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ORIGINAL RESEARCH ARTICLE

User perspectives on sustainable innovation in the construction industry

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Abstract: Housing availability relative to population size is widely regarded as the main qualitative indicator of housing development standards. In Central Europe, there has been a notable trend of residents relocating from larger urban areas, where most housing is apartment buildings, to smaller satellite towns. Many investors and users are placing greater emphasis on construction methods, material bases, and sustainability. Among the sustainable housing options in Central Europe (V4 countries), single-family wooden houses are gaining popularity. Despite their advantages, the broader adoption of wood-based sustainable construction is hindered by limited public awareness. Hence, this study explores the perception of potential users and investors on wood-based constructions compared to traditional construction methods. Results show that potential users and investors perceive wooden constructions as capable of meeting the current legislative, energy-related, technological, and economic requirements. Correlation analysis of the data revealed differences in the perception of the parameters of constructions among various respondent groups. The primary contribution of this study lies in increasing awareness of wood-based constructions and analyzing the interactions among the selected parameters of constructions. Findings from this study highlight the potential for innovation aimed at enhancing efficiency and sustainability in housing developments.

Keywords: Wood-based construction; Environment; Innovation, Region of central Europe; Socioeconomic research; Sustainability

1. Introduction

Housing is a fundamental human need, and its satisfaction should correspond to the overall social levels and economic development.[1-3] Housing is also a pre-requisite for starting a family and significantly influences population development.[4,5] In Central Europe, considerable attention is paid to housing policies and housing. The main goal of housing policy is to ensure the availability of housing for all social groups in the population.[6,7] Many promising activities are being implemented to promote more environmentally sustainable lifestyles.[8] In the context of climate change, various alternatives are also preferred, particularly those contributing to more efficient use of raw materials for energy production,[9-12] which is necessary for the operation of buildings.

According to Klincka *et al*.,[13] single-family housing construction is driven by wealthier social groups who can afford land investment and build a family house, particularly in locations with established infrastructure. As a standard rule, land prices increase in correlation with better access to basic infrastructure (water, sewerage, gas, and heating). According to Cár,[14] the number of households is an important indicator in assessing the need for housing. The present state of the housing stock is largely the product of earlier construction of family houses and apartment buildings, with significant regional variations. The ability to acquire a property depends on various factors, with income levels playing an important role.[15-17] This means that the ability to acquire a property largely depends on the region's economic performance, which is typically improved when more jobs are created due to more private investment coming into the region.[18,19]

New technologies make it possible to build lucrative housing without centralized infrastructure (water, sewerage, electricity, and heating) in more remote locations with adequate environmental protection.[20-23] It is possible to build diversified systems for the water supply, energy and heating, and waste management, which is particularly important in housing development, considering the ever-growing prices of water, energy, and heating.[24-27]

According to Cholujová,[28] the urban population growth in cities, economic development, and cultural and social changes pose various challenges, including the urgent need for changes in the government's housing policy to provide new housing.[29] With the transition to a market economy, the responsibility for securing housing has shifted from the state to individuals.[30,31] This shift has opened up new methods and opportunities for addressing individual housing needs. A notable trend is the movement away from impersonal and restrictive housing within pre-fabricated apartment buildings toward more natural and liberating environments consisting of family homes.[32-34] Housing companies respond to this demand change by offering various options. In addition to traditional, proven building materials, such as brick or wood, companies also provide modern and full-fledged alternatives.[35-38] One such alternative is wood-based houses.

The sustainability of buildings, especially wood-based buildings, is currently one of the topics in the construction industry. Innovative wooden buildings offer significant advantages in terms of ecological, economic, and social sustainability. In an environmental context, wood as a natural material has a low carbon footprint compared to traditional building materials, such as concrete or steel. As trees absorb carbon dioxide during growth, the use of wood in buildings effectively stores carbon, thereby contributing to climate change mitigation. The ecological advantages are also reflected in the energy intensity of wood production and transportation, which is significantly lower than that of other materials. From an economic viewpoint, wood is more cost-effective, while its easy handling and speed of construction reduce labor and time costs. In addition, wooden buildings have long-term durability, often resulting in lower maintenance costs. The social aspect of the sustainability of wooden buildings includes creating a healthy and comfortable environment for residents. Wooden buildings contribute to better acoustics, humidity regulation, and a healthier indoor microclimate, positively impacting health and well-being. These factors make wooden buildings an attractive solution for a sustainable future within the construction sector.

Timber buildings are structures that use wood as the main building component, and are divided into different types according to their construction and purpose. In the housing sector, the most commonly implemented timber frame buildings (prefabricated wooden houses) are characterized by fast construction and good energy efficiency. Solid timber buildings, such as cross-laminated and glued-lamella timbers, offer high load-bearing capacity and durability. In commercial construction, modern timber buildings using cross-laminated timber panels are increasingly used, allowing multiple floors to be implemented while combining esthetics, sustainability, and strength. In addition, timber buildings are also used in other sectors, such as school buildings, administrative buildings, and public buildings, where they are used primarily for their low ecological footprint and excellent thermal insulation properties. These timber buildings are increasingly popular in Central Europe, as they combine the advantages of sustainability, energy efficiency, and short construction time.

These considerations necessitate an analysis of the perception of modern wood-based construction systems designed for housing construction. This study aimed to analyze the results of socioeconomic research focused on the perception of the parameters of wood-based buildings compared to traditional construction methods among potential users and investors.

2. Methodology

A methodology was designed for data collection before the socioeconomic research. The qualitative and quantitative research was conducted in line with the stated objective and hypotheses. As part of the research, responses were collected from users and investors regarding the advantages and disadvantages of modern wood-based buildings. The methodology included a questionnaire and a controlled interview.

The questionnaires were designed to cover all three key areas of research: Architectural-structural-technical area (questions related to the technical properties of wooden buildings, as well as their comparison with other materials in terms of durability and energy efficiency), social area (respondents answered questions regarding the comfort of living in wooden buildings, health, impact on the psyche, and quality of life), and technological-economic area (these questions focused on the costs of construction, maintenance, and operation of wooden buildings compared to other types of buildings).

The hypothesis focused on the influence of age in relation to the interdependencies among the individual criteria. The questionnaire included items addressing the technological and economic aspects of wood-based constructions. The collected data were analyzed using a statistical tool (Statistica, version 12), applying the correlation coefficient method to determine the strength and direction of relationships between two numerical variables. This correlation analysis enabled the identification and evaluation of the intensity of associations between individual criteria (e.g., the influence of age on the perception of wooden buildings in technological, economic, and social areas).

2.1. Sampling strategy and sample selection considerations

This study used stratified random sampling to ensure the representativeness of the participating respondents from different age groups. This sampling strategy was appropriate to consider potential differences in perceptions of wooden buildings between different demographic groups, allowing for a more detailed evaluation of factors, such as the influence of age on the perception of technological, economic, and social aspects of wooden buildings. Based on this approach, a sufficient number of respondents ($n = 172$) were selected from a sample of users and investors, thus obtaining diversified data for accurate analyses.

2.2. Response rate and potential biases

The response rate was monitored to ensure adequate representativeness of the sample. Given the methodology, which included online questionnaires and controlled interviews, the response rate was in the optimal range of 60 – 70%. Possible biases may have arisen if respondents with previous experience in timber construction or strong preferences for a specific construction type had exerted a disproportionate influence on the responses. To minimize this type of bias, the questions were formulated neutrally, promoting objectivity of the answers and ensuring a balance of views from all groups of respondents.

The results of the correlation analysis provided valuable information on how the perception of wooden buildings differs between different groups of respondents and how these factors influence decision-making about the use of wooden buildings compared to traditional construction methods.

3. Results and discussion

This section presents the research results focused on the perception of the parameters of wood-based buildings compared to traditional construction methods among potential users and investors. A total of more than 172 responses were collected in the research. The research sample was 57.1% men and 42.8% women. Age groups were represented as follows: 18 – 25 years (12.2%), 26 – 35 years (31.2%), 36 – 45 years (24.5%), and over 45 years (32.1%).

3.1. Architectural and construct-technical breakdown

A total of 63.1% of respondents answered that they were familiar with the term wood-based building, while 31.5% responded that they had encountered it only partially, and only 5.4% stated that they had not heard of it. These findings suggest that the term wood-based building is well-known among the surveyed population. Regarding architectural flexibility, 51.4% of respondents stated that wood-based buildings were not limited in terms of architectural design, 36.3% considered them partially limited, and 12.3% viewed them as architecturally constrained. In terms of design preferences, most respondents' preferred combined shapes (57%), 28.2% preferred cubic shapes, and 18.8% preferred proven design shapes.

3.2. Social breakdown

As for internal comfort of use in wood-based buildings (air quality, temperature, light, and sound), 82% of the respondents stated that modern wood-based buildings could achieve the desired comfort of use, 15% believed it was achievable only at a higher cost, and 3% deemed that internal comfort of use was not attainable. Respondents perceived family houses (96%), superstructures (71%), and schools (54%) as the most ideal applications of wood-based designs.

3.3. Technological-economic breakdown

As for construction time, respondents stated that wood-based constructions were completed faster than traditional constructions. Only 15% responded that their completion time was almost identical, and 6% believed it was longer than traditional constructions. In terms of quality, 64% stated it was comparable to traditional buildings, 31% thought it was better, and only 5% deemed it worse.

Based on the analysis, respondents believed that the costs of project documentation for wood-based buildings were lower or comparable to those of traditional buildings. Only 7% of respondents stated that the costs involved were higher. As for the construction costs of wood-based buildings, it was found that 54% of respondents believed they were lower, 29% deemed them comparable, and 17% thought they were higher than traditional buildings. A total of 63% of respondents saw perceived costs of wood-based constructions as comparable, while 23% considered them higher, and 14% viewed them as lower compared to traditional buildings.

3.4. Correlation analysis

Individual data groups were selected for correlation analyses per the research objective and hypothesis. Data selection (groups of respondents) was focused on three areas in line with the stated hypothesis, namely, age (Tables 1 and 2). Notably, more correlations among individual parameters within respondent groups suggest that the answers are not random but reflect logically interconnected perceptions of the assessed construction criteria. This indicates that respondents' views are based on consistent relationships among parameters, reinforcing the reliability of the observed patterns. Due to the large number of correlations among individual parameters for the selected groups of respondents, a detailed commentary on all statistical findings is limited, as a comprehensive description of each partial finding would be too long. However, Tables 1 and 2 offer valuable insights into the relationships among the individual parameters, highlighting which parameters affect others when analyzed within subgroups of respondents.

Based on the correlation analysis, there are significant dependencies among the selected parameters evaluated by the respondents. There were also differences among the respondents' age groups (generations). These findings suggest that each age group influences the perception of the individual parameters of wood-based buildings compared to traditional buildings.

Based on Table 1, most correlations among the assessed parameters showed similar trends (positive or negative correlations) across the different respondent groups. These findings suggest that perception does not differ significantly across age groups when correlations are present. Only two instances revealed differences in the direction of correlation, that is, the correlations between construction time and shape limitation and between stability and shape limitation. The smallest number of correlations was recorded in the age group of 18 – 25 years (11), followed by 26 – 35 years (14), and the age group of more than 45 years old (14). In contrast, the largest number of correlations between the parameters was recorded in the group of respondents aged 36 – 45 years (18). This finding suggests that the age group of 36 – 45 years, the productive age group, perceives the parameters of buildings comprehensively, with the logical connections among the individual parameters, and their responses are solely based on a single isolated parameter.

There is a growing interest and popularity in wood-based constructions.[39] This interest stems from the beneficial properties of wood,[40] particularly its weight ratio to static load capacity,[41] making wood-based construction systems a key competitor to traditional construction systems that are based on concrete, steel, and masonry.[42,43] Other advantages include the possibility of using the dry construction method[44] as well as more favorable environmental parameters compared to the traditional construction method.[45,46] A substantial body of research has explored wooden buildings from various perspectives, such as their material and structure.[47-50] Our findings align with the findings of Mozolová,[51] who focused on people's views on wooden buildings. Similarly to our study, Mozolová[51] confirms the growing interest in wooden buildings as an ecological housing alternative, but acknowledges certain barriers precluding these constructions from becoming more widespread. Continued lack of experience and confidence in this construction method and poor promotion of its benefits compared to the traditional construction method are identified as the main barriers. A study by Lindblad and Gustavsson[52] focused on how residents and architects in Sweden perceived housing quality, and whether these

Table 1. Correlations among the selected parameters relative to the lower age groups

Age groups	Knowledge of wooden buildings	Shape constraints	Architectural appearance	Materials	Energy standard	Stability	Internal comfort	Time of construction	Quality	PD costs	Realization costs	Operating costs
Knowledge of wooden buildings	1. 0000											
Shape constraints	–	1. 0000										
Architectural appearance	–	–	1. 0000									
Materials	–	0.7958^a 0.4263^b	–	1. 0000								
Energy standard	–	–	–	–	1. 0000							
Stability	–	–	0.3464^b	–	–	1. 0000						
Internal comfort	–	0.6407^a 0.4477^b	–	0.6742^a 0.5731^b	–	–	1. 0000					
Time of construction	0.7137^a	-0.7159^a	–	-0.6666^a	–	–	-0.7606^a	1. 0000				
Quality	–	–	–	-0.4849^b	–	–	-0.3848^b	–	1. 0000			
PD costs	–	-0.6009^a	–	0.5015^b	–	0.6396^a	0.3298^b	–	-0.5181^b	1. 0000		
Realization costs	-0.3320^b	0.6950^a	–	0.5925^a	–	–	–	–	–	–	1. 0000	
Operating costs	-0.3746^b	–	–	–	-0.3588^b	–	–	–	-0.3403^b	–	0.3679^b	1. 0000

Notes: "–" refers to not significant; ^{a}values represent the age group 18 – 25 years; and ^{b}values represent the age group 26 – 35 years.

Table 2. Correlations among the selected parameters relative to the higher age groups

Age groups	Knowledge of wooden buildings	Shape constraints	Architectural appearance	Materials	Energy standard	Stability	Internal comfort	Time of construction	Quality	PD costs	Realization costs	Operating costs
Knowledge of wooden buildings	1. 0000											
Shape constraints	–	1. 0000										
Architectural appearance	–	–	1. 0000									
Materials	–	0.7298^a	–	1. 0000								
Energy standard	0.6398^a	0.7857^b	–	–	1. 0000							
Stability	–	–	-0.7115^a	–	0.3082^b	1. 0000						
Internal comfort	–	–	0.3495^b	0.6160^b	-0.4162^a	–	1. 0000					
Time of construction	$^a0.5351^a$	0.6634^b	–	–	0.5188^a 0.3899^b	–	-0.4820^a	1. 0000				
Quality	0.4577^b	-0.3911^a -0.5560^b	–	-0.5520^b	–	0.3104^b	-0.4399^a -0.4461^b	–	1. 0000			
PD costs	-0.3979^b	–	-0.4024^b	–	-0.4363^a	–	–	–	–	1. 0000		
Realization costs	-0.5287^a -0.3597^b	–	–	–	-0.7370^a	–	–	-0.8153^a -0.4416^b	–	0.4255^a 0.4863^b	1. 0000	
Operating costs	-0.4376^b	–	–	–	-0.5386^a	–	0.4072^a	-0.4270^a	-0.3888^a -0.6051^b	0.6766^b	0.4545^a 0.3661^b	1. 0000

Notes: "–" refers to not significant; [a]values represent the age group 36 – 45 years; and [b]values represent the age group over 45 years.

perceptions differed based on building type and choice of material (i.e., multigenerational wood-based or concrete buildings). The results revealed discrepancies regarding what factors were important in developing new housing. Notably, neither group was willing to pay more for a wooden building than a concrete one. There are certain parallels between their research and our study, particularly in identifying bias and the lack of trust in wood-based constructions as the main barriers to their more widespread use. As such, our study contributes to the field by raising awareness of wood-based constructions. Ulu and Durmuş Arsan[53] state that the construction industry is the biggest energy consumer in Europe, with a share of about 40%. For this reason, it is necessary to focus on the energy efficiency of the existing and future housing stock. They also state that energy efficiency is directly related to economic, environmental, and social sustainability. These claims match our views based on the research we conducted. As evident from our findings, the energy-related properties of constructions affect many other parameters and the overall living comfort. A study by Caniato *et al*.[54] was focused on the thermal-technical and acoustic parameters of wood-based buildings, as wood-based buildings generally have poor acoustic parameters. Based on their findings, modern wood-based buildings can largely eliminate these shortcomings and achieve higher efficiency when compared to original wood-based buildings. They can also compete with traditional construction solutions (such as masonry buildings). A study by Gardezi *et al*.[55] focused on a multivariate regression tool for predicting the embodied carbon footprint of housing habitats. They found that an evaluation of housing requires a clear understanding of the parameters or criteria that can be evaluated and modeled in relation to buildings. They also emphasize that different tools are applicable for assessing buildings at various life cycle stages. These assertions are supported by Fastofski *et al*.[56] Based on our own research experience, we concur with these perspectives. We can only understand which parameters affect other parameters by examining different aspects of construction. For example, the correlation analysis in our study determined how individual construction parameters influenced each other as perceived by future users, representing a valuable contribution to this field. This insight not only enhances the ability to predict building performance more accurately but also supports the development of more sustainable and efficient solutions with a positive impact on housing and housing quality. A study by Dadashpoor and Ahani[57] on the conceptual typology of the suburban areas of cities found that global urban population growth and large-scale urbanization in suburban areas is a phenomenon that emerged in the 20th century. This phenomenon was an implicit topic in urban and regional studies for several years. Our findings confirm a growing trend in which certain population groups relocate from densely populated urban centers to suburban or peripheral areas. Our research indicates that the demand for individual housing is greater than ever. Various construction companies respond to this demand by offering various construction and material solutions. However, it is essential to verify these solutions and study their properties. The expansion of knowledge in the field of wood-based construction presented in this study serves as a step toward addressing the lack of public confidence, which remains a barrier to wider recognition of its benefits compared to traditional construction methods.

Three different limitations can be identified for this research. The first limitation is the number of respondents or the research sample. Considering this limitation in future research is necessary, as it is not always easy to find respondents willing to provide sincere answers. The general rule is that the larger the sample of respondents and the resulting volume of data, the greater the validity of the research. The second limitation is the respondents' awareness or prior knowledge regarding the theme of the questionnaire. There is a difference between answers from respondents with experience with wood-based construction and those who do not. This leads to certain distortions in answers. The third limitation applies to interpreting the findings from the correlation analyses of parameters. As the analyses produced an enormous number of correlations according to the individual selected groups of respondents, it is impossible to evaluate each correlation between the individual parameters separately. Such a detailed interpretation of findings would require a separate article focused solely on the evaluation.

This study, which focuses on potential users and investors, shows that despite the small market share of wooden buildings, their design, technological, or user-related parameters are generally well understood, even compared to traditional construction technologies. The conclusions confirm a growing interest in sustainable and healthy housing, highlighting significant potential for growth in this construction sector.

4. Conclusion

This study explored the perception of wood-based construction among potential users and investors compared to traditional construction methods. The research generated a range of findings that expand knowledge in wood-based construction, with benefits for potential customers, construction professionals, and the scientific community. Based on the findings from the respondents' opinions, it can be concluded that wood-based structures are characterized by faster construction times and often have comparable or better quality than traditional structures. Project documentation and construction costs were considered lower or comparable while operating costs were mostly similar. Overall, wood-based construction was viewed favorably, particularly in terms of speed and cost-efficiency.

The correlation analysis revealed significant dependencies among the selected parameters evaluated by the respondents. In addition, certain differences among the age groups (generations) were also discovered, indicating that generational factors influence how individual parameters of wood-based constructions are perceived compared to traditional constructions. These findings have the potential to stimulate interest in wood-based housing and promote its adoption. It can be concluded that modern constructions based on wood offer an efficient and sustainable housing alternative.

From a sustainability perspective, timber buildings can play a key role in mitigating climate change, as timber is a renewable material that sequesters carbon dioxide as it grows, thereby contributing to reducing the carbon footprint of buildings. Stakeholders, such as building professionals, investors, and policymakers can use these findings to support developing and implementing timber buildings as a sustainable housing alternative. Promoting this construction method at both local and global levels could significantly contribute to achieving the Sustainable Development Goals and combating climate change. It is recommended that the focus be on raising awareness of the benefits of timber buildings among different age groups, as the results suggest that these factors influence perceptions of timber buildings. Investment in research and development of timber building technologies and supporting legislative measures to stimulate a sustainable construction sector can provide a solid basis for the wider adoption of this technology. Implementing these measures at the local and global levels will support not only economic efficiency but also environmental and climate goals in the construction sector. At the same time, it is important to invest in educating professionals and the public about the benefits of timber construction, which can contribute to their wider use and ultimately support the transition to a more sustainable and climate-resilient construction sector.

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Conflict of interest

The authors declare that they have no competing interests.

Author contributions

Conceptualization: All authors
Formal analysis: All authors
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Methodology: Jozef Švajlenka, Terézia Pošiváková
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Availability of data

Data are available upon reasonable request from the corresponding author.

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