 \end{pmatrix}, a_{ij} = \frac{1}{a_{ji}}, a_{ji} \neq 0. \quad (1)$$

Step 2—Construct the normalized matrix:

In this step, the mathematical process to normalize and find the relative weights for each matrix is conducted. The relative normalized weight (W_i) of each factor is obtained by calculating the geometric mean (GM) of i row and normalizing the geometric means of rows in the comparison matrix (Equations (2) and (3)).

$$GM_i = \{a_{i1} \times a_{i2} \times a_{i3} \times \ldots \times a_{ij}\}^{1/n} \quad (2)$$

$$W_i = GM_i / \sum_{j=1}^{j=n} GM_i \quad (3)$$

Then, the matrix X is calculated, which refers to an n-dimensional column vector of the sum of the weighted values for the importance degrees; then, X = A × W, where:

$$W = [W_{1,}, W_2, W_3, \ldots, W_n]^T \quad (4)$$

$$X = A \times W \begin{bmatrix} 1 & a_{12} & \_ & a_{1n} \\ a_{21} & 1 & \_ & a_{2n} \\ \_ & \_ & \_ & \_ \\ a_{n1} & a_{n2} & \_ & 1 \end{bmatrix} \begin{bmatrix} W_1 \\ W_2 \\ \_ \\ W_n \end{bmatrix} = \begin{bmatrix} c_1 \\ c_2 \\ \_ \\ c_n \end{bmatrix} \quad (5)$$

where c_i (j = 1, 2, . . ., n) is the set of criteria.

Step 3—Calculate the consistency ratio:

Obtain the largest eigenvalue λ max. It is the average of the consistency values. Calculate the consistency index (CI) with Equation (6).

$$CI = \frac{\lambda_{max} - n}{n - 1} \quad (6)$$

The λmax is the highest value in the matrix. To calculate the λmax, Equation (7) is used. The λmax is calculated via the normalized matrix's average weight sum value (WSV) divided by the criterion weight (CW).

$$\lambda_{max} = \text{mean vector} \frac{WSV}{CW} \quad (7)$$

To validate the results of the AHP, the consistency ratio (CR) is calculated in Equation (8), as recommended by Taherdoost [52]. The random index (RI) value depends on values corresponding to the value shown in Table 3.

$$CR = \frac{CI}{RI} \tag{8}$$

Table 3. Random index (RI).

n	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49

The random index (RI) is calculated for square matrices of order n used for pairwise comparisons. It was established by the Oak Ridge National Laboratory (USA), and the proof of RI was not the subject of this research, as shown in Table 3.

To verify the consistency of relative priorities, the consistency index (CI) is calculated, and the resulting consistency ratio (CR) is examined to ensure that the responses are coherent and logical. An acceptable CR value should be less than 0.1, and the result is validated. In this study, all of the results obtained from the questionnaires utilized for the AHP analysis were modeled using R programming language version 4.1.1106. All of the previous equations for the AHP calculations were facilitated by the open-access calculation package provided in the ahpsurvey package version 0.4.1 [53].

3. Results and Discussions

3.1. Profile of the Respondents

A summary of the years of experience (Figure 1a), the level of study (Figure 1b), and the position in the buildings industry (Figure 1c) of the profile of the group of experts who composed this study are presented below. The names of experts are undisclosed to respect their anonymity. Figure 2 shows the level of knowledge on the subjects: building materials (a), prefabricated wood building systems (b), and prefabricated wood buildings (c). Information on the respondents shows that the group which participated in the study are professionals within the industry directly involved in the decision-making process and wood construction. The respondents are professionals currently working with or have experience with, i.e., have worked with, or an expert, i.e., is constantly working on building materials, prefab wood systems (2 D elements), or prefab wood buildings (3 D or volumetric elements). In addition, as professionals are at the top of the decision making of products used in the most diverse projects, they offer valuable insights, as Cheng and Li [54] indicated. Furthermore, the experts' recruitment criteria show that the experts belong to different backgrounds (academia and industries).

3.2. AHP Analyses

As Irfan et al. [55] pointed out, using AHP pairwise comparison matrices is a tool to calculate the weights of the main criteria and the subcriteria using a geometric mean. Three main criteria and their respective subcriteria were used to construct the pairwise decision matrices (i.e., technical properties, site conditions, logistics, and social benefit) recognized from a previous study [32] for the AHP analysis. In the survey, the weights for the criteria were calculated as a first step. Subsequently, the weights for the subcriteria for each criterion were weighted.

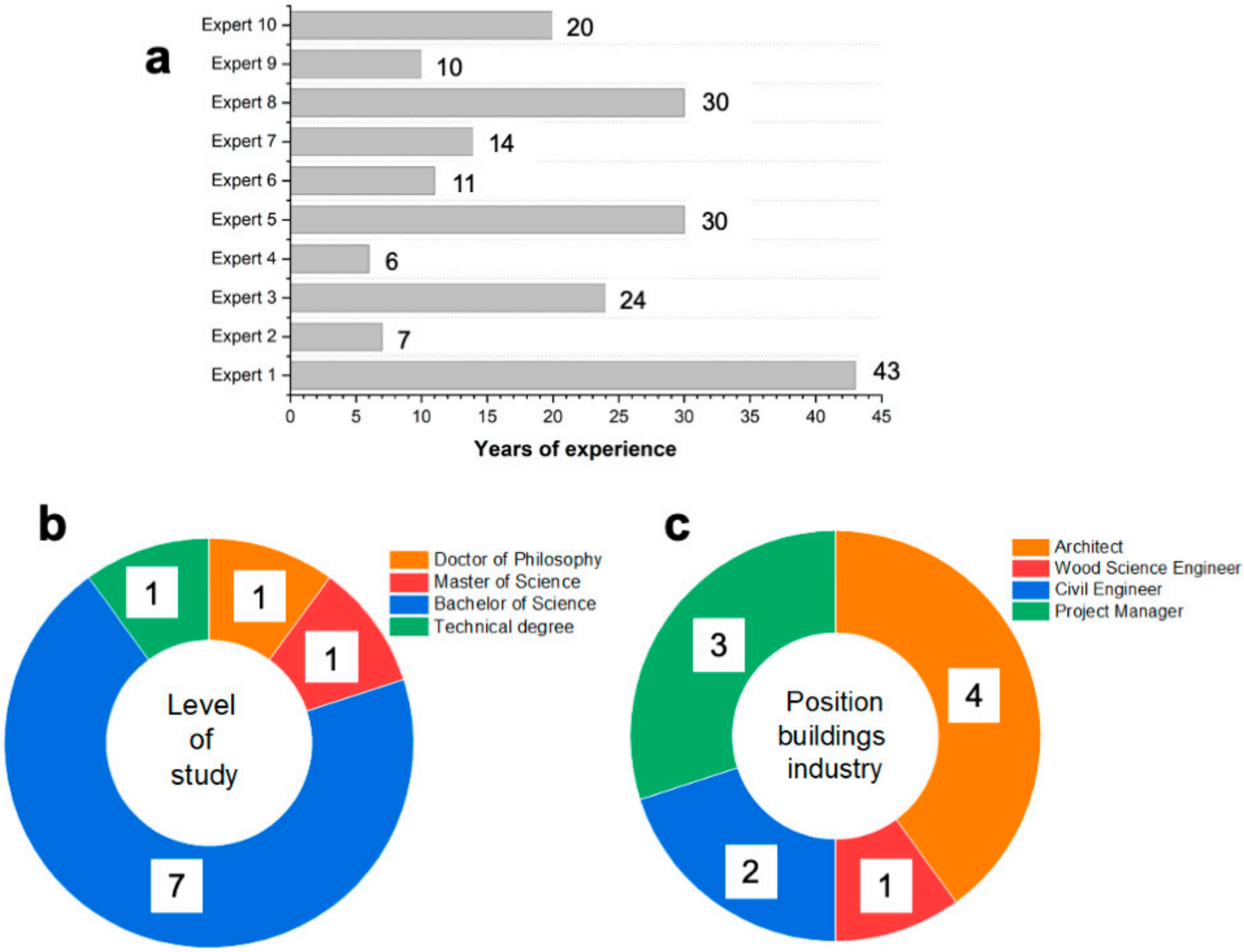

Figure 1. Respondents' profile: (**a**) years of experience in the building industry, (**b**) level of study, and (**c**) position in the building industry.

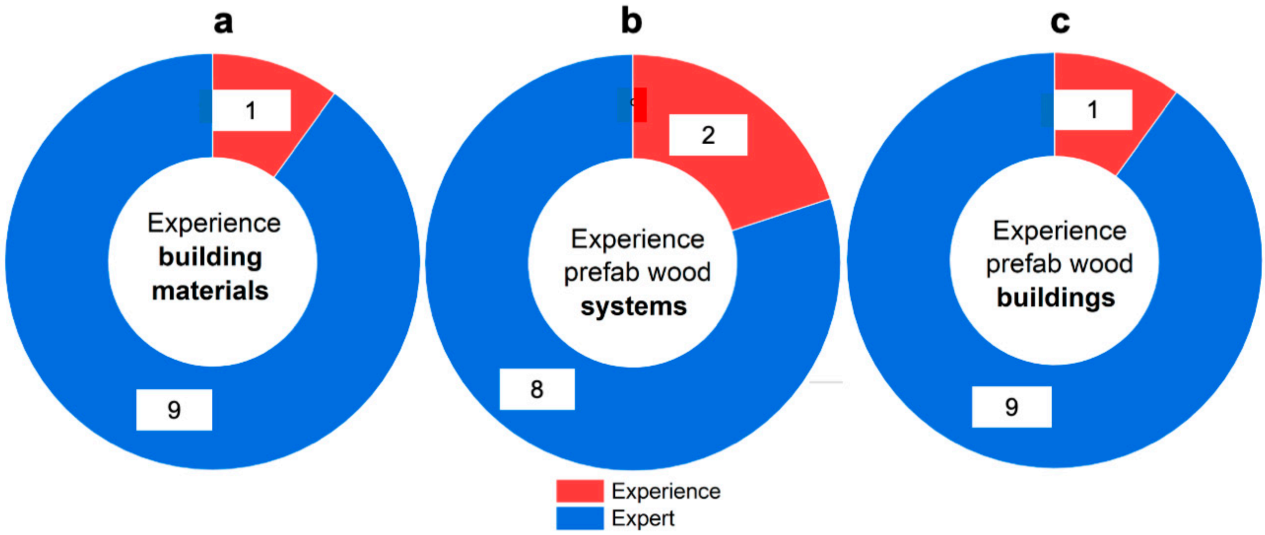

Figure 2. Level of knowledge on building materials (**a**), prefabricated wood building systems (**b**), and prefabricated wood buildings (**c**).

3.2.1. Ranking of Criteria

Table 4 shows the weights, the ranking, and the consistency values for the criteria calculated with the AHP for structural and envelope materials. For structural and envelope materials, the social benefits criteria were placed in the first rank for choosing the materials, i.e., the weight of 0.512 and 0.592, respectively. After social benefits, the second most important criteria were the site condition and logistics for selecting a material for buildings, weighing 0.386 (structures) and 0.301 (envelopes). Finally, technical properties are the least significant criteria in the scenario, as they obtained the minimum weight of 0.100 for structural materials and 0.105 for envelope materials.

Table 4. Weights, rankings, and the CR values for the criteria calculated with the AHP.

	Structures		Envelopes	
Criteria	**Weight**	**Ranking**	**Weight**	**Ranking**
Technical properties	0.100	3rd	0.105	3rd
Site condition and logistics	0.386	2nd	0.301	2nd
Social benefits	0.512	1st	0.592	1st
Consistency Ratio	0.0008		0.0012	

3.2.2. Ranking of Subcriteria

Technical Properties

As shown in Figure 3a, the preference order of subcriteria under the technical properties criterion for selecting materials for structures was watertightness, mechanical properties, fire performance, and durability. The priority order of envelope materials for subcriteria under technical properties criteria is as follows: watertightness, fire performance, durability, and mechanical properties (Figure 3b).

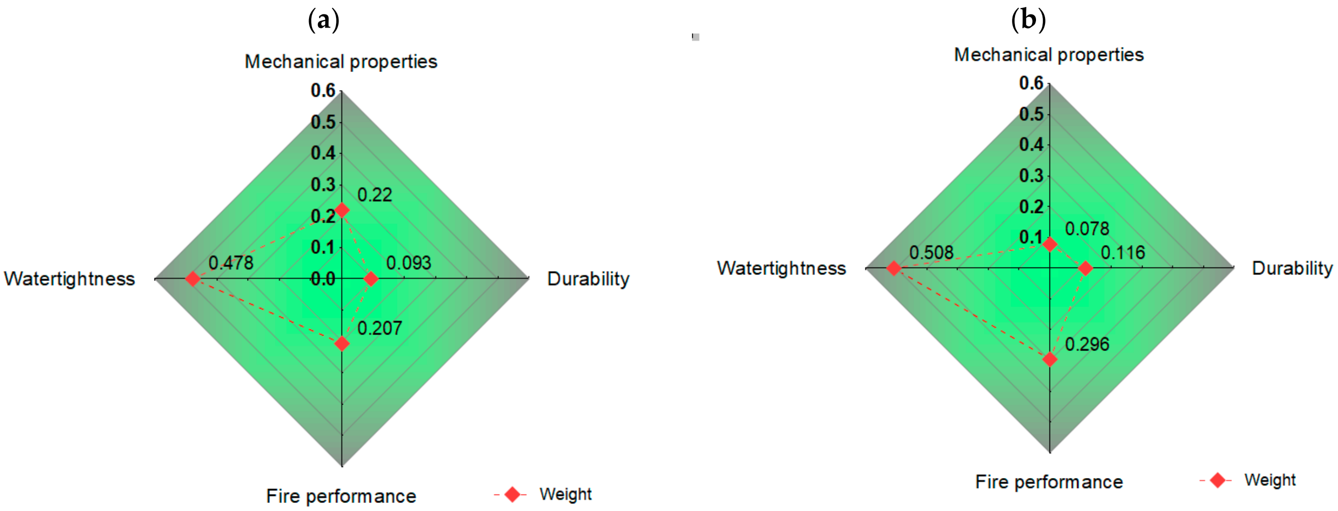

Figure 3. Ranking of subcriteria under technical properties for selecting materials: (**a**) structures and (**b**) envelopes.

The most crucial subcriteria for structures and envelopes is watertightness, with a weight of 0.478 and 0.508, respectively. The prioritization for watertightness can be explained, since rain or other types of water penetration or moisture into the building structure or envelope can create problems that affect the durability of building materials, causing material degradation, mold growth, wood decay [56], steel corrosion, and concrete deterioration. Water infiltration is a common issue that can occur at the connections between various building envelope elements, including joints between prefabricated façade elements or windows [57]. According to Saito [58], rainwater especially reaches inner structures through the areas where nails and staples fasten the roofing underlayment. Furthermore, the author states that the wood decay analysis for the roof assembly suggested that the rain penetration into the surface of the plywood should be approximately 1 kg/m^2 per year, a critical value to prevent wood deterioration by wood-decaying fungi.

Whether constructed using dimension lumber with or without structural sheathing or utilizing multiple layers of plywood or alternative panels, wood products can be vulnerable to significant moisture exposure [59]. This susceptibility arises due to the tendency for water to become trapped between the boards or panels, leading to prolonged moisture retention. Even when subjected to elevated temperatures, the dissipation of this trapped moisture remains slow, risking durability loss and fungal growth [59–61]. Therefore, much research has been carried out on alternative materials and techniques for achieving watertight seals in joints, which has surged recently, as indicated by the increasing number of references in publications [57,62–64]. Gaspari et al. [39] demonstrated the effectiveness of utilizing a breathable yet water-resistant membrane on the exterior of mass timber wall assemblies to reduce water exposure. This innovative solution not only prevents water damage but also functions as an air barrier for the timber wall assembly and also serves as an air barrier. In addition, increasing the moisture of wood materials significantly reduces the mechanical properties of the materials and affects their thermal conductivity and heat capacity, thus affecting their thermal performance [65]. Therefore, using a building material that prevents water intrusion would reduce these challenges and concerns of wood buildings.

The subcriterion mechanical properties was prioritized in second place for structural materials under the technical properties criterion, with a weight of 0.220. It is well known that mechanical performance is an essential reference value for structural materials. A high mechanical strength can protect the whole structure when subjected to external force [66]. In their research, Jiloul et al. [67] have shown that corrugated panels (bio-based) are highly promising as a structural material for various applications, mainly when used as web components in I-joists. The study thoroughly examined the panels' compressive, tensile, and bending properties, parallel and perpendicular to the corrugations. Innella et al. [68] assessed prefab building transport and found that vibrations could affect plywood and steel joints. About 96% of shear stresses on plywood during transport might exceed its strength, highlighting the importance of selecting robust plywood for optimal building performance.

For envelopes, fire performance was prioritized in second place with a weight of 0.296. While for structures, fire performance was prioritized in third place with a weight of 0.207. This result can be explained due to the evacuation-related risks of materials in residential fire scenarios [69]. A fire in a building can be a phenomenon that causes human losses by damaging the wall or as a potential path for the spread of fire to compartments above or to an adjacent building [70]. In addition to the risk to life that these fires present, the risk of structural collapse also increases due to the structural system's severe and complex thermomechanical response [71]. With this regard, fire-retardant strategies have been used to improve the fire performance of building materials used in structures and envelopes [72]. For both structures and envelopes, durability was prioritized in fourth place with a weight of 0.093 and 0.116, respectively. Research has proposed employing alternative materials, such as wood composites, silica boards, and bamboo scrimber reinforced with glass fibers, which can integrate fire-resistant additives [73]. Moreover, innovations in the architectural design of these structures have also been suggested to enhance the safety of occupants in case of fires [74].

On the other hand, this subcriterion must be addressed during the selection process. As mentioned, wood can present susceptibilities to biodegradation, such as under weathering and climate conditions, or biological attacks (decay fungi and insects such as termites). In addition, losses attributed to the biodegradation of wooden materials in the United States can reach approximately USD 5 billion annually [75].

According to Winandy and Morrell [76], utilizing wood-based composites and bio-based materials in construction and specialty products can prioritize environmental sustainability and resource conservation. These materials are expected to provide high performance, long-lasting quality, durability, and increased value. Concerning the technical properties criterion, the results suggest that a better route for choosing the structure products might be selecting materials that provide greater watertightness and mechanical performance. The results suggest selecting materials that provide greater watertightness and better fire performance for envelope products.

Site Conditions and Logistics

The priority order of subcriteria under the condition and logistics criterion for selecting materials for structures and envelopes is as follows: location, shape, and height of the building; availability of materials; ease of use (Figure 4). The most critical subcriterion in this criterion is the building's location, shape, and height, with a weight of 0.567 for structural materials (Figure 4a) and 0.592 for envelopes materials (Figure 4b).

Figure 4. Ranking of subcriteria under site condition and logistics for selecting materials: (**a**) structures and (**b**) envelopes.

The literature supports these results since the proper logistics, location, and materials available for buildings and prefabricated components, especially for industrialized construction, enhance construction efficiency [77]. Chew et al. [40] found similar results, demonstrating that using complex materials or systems (in width and height or format) reduces the possibility of a working platform. On the other hand, it needs to be fixed with the system's design and the access and security of the workers. Bhandari et al. [78] argue that the choice between 2D and 3D prefabrication in construction considers transportation efficiency and duration. 2D modular components offer better transport efficiency and shorter construction times than 3D modules. The proximity to manufacturers and logistics also influences this choice. A possible route could be mobile fabrication near sites that enhance prefabrication and adaptability, particularly in emergencies or rapid housing needs. Module variety impacts construction and logistics flexibility; a single type streamlines processes, while multiple types offer spatial options. Striking a balance between flexibility and cost determines the module type.

Significant impacts can arise in scenarios involving challenging weather risks during development, constraints on construction timelines, and elevated labor expenses [79,80]. The building type also plays an essential role in the construction's operation. It directly influences the project's quality since this subcriterion might account for up to 70% of the total construction cost estimation [81]. It is also important to highlight that using lightweight materials (e.g., wood) can reduce costs, as it allows additions to the building height without foundation reinforcement that might be required if other building heavyweight materials (e.g., concrete and steel) were used [82].

Furthermore, as it is widely known in the scientific community, using wood and its materials proves to be a renewable option thanks to the carbon sequestration capabilities of the wood building, bringing class energy efficiency and future end-of-life opportunities. In addition, the idea that wood construction strengthens local businesses was identified as a strategic and political issue [37], demonstrating alignment with the materials availability subcriterion, which proved to be the second priority with a weight of 0.256 for structures and 0.261 for envelopes. For this section (site condition and logistics), the results suggest that the route to choose both structural and envelope materials is to select materials that are easy to use, regardless of the construction conditions, and that are easily found in the market. These findings align with the research conducted by Li et al. [83], which involved an analysis of 100 studies about prefabricated construction management. The authors identified that the pivotal determinants for successful prefabricated building encompass the technological integration, design environment, and production, transportation, and assembly strategies. Also, as Kamali and Hewage [4] highlighted, prefabrication's primary factors encompass heightened preplanning endeavors and on-site logistics and transportation challenges.

Social Benefits

Figure 5 shows the ranking of subcriteria under the social benefits criterion for selecting materials. The priority order of subcriteria for this criterion for structures is as follows: safety and security of the building's occupants, comfort satisfaction of the building, and occupation health. The results showed that the criterion of safety and security of the building's occupants was prioritized first, weighing 0.458 (Figure 5a).

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

Figure 5. Ranking of subcriteria under social benefits for selecting materials: (**a**) structures and (**b**) envelopes.

This criterion refers to materials that ensure the safety of the construction, the workers, and the occupants. Considering the implementation of materials, the importance of this criterion in construction projects is given due to the extremely high rate of injuries and fatalities [84]. The Bureau of Labor Statistics [85] stated that in the United States, about 1000 people were involved in accidents and were killed during construction between 2016 and 2020. In Canada, the proportion of work accidents varies according to the region; New Brunswick and Ontario have lower fatalities than the national level, with 7.8% and 11.4%, respectively, while Saskatchewan and Alberta have the higher national levels, accounting for 23.6% and 19.7% of work accidents [86]. The Association of Workers' Compensation Boards of Canada stated that between 2017 and 2019, about 200 deaths were reported yearly in the construction industry, representing about 20% among other evaluated sectors [87]. Bavafa et al. [88] state that a construction worker has a one in 300 chance of being killed at work. Moreover, it is essential to mention that increased safety in the construction process reduces insurance for workers and the building, which translates into lower costs for the project and the life of the building [89].

This highlights the crucial importance attributed by construction experts to the safety of workers. Similar results were found in previous research [4,90]. They emphasize that using prefabricated material (e.g., mass timber) approaches can significantly vary labor health and safety levels throughout building projects. Notably, adopting prefabricated systems and materials has been shown to potentially lead to an impressive up to 80%

reduction in on-site reportable accidents [91]. From the occupants' perspective, safety is also an essential issue since, as indicated by recent studies, increasing the occupants' safety can help people maintain their physical well-being [92,93]. For tall buildings, for example, Kwok et al. [94] stated that prolonged wind excitation could cause occupants to suffer from dizziness, migraines, and nausea. In addition, the resonated dynamic response due to wind load can even lead to catastrophic structural failure [95]. According to Husin et al. [96], structural elements are critical safety factors for performance assessment. Therefore, decision makers are in a position to help improve building safety by addressing security [24]. Foraboschi [84] concluded that designed structural mechanics, innovative failure analysis, and specially devised construction techniques allowed the structural design to exploit materials fully. This result is supported by previous studies which describe that the type of structural material and its deterioration impact the quantification of performance in terms of collapse, safety, and health of users [97].

The criterion of comfort satisfaction of the building was prioritized in second place for structural materials and in first place for envelopes, with weights of 0.303 and 0.426 (Figure 5b), respectively. Comfort connects physiological and psychological aspects of environmental satisfaction with physical outcomes such as enhanced work performance and increased organizational productivity [98]. According to Mansor and Sheau-Ting [99], environmental factors that define indoor environmental quality are thermal comfort, indoor air quality, acoustic comfort, and visual comfort, including color, humidity, and ventilation. Considering thermal comfort in buildings, there is an urgent need for energy-saving solutions for reducing building energy use. The International Energy Agency (IEA) reports that building energy use will rise by 50% in 2050 if no building energy efficiency improvements are implemented [100]. In buildings, as the envelope separates the indoor and outdoor environment, the materials used play a crucial role in total building energy consumption and comfort. Improving the building comfort for working spaces improves the energy demand and ensures occupants' improved productivity [101]. Thus, considering this, research has been conducted on advanced regulating materials and systems to reduce the associated energy consumption while maintaining indoor thermal comfort [102]. These results follow those found by Khalil et al. [34]

3.2.3. Final Ranking of Subcriteria

The final classification of the subcriteria is calculated by multiplying the weight of the respective criterion with the subcriterion, as recommended by Irfan et al. [55]. Table 5 (structures) and Table 6 (envelopes) show the overall weights for the criteria and subcriteria, the consistency ratio, and the final rankings. For structural materials, the safety and security of building occupants is the top-ranked subcriterion, obtaining a weight of 0.234, followed by location, shape, and height of the building, with a weight of 0.218. Comfort, satisfaction, and well-being of the building, occupant health, and availability of materials are ranked as the third, fourth, and fifth most significant subcriteria for structural materials, with weights of 0.155, 0.121, and 0.098, respectively. The least ranked subcriteria are ease of use (0.067), watertightness (0.047), mechanical properties (0.022), fire performance (0.020), and durability (0.009). For envelope materials, comfort, satisfaction, and well-being of the building is the top-ranked subcriterion, obtaining a weight of 0.252, followed by safety and security of the building with a weight of 0.206. Location, shape, and height of the building, occupant health, and availability of materials were ranked as the third, fourth, and fifth most significant subcriteria, with weights of 0.178, 0.132, and 0.078, respectively. The least ranked subcriteria for choosing envelope materials were watertightness (0.053), ease of use (0.044), fire performance (0.031), mechanical properties (0.021), and durability (0.012).

Table 5. AHP for ranking of criteria for structural materials.

Criteria	Weights of Criteria	Subcriteria	Consistency Ratio	Weight of Subcriteria	Global Priority Weight	Overall Ranking
Technical properties	0.100	Mechanical properties	0.09	0.220	0.022	8th
		Durability		0.093	0.009	10th
		Fire performance		0.207	0.020	9th
		Watertightness		0.478	0.047	7th
Site condition and logistics	0.386	Ease use	0.05	0.176	0.067	6th
		Availability of materials		0.256	0.098	5th
		Location, shape, and height of the building		0.567	0.218	2nd
Social benefits	0.512	Occupant health	0.08	0.238	0.121	4th
		Comfort, satisfaction, and well-being of the building		0.303	0.155	3rd
		Safety and security of building occupants		0.458	0.234	1st

Table 6. AHP for ranking of criteria for envelope materials.

Criteria	Weights of Criteria	Subcriteria	Consistency Ratio	Weight of Subcriteria	Global Priority Weight	Overall Ranking
Technical properties	0.105	Mechanical properties	0.05	0.007	0.021	9th
		Durability		0.116	0.012	10th
		Fire performance		0.296	0.031	8th
		Watertightness		0.508	0.053	6th
Site condition and logistics	0.301	Ease use	0.06	0.147	0.044	7th
		Availability of materials		0.260	0.078	5th
		Location, shape, and height of the building		0.592	0.178	3rd
Social benefits	0.592	Occupant health	0.05	0.223	0.132	4th
		Comfort, satisfaction, and well-being of the building		0.426	0.252	1st
		Safety and security of building occupants		0.349	0.206	2nd

4. Conclusions and Limitations

This research investigated the use of the Analytical Hierarchy Process (AHP) for selecting materials in prefabricated wood buildings in Canada and the United States. The findings help to fill gaps in current research on this topic. The findings from the AHP analysis underscore the importance of prioritizing occupants' safety and comfort in building design. The results illuminate that social benefits are the most critical factor when selecting structural and envelope materials. Following this, considerations tied to site conditions, logistics, and technical properties emerge as key determinants. Delving into the AHP's finer details, the experts' input has highlighted the top five subcriteria for each material type. For structural materials, safety and security of occupants, location suitability, building form, occupant comfort, satisfaction, and health have emerged as the leading factors, with corresponding global weights of 0.234, 0.218, 0.155, 0.121, and 0.098. Similarly, for envelope materials, comfort, satisfaction, and well-being of occupants takes precedence, closely followed by safety and security of occupants, location suitability, building form, and occupant health, carrying respective global weights of 0.252, 0.206, 0.178, 0.132, and 0.078.

The findings from applying the AHP in selecting materials for prefabricated wood buildings offer valuable insights. However, it is essential to highlight some limitations that may affect the generalizability and applicability of these conclusions. Firstly, this research specifically focused on prefabricated wood buildings within Canada and the United States. These outcomes might not transfer directly to other geographical regions with distinct climatic conditions, diverse building regulations, or varying cultural preferences. Furthermore, the dynamic changes within the construction sector, including technological advancements, new regulations, and evolving user preferences, impact the relevance and applicability of the identified criteria over time. Finally, the practical feasibility of implementing decisions based on these AHP results could be influenced by budgetary constraints, market availability of materials, and specific project requirements, potentially affecting the direct applicability of the conclusions.

Author Contributions: Methodology, M.R.C.; writing—original draft preparation, M.R.C.; writing—review and editing, M.R.C. and P.B.; supervision, P.B.; project administration, P.B.; funding acquisition, P.B. All authors have read and agreed to the published version of the manuscript.

Funding: The authors are grateful to Natural Sciences and Engineering Research Council of Canada for the financial support through its IRC and CRD programs (IRCPJ 461745-18 and RDCPJ 514294-17).

Data Availability Statement: The data presented in this study are available in article.

Acknowledgments: The authors are grateful to the industrial partners of the NSERC Industrial Research Chair on Eco-responsible Wood Construction (CIRCERB), the industrial partners of the Industrialized Construction Initiative (ICI), and the Créneau Accord Bois Chaudière-Appalaches (BOCA).

Conflicts of Interest: The authors declare no conflict of interest.

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