Factors Influencing the Sustainability of Wood-Based Constructions’ Use from the Perspective of Users

Jozef Švajlenka * and Mária Kozlovská

Abstract: Traditional construction solutions face increasing competition from more ecological materials such as construction systems based on wood. Thanks to the numerous favourable properties of wood, wood construction enjoys great popularity and allows building economical and modern constructions that are durable and contribute to an ecological future. This study is motivated by the need for innovative solutions in construction and offers numerous findings based on examining actual constructions based on wood. By examining the interactions among selected factors of constructions and their users, the study reacts to the global challenges that call for increased efficiency and sustainability in construction. The examination of the interactions among the selected factors offers more extensive knowledge in the field of constructions based on wood and points towards possible innovative approaches for more sustainable housing and for a more efficient construction industry. The analyses showed that the key aspects that determine the sustainability of housing from the perspective of users are the standard of construction workmanship and construction time, which depend on the choice of construction system, cost-efficiency of use, and material composition and floor plan design. These aspects also interacted with other technical and design aspects, which also played an important role in the perception of housing sustainability.

Keywords: wood construction; sustainability; clean technologies; wood; user preferences; housing; sustainable development

1. Introduction

Global economic development proportionately increases living standards in the developed industrialised world, resulting in growing global consumption of energy resources. It is estimated that by 2030, the global energy demand will increase by 50 percent, and fossil fuels will represent 80 percent of reserves. This trend is further exacerbated by the inability to reduce the loss of biodiversity, with serious consequences for long-term economic sustainability. The environment is constantly modified by human activity. This activity includes construction, which shapes both human settlements and the surrounding landscape. Every newly built building becomes part of the space transformed by humans [1,2]. The user of a building, the building itself, and the environment interact to form a coherent whole. Construction culture determines the built-up environment for people and substantially affects their quality of life [3]. This means that architecture and construction culture are a topic that receives a great deal of attention. By protecting architecture and construction culture, it is possible to ensure good social, economic, ecological, and cultural conditions for the present and future generations [4–6].

The technological progress of society has far-reaching consequences, and the globalization process significantly affects the state of the environment [7–9]. The construction industry contributes enormously to environmental degradation [10]. This means that sustainable construction is one of the main areas that can help address the global problem of climate change and contribute to sustainable global development [11,12]. Many studies...
focus on sustainable architecture and urbanism, integrated territorial development, the use of energy-efficient technology, heat loss reduction in buildings, etc. Another important area is also research in the field of more sustainable building materials and structures, such as those studied by Zubizarreta et al. [13] and García et al. [14]. It is impossible to achieve an environmentally suitable construction without using ecological materials and products with a low carbon footprint [15], low emissions of hazardous substances, and higher biological stability.

The economic transition from the secondary sector based on manufacturing to the tertiary sector dominated by services has led to social changes resulting in the mass relocation of people to cities and suburban areas [16,17]. A growing population increases demand for new construction, making the sustainability of urban life a pressing issue [18]. The transformation of economic activity also means that some of it moves to the countryside, which changes the structure of rural settlements [19]. The growth of settlements is influenced by the needs of various private initiatives. The result of this transformation of cities and villages affects the life of all inhabitants.

Buildings are an environment where people spend 90% of their time [20]. Every building is part of a city or village forming an entity whose harmonious and aesthetic composition should ideally meet the criteria of functionality and safety and comfort, in other words, it should be a pleasant place to live. An assessment of the degree of sustainability of buildings involves economic, social, and environmental criteria and their interconnections [21,22]. The ideal outcome is a situation where the aspects of all three interacting areas are represented in a balanced way. For example, the economic sphere does not only incorporate economic aspects but also social and environmental aspects [23]. This interconnection also applies to the social and environmental spheres, where the aspects of the other two spheres are represented complementarily. Population growth, growing demand in society, and the ever-growing use of new technologies increase the consumption of energy and mineral resources. The growing pressure on energy resources also increases environmental burden, threatening the balance of the three spheres mentioned above [24,25]. The perception of the environment by individuals is influenced by their biological needs and abilities and by their commonly used technical equipment [26,27]. At the same time, the needs and desires of individuals may be vastly different. When designing a modern sustainable building, it is necessary to consider which requirements are genuinely necessary and which it is sensible to eliminate with respect to sustainability. It is necessary to consider the location and functions of a construction, its adaptability to changes, durability, orientation, size, form and structure, the materials to be used, and its method of heating and ventilation [28,29]. These aspects determine the amount of energy required for construction and for the transport of construction materials and then for the maintenance and operation and transport of users to and from their construction. Considerations regarding the demolition method are also essential for sustainability.

The quality of the environment in which people live substantially affects their behaviour [30]. In the current conditions of market economy, it is mostly private interests that affect the resulting built-up environment. The quality of the outcome and its benefits then depend on how educated and cultured private investors are. To support the interests of the majority, it is important to develop a sense of community within an urban unit, where individuals pursue a beneficial solution together, tolerating and understanding individual differences. The criteria that accommodate social and cultural needs within an urban unit include cultural and aesthetic values and traditions and customs [31,32]. The requirements for function, comfort, quality of floor plan design, flexibility, identity, opportunities for social life, enjoyment of culture and sports, and accessibility and safety are associated with regional conditions and customs [33]. The general relationship with the location and the local natural environment is also important, along with employment as a reason to settle in the location [34]. The environment of buildings is created by using materials, products, and technologies whose arrangement, composition, properties, functions, and appearance affect the residents [35,36]. The environment of buildings affects people’s mental and
physical health and their moods and work performance, which brings us back to economic aspects and highlights the interconnections among the individual criteria.

Buildings consume 35% of all produced energy and generate 40% of direct and indirect CO₂ emissions \([37–39]\). They also use 12% of our water and produce more than 30% of greenhouse gas emissions. The construction industry can contribute to the better management of limited resources and to a reduction in greenhouse gases (particularly CO₂) more than transport or any other industry \([40]\). It is apparent that buildings are the biggest polluter of the planet and the biggest consumer of energy and mineral resources \([41]\). This is also confirmed by the Energy Performance of Buildings Directive (2002/91/EC), adopted as a result of the highly negative impact of buildings on the environment \([42]\) rather than for the sake of systematic energy saving (updated by European Parliament and Council Directive 2010/31/EU, known as the “20-20-20” strategy). The design and construction of sustainable buildings has become an important international trend \([43]\), which is also evidenced by the practice of issuing energy certificates for buildings \([44]\). The last decade has been characterised by a more extensive use of insulation, window replacement, and the construction of low-energy buildings, which is natural, as the most can be saved where the most is spent.

The conditions of construction sustainability make it clear that every building is closely connected with its environment \([45]\). The surrounding area of a house should, to the largest extent possible, satisfy the needs of its construction and use, and of the activities performed by its users to provide food, materials, and energy \([46,47]\). In an ideal situation, the material for construction should come from the surrounding area, which means that straw, wood, clay, stone, etc., can be used. This principle is not new, as a few centuries ago, constructions did meet this condition (this is still true in developing countries) by using material from the surrounding area. According to the WHO, as many as 30% of the population of developing countries suffered from the so-called sick building syndrome \([48–50]\), and this figure rose to an alarming 60% in 2002. It turns out that life in buildings from traditional materials (concrete, plasterboard, etc.) does not have a favourable effect on the persons exposed to them, as they release harmful substances into the air \([51]\). On the other hand, people living in houses built from natural materials claim that they have a pleasant, happy, and healthy life in them \([52,53]\).

The use of ecological material solutions such as wood and materials based on wood is increasingly favoured in connection with the sustainability trend. The use of wood in all areas of life is almost as old as humanity itself. Wood, being one of the oldest construction materials, is by no means obsolete for use in construction \([54]\). The advantage of this construction material is its easy processing, high degree of rigidity relative to its weight \([55,56]\), relatively good insulation properties \([57,58]\), and high durability (only with the right choice of wood species and a correct design and maintenance) \([59]\). Wood can be used in residential and commercial buildings as a construction or aesthetic material \([60]\). In buildings built from other materials, it is still represented particularly in roof structures, internal doors and their frames, stairs, floor layers, and facades \([61]\).

We are increasingly confronted with the decision making of future users regarding wood constructions \([62]\) on the basis of their preferences with respect to the material and technological base \([63]\). Another important factor in this decision-making process is certainly the economic criteria influencing the overall efficiency of a particular technology within the construction life cycle \([64,65]\). All of this is also associated with the basic sustainability criteria that are commonly used today \([66,67]\).

The trend of sustainable and efficient solutions in the construction industry gives rise to the need for studying the interactions among the individual elements of constructions and their end consumers. The presented research was focused on actual constructions and the interactions among their criteria and user ratings. The set objective gave rise to a hypothesis to examine, i.e., whether the individual criteria of constructions affect the sustainability factors from the users’ point of view. The examination of the interactions among the selected factors leads to a better understanding of the components of sustainability
and efficiency in the life cycle of constructions and helps identify innovation approaches for a more sustainable and cleaner construction industry. A deeper understanding of the components affecting the sustainability of a project allows their future innovation with a direct impact on the efficiency and sustainability of housing, buildings, and, ultimately, the construction industry itself. The following part of the work presents the methodology through which the correlation analysis suitable for such types of hypotheses was implemented. This part is followed by the results of the research, presenting the findings of a quantitative and qualitative statistical analysis. Cluster analysis was also applied to further assess the data examined. The last part is dedicated to discussion and to identifying parallels with the works published in this area.

2. Material and Methods

This work is focused on analysing selected factors of actual constructions as they interact with their users. The study examined actual constructions based on wood and the opinions of their users on the examined aspects of use. The examined constructions were built using different construction systems based on wood, such as column, prefabricated panel, log, skeleton, and half-timbered constructions. The analyzed constructions were located in Central Europe (Slovakia and the Czech Republic). The data for the research were obtained in a combination of personal interviews with users and an online electronic questionnaire, deemed to be an effective way of obtaining data from specific users. Of the total number of users who answered the questionnaire, 64% were men and 36% were women. As for age groups, 5.4% of the respondents were aged 19–26 years, 24.3% were aged 27–34 years, 47.1% were aged 35–49 years, 18.9% were aged 50–64 years, and 4.3% were aged over 65 years. The study sample that underwent a statistical analysis consisted of 112 constructions, where the constructions built using the column and prefabricated technology made up the highest share, i.e., almost 90% (101 h). The panel construction system was represented by 45 buildings, the column construction system represented 35 buildings, and the log construction system was represented by 21 buildings. These shares show that these types of constructions based on wood are the most common in the standard conditions of individual construction. The appearance of these constructions is indistinguishable from traditional masonry constructions, but their material basis determines their construction method, use, and final disassembly at the end of their lifetime. Figure 1 shows examples of the three types of constructions. The Statistica 12 software, using the Spearman correlation method, was chosen as the statistical tool for the analysis. The statistical analysis was performed with $p = 0.05$, $p = 0.01$, and $p = 0.0001$ significance levels. The correlation analysis was applied in the examination of the stated hypothesis of the research, where the priority was to determine whether a correlation exists between the examined parameters of the constructions and the perceptions of their users. The results of the statistical analysis should indicate which parameters mutually interact and how, so that innovation activities to improve the efficiency and sustainability of constructions based on wood could be identified. The so-called cluster analysis was chosen for a preliminary analysis of the connections among the parameters and applied to selected groups of parameters. Cluster analysis is a normative method of analysing systems or processes in which different levels of complexity and hierarchy exist.
The assessed parameters were related to the constructions themselves and on the specific users living in the constructions. The first group of parameters was related to the structural and technical aspects of the constructions, the second group of parameters was related to technical-economic aspects, and the third group of parameters was related to the users’ perceptions regarding the sustainability of use. The technical parameters included details about the type of the construction based on wood, the type of the construction design (whether it was a custom design or a catalogue design), the construction method used for the construction, the energy standard, the number of floors and rooms, the size of the useful area, and the type of heating and cooling used in the construction. The technical-economic parameters were related to the construction time, the period of use, the investment costs for construction, and the specific average operating costs. The parameters related to the sustainability of use, i.e., the users’ opinions during use, were determined by the standard of workmanship, exterior and interior visual comfort, the functionality of the entire construction, floor plan design (variation possibilities and suitability for use), living

Figure 1. Example of the most numerous analyzed structures of wood-based buildings. (Note: (a)—prefab panel construction system; (b)—column construction system; (c)—log construction system).
comfort, the materials used for construction, thermal comfort depending on the season, acoustic and lighting comfort in the interior, and the quality of interior air and overall health safety.

3. Results

The analysed parameters were related to the constructions themselves and to the specific users living in the constructions. The individual areas were assessed in terms of correlations in order to determine dependencies and identify the innovation potential of the examined constructions based on wood. Figure 2 presents an analysis of the effect of structural and technical aspects on the users’ perceptions regarding the sustainability of use.

![Figure 2](image_url)

Figure 2. Analysis of the effect of structural and technical aspects on the users’ perceptions regarding the sustainability of use.

The analysis of the correlations among structural and technical aspects in the context of the users’ perceptions regarding the sustainability of use revealed statistically significant correlations among the groups of parameters mentioned above. Correlations existed among the following parameters in the group of structural and technical aspects: construction system, design type, energy standard, number of floors, heating medium type, and ventilation method. Correlations existed among the following parameters in the group of parameters related the users’ perceptions: standard of workmanship, floor plan design,
thermal comfort in winter, acoustic properties, lighting properties, indoor air quality, and health safety.

A more detailed analysis of the correlations of the structural system with the sustainability of use revealed statistically significant correlations with the following parameters: standard of workmanship \((p = -0.2085)\), thermal comfort in winter \((p = -0.2687)\), acoustic properties \((p = -0.3622)\), lighting properties \((p = -0.3039)\), and health safety \((p = -0.2009)\). This means that the panel construction system received the best ratings in terms of all five parameters, followed by the column system and the log construction system.

Another statistically significant correlation was recorded for the design type parameter and the floor plan design \((p = 0.1984)\). This means that those users who had chosen their construction design from a catalogue did not give a positive rating for floor plan design. Those users who had chosen a custom construction design gave a positive rating for floor plan design, which suggests that more users prefer a custom design of the floor plan of their constructions.

A positive correlation was also recorded between the energy standard parameter and thermal comfort in winter \((p = 0.2833)\) and energy standard and health safety \((p = 0.2140)\). These correlations confirm the assumption that a higher energy standard would result in more positive ratings for thermal comfort in winter and health safety.

Negative correlations were recorded between the number of floors and acoustic comfort \((p = -0.2971)\), and the number of floors and interior air quality \((p = -0.0565)\). It can be stated based on these findings that the ratings for acoustic comfort were negatively affected by the number of floors, i.e., more floors lead to more problems with acoustic properties and with the spread of sound in the construction. There were similar findings for interior air quality, which deteriorated as the number of floors increased.

Another correlation was recorded between heating medium type and the standard of workmanship \((p = -0.2151)\). A detailed analysis of this dependency showed that if electric and solar energy was used for heating, the ratings for the standard of workmanship were positive, and if gas was used as the source of heating, the ratings were negative.

Another correlation showed that the ventilation method had an impact on the construction’s health safety \((p = 0.2123)\). The most positive ratings for health safety were given by those users who used air conditioning as their ventilation method, followed by recuperation, and those who used windows (mechanical ventilation) for ventilation gave the least positive health safety ratings.

Figure 3 presents the analysis of the effect of the technical-economic aspects on the users’ perceptions regarding the sustainability of use.

The analysis of the correlations of the technical-economic aspects in the context of the users’ perceptions regarding the sustainability of use revealed certain statistically significant correlations among the groups of parameters mentioned above. There were certain correlations among all of the technical-economic parameters. Correlations existed among the following parameters in the group of parameters related to the users’ perceptions: standard of workmanship, interior visual comfort, materials used for construction, thermal comfort in winter, acoustic properties (comfort), interior air quality, and health safety.

A more detailed analysis of the correlations of construction time with the parameters of the sustainability of use revealed statistically significant correlations with the following parameters: standard of workmanship \((p = -0.2350)\), thermal comfort in winter \((p = -0.2092)\), and acoustic properties \((p = -0.3251)\). This means that longer construction time reduced the standard of workmanship, thermal comfort in winter, and acoustic properties. This finding confirms the assumption that the construction processes carried out on the construction site are affected by various factors (weather, qualitative factors, etc.) that can ultimately undermine the standard of workmanship. Prefabricated construction systems are more efficient, as, unlike on-site constructions systems, they can reduce construction time to a minimum, eliminating the impact of weather on both the construction elements and the standard of workmanship.
An interesting finding was the correlation of the construction time parameter with interior visual comfort \( (p = -0.2271) \), and with interior air quality \( (p = -0.2622) \). This means that the longer the examined constructions had been used, the less positive the perceptions of visual comfort and interior air quality were. Unlike visual comfort, which can only be improved to a limited extent, the air quality parameter can be improved thanks to the constant technological development of ventilation and air regulation methods (smart air regulation together with sensors for monitoring these parameters).

A correlation was also recorded between investment costs for construction procurement and interior air quality \( (p = 0.2311) \). This finding is confirmed by the fact that higher costs for the structural and technical equipment of constructions can achieve higher comfort in terms of interior air quality.

Another surprising correlation was recorded between higher average monthly costs for heating and thermal comfort in winter \( (p = -0.2493) \) and between these costs and health safety \( (p = -0.3248) \). This means that if users felt that they should spend more on the operation of their constructions, this had a greater impact on their comfort in winter and their perception of their constructions’ health safety.

The ‘other average monthly operation costs’ parameter affected interior visual comfort \( (p = -0.2415) \) and the ‘materials used for construction’ parameter \( (p = 0.2366) \). Increased ‘other costs’, such as those for lighting and other operation costs, lead to more negative user ratings. This can be solved by producing a better structural design (lighting simulations to achieve an efficient floor plan design) prior to construction to achieve a better perception of visual comfort. The correlation between higher ‘other operation costs’ and the ratings of the materials used for construction came as a surprise, as those users who had chosen their construction materials themselves prior to construction should not be surprised by the associated operation costs or should have been made aware of the amount of these costs during the design phase (energy assessments and construction certificates). If users choose their materials without having sufficient information about them (regarding energy

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**Figure 3.** Analysis of the effect of the technical-economic aspects on the users’ perceptions regarding the sustainability of use.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Standard of workmanship</th>
<th>Construct time</th>
<th>Time of use</th>
<th>Investment costs for the acquisition of a wooden building</th>
<th>Average monthly heating costs</th>
<th>Other average monthly operating costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interior visual comfort</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
</tr>
<tr>
<td>Exterior visual comfort</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>-0.2415*</td>
</tr>
<tr>
<td>Functionality</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
</tr>
<tr>
<td>Floor plan design</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
</tr>
<tr>
<td>Living comfort</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
</tr>
<tr>
<td>Materials used for construction</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>0.2366*</td>
</tr>
<tr>
<td>Thermal comfort in the summer</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
</tr>
<tr>
<td>Thermal comfort in winter</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>-0.2493*</td>
<td>ns</td>
</tr>
<tr>
<td>Acoustic comfort</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>-0.2622***</td>
<td>0.2311*</td>
<td>ns</td>
</tr>
<tr>
<td>Lighting comfort</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
</tr>
<tr>
<td>Interior air quality</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>-0.3248***</td>
</tr>
<tr>
<td>Health safety</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
</tr>
</tbody>
</table>

Notes: *P* 0.05, **P* 0.01, ns - not significant
balance), they may later be surprised by the resulting operation costs. Other operation costs ultimately depend on the number of occupants and the intensity of use (possible inadequate capacity of the construction).

Figure 4 presents the analysis of the mutual effects and interactions of the users’ perceptions regarding the sustainability of use.

The analysis of the mutual effects and interactions of the users’ perceptions regarding the sustainability of use revealed correlations among almost all of the rated parameters. The correlations were significant particularly at higher significance levels, which adds further weight to the interactions among the rated parameters. Less significant or insignificant correlations were recorded between thermal comfort in winter and summer and the other parameters.

To arrange the examined sustainability parameters as perceived by users in order of significance, the individual parameters were assigned points according to statistical significance and the number of correlations, which resulted in the following hierarchy: The functionality parameter achieved the highest score (33), followed by materials used for construction.

### Table 1: Correlations among Sustainability Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Winter</th>
<th>Summer</th>
<th>Winter</th>
<th>Summer</th>
<th>Winter</th>
<th>Summer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard of workmanship</td>
<td>1.000</td>
<td></td>
<td>0.4768</td>
<td>1.000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Interior visual comfort</td>
<td>0.3647</td>
<td>0.5781</td>
<td></td>
<td>1.000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Exterior visual comfort</td>
<td>0.5493</td>
<td>0.3563</td>
<td>0.5714</td>
<td>1.000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Functionality</td>
<td>0.3274</td>
<td>0.3098</td>
<td>0.3596</td>
<td>0.3409</td>
<td>1.000</td>
<td></td>
</tr>
<tr>
<td>Floor plan design</td>
<td>0.4486</td>
<td>0.4463</td>
<td>0.3681</td>
<td>0.5975</td>
<td>0.5400</td>
<td>1.000</td>
</tr>
<tr>
<td>Living comfort</td>
<td>0.4269</td>
<td>0.3943</td>
<td>0.4239</td>
<td>0.6211</td>
<td>0.2697</td>
<td>0.4938</td>
</tr>
<tr>
<td>Materials used for construction</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thermal comfort in winter</td>
<td>ns</td>
<td>ns</td>
<td>0.2699</td>
<td>ns</td>
<td>0.2528</td>
<td>0.2765</td>
</tr>
<tr>
<td>Thermal comfort in summer</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.3019</td>
<td>0.3809</td>
</tr>
<tr>
<td>Acoustic comfort</td>
<td>0.3400</td>
<td>0.2718</td>
<td>0.2803</td>
<td>0.4020</td>
<td>0.2438</td>
<td>0.3360</td>
</tr>
<tr>
<td>Lighting comfort</td>
<td>0.2578</td>
<td>0.3196</td>
<td>0.2966</td>
<td>0.2832</td>
<td>0.2808</td>
<td>0.2231</td>
</tr>
<tr>
<td>Interior air quality</td>
<td>0.4007</td>
<td>0.2964</td>
<td>0.3572</td>
<td>0.3785</td>
<td>0.3833</td>
<td>0.4126</td>
</tr>
<tr>
<td>Health safety</td>
<td>0.4795</td>
<td>0.2781</td>
<td>0.2420</td>
<td>0.4864</td>
<td>0.2610</td>
<td>0.3828</td>
</tr>
</tbody>
</table>

Notes: P 0.05*, P 0.01**, P 0.001***, ns - not significant

Figure 4. Analysis of the mutual effects and interactions of the users’ perceptions regarding the sustainability of use.
Cluster analysis (Figure 5) was chosen for the preliminary analysis of the connections among the parameters, applied to selected groups of parameters. The cluster analysis allowed identifying possible different levels of complexity and hierarchy. The analyses indicated two main areas, i.e., an area related to the technical aspects of constructions and an area that includes a certain part of technical aspects (energy standard) and aspects representing the sustainability criteria rated by users. Cluster analysis is a normative method of analysing systems or processes in which different levels of complexity and hierarchy can be identified for deducing the innovation potential to improve the sustainability of constructions based on wood.

The analysis of the mutual effects and interactions of the users' perceptions regarding sustainability of constructions and their use.

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The limits of this research can be summarized in the following points: increasing the number of research subjects for comparison with other conventional building solutions to implement other conventional structural systems of buildings and the interpretation of results through other methods focused on factor data analysis. As for the future direction of the research, it is possible that the research will also deal with another segment of buildings and will not be limited to individual housing.

4. Discussion

Based on the research, it can be stated that sustainable buildings should utilise sustainable methods, materials, and processes. Their construction and maintenance should have a neutral impact on the environment. The orientation of sustainable buildings typically ensures a minimal negative impact on the environment. If possible, they are oriented to the Sun to create an optimal microclimate (usually the longitudinal axis should run from east to west) and provide natural shading or a wind barrier. The structure makes use of
daylight/natural light and heating by creating “heat memory” zones by means of a veranda or a long roof overhang, which helps creating a favourable microclimate, etc. [68–71]. Buildings built using sustainable construction methods also involve eco-friendly construction waste management, such as recycling or composting, or use non-toxic, renewable, recycled, or regenerated materials or materials that were produced and treated in a sustainable way. If possible, they use locally available materials and tools to reduce the need for transport. They also use production processes and methods which minimise environmental impact [70,71].

Constructions based on wood are growing in popularity [72]. The popularity of construction systems based on wood is due to the properties of wood [73], such as their statics-related properties [74]. Wood-based systems are increasingly being compared with traditional construction systems as their relevant alternative [75,76]. These ideas stem from their additional properties resulting from their design [77] and especially the environmental benefits [78–80]. There is a substantial body of research on wood constructions from various perspectives. Some of the research focuses on the materials and construction methods used for wood constructions [81,82]. Fewer studies assess constructions based on wood in terms of the users’ perceptions. The presented study contributes to the knowledge in this area of wood construction research.

According to Johnsson and Meiling [83], the lack of assessment criteria prevents an effective comparison of prefabrication and off-site manufacturing with conventional construction, which prevents highlighting the advantages of off-site approaches to construction. Based on their research, these authors state that the main criterion for investors in their choice of a specific construction technology for their project is price, which, along with construction time and quality, they consider more important than the choice of technology. Sustainability and procurement process were less important, while health and safety and regulatory and statutory aspects were considered mandatory, not providing an opportunity for a compromise. Construction time is an important factor in construction procurement. According to our findings, these criteria are also met by prefabricated technological solutions, i.e., the off-site construction method analysed in our work. They are more efficient and sustainable solutions than traditional construction solutions, mainly in terms of completion time and the related project costs. A study by Smith et al. [84] focused on similar problems, analysing the on-site construction method as compared to the off-site construction method. This is similar to our study. In addition to other findings, the study found that the off-site construction method produces higher quality structural parts than the on-site method. The main reason is that constructions produced off-site are not affected by weather conditions, and the production process in a production hall is more rigorous and easier to control, which makes it more efficient.

A construction that uses materials from the surrounding area causes a less severe environmental burden than a construction from materials transported over long distances [85]. This presents an opportunity to implement a sustainability vision with a positive effect not just on the ecology of materials and constructions but also on the sustainability of local economies. The first sustainable construction condition (confirmed by the LCA approach) [86] is the minimisation of the amount of energy required for construction, i.e., all energy used up to the point of commissioning. The other condition is the amount of energy necessary for operation [87], i.e., the building must use energy resources efficiently with minimal consumption. The end of the building’s life cycle and its demolition represents the final sustainability-related stage [88,89]. Construction materials should be easy to recycle, with a minimal environmental impact.

Creating such an optimal construction concept with minimal energy consumption and environmental impact is a difficult optimisation task requiring comprehensive planning, where partial elements serve the overall performance of the building. Such integrated planning offers a real opportunity to reduce the costs of materials and, more importantly, operation costs, as the planning of building equipment starts with the planning of the building’s exterior rather than the building itself. In principle, it can be stated that taking
into account the important preferences of final consumers before and when designing a building, it is possible to prevent possible future complications and design a tailor-made and more sustainable solution for their construction.

Another important part of any innovation technique leading to increased sustainability is the need to thoroughly understand as many of the interactions between the components involved as possible. In this sense, the conditionality of the different aspects in the context of their dominance and the possibility of improving them also plays an important role. In this sense, the contribution of the presented research is considerable, both in terms of examining the interactions of users’ attitudes in relation to their constructions but also to their parameters, which ultimately affect user comfort and the associated sustainability of housing.

5. Conclusions

In the fast-changing urban environment, providing adequate and affordable housing is a key priority for all governments. The effort to provide good-quality and sustainable housing requires cooperation with owners and users, and the monitoring and analysis of possible improvements and innovations. With this in mind, this study was conducted to examine the interactions between actual constructions and the perceptions of their users to identify potential construction system innovations for more sustainable housing. The analyses of the specific constructions and the perceptions of their users suggested certain areas for improving the design and construction of buildings based on wood. It is energy standard, the standard of workmanship, and the users’ individual requirements determining the floor plan design and material solution for their constructions that are the most important aspects. These aspects exhibited significant correlations with the users’ perceptions of sustainable housing. To arrange the examined sustainability parameters as perceived by users in order of significance, the individual parameters were assigned points according to statistical significance and the number of correlations, which resulted in the following hierarchy: The functionality parameter achieved the highest score (33), followed by materials used for construction (31), interior air quality (29), living comfort (29), acoustic comfort (26), standard of workmanship (26), interior visual comfort (25), health safety (24), thermal comfort in winter (24), floor plan design (23), exterior visual comfort (22), lighting comfort (19), and the ‘thermal comfort in summer’ parameter achieved the lowest score (11). As these rankings show the best-rated parameters, they can provide guidance for construction design or reconstruction projects to improve structural variants and their effect on the sustainability of constructions and their use. The results of this research expand the knowledge in the field of constructions based on wood regarding technological and economic sustainability criteria.

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