

User-Centered Perspectives in Prefabricated Timber Buildings: A Scoping Review

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Abstract

The construction of prefabricated timber buildings is a topic of growing interest, although research has primarily focused on technological aspects, while the users' perspective remains underexplored. Accordingly, this paper aims to map the existing literature on prefabricated wooden buildings from a user-centered perspective, considering the whole-building scale. A systematic literature search of publications between 2010 and 2025 was conducted following PRISMA guidelines, identifying relevant studies. A bibliometric analysis was then performed to map key research themes, which were further examined through a scoping review. Four main themes emerged, i.e., indoor comfort, indoor air quality, sustainability and energy efficiency, and building architectural design. The findings highlight numerous aspects that should be considered in prefabricated timber buildings design, including thermal, vibrational and acoustic comfort, air pollutant and ventilation control, user behavior in relation to energy use, and spatial design based on users' needs. However, the limited number of existing studies makes comprehensive evaluation difficult. Furthermore, the results emphasize the need for multidisciplinary approaches to adequately integrate user experience into the design of these buildings.

Keywords: prefabrication; timber construction; timber buildings; human factor; comfort; user satisfaction; occupants; architectural engineering



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1. Introduction

Building prefabrication is not a new construction approach [1], although it has historically been underutilized due to a strong attachment to conventional construction methods [2,3]. Recent studies identified the main barriers to the adoption of prefabricated construction techniques, which primarily include technical factors [4], initial costs and technical issues [5], although many other factors are found to determine their successful implementation [6]. In this framework, the perception of people also seems to play a decisive role, both in terms of end users [7] and industry professionals [8]. Notably, although prefabrication has been discussed for decades, this method still offers substantial opportunities for further exploration [9,10].

Nowadays, prefabrication is attracting increasing attention, not only due to its potential to reduce construction time and costs, but also due to the international emphasis on sustainable building practices [11], as this approach offers significant potential for lowering environmental impact [12]. Studies have shown that prefabricated buildings can reduce embodied carbon by up to 40% and end-of-life impacts by up to 90%, resulting in a decrease

of approximately 6% in EU-27 building-related carbon emissions and a 10% reduction in costs [13]. As is well known, sustainability has become a pivotal topic in recent years within the global struggle against climate change, driving growing interest in sustainable construction practices [14]. Indeed, the construction sector has been recognized as one of the main contributors to greenhouse gas (GHG) emissions [15], thus highlighting the need to rethink traditional construction approaches.

Prefabrication involves the manufacture of building components in industrialized environments, followed by their transport and on-site assembly, enabling a reduction in construction time while improving the overall construction quality [16]. Typically, off-site construction can be categorized based on the degree of off-site work, including component subassembly, non-volumetric preassembly, volumetric preassembly, and complete modular construction [17]. The industrialization of construction processes ensures efficiency during the production phases, limiting errors and defects in products, as well as reducing waste generation, thus optimizing the use of natural resources and the production process as well [18]. Furthermore, prefabrication allows construction solutions to be designed and tested prior to implementation, facilitating the building performance optimization and thus significantly improving building quality. Finally, prefabricated buildings are characterized by seriality and modularity, which enable adaptability to different design requirements and contexts, as well as ease of disassembly and reuse [19].

In this context, prefabricated timber constructions are attracting growing interest compared to conventional steel and concrete systems [20], thanks to their ease of processing, assembly, and disassembly [21], the simplicity of their connections [22], and the light weight of the material [23]. Furthermore, compared to other materials, wood appears to be particularly sustainable from an environmental point of view, owing to its low embodied energy content and reduced greenhouse gas emissions [24], as well as the ease of reuse of waste generated during the production process [22].

For these reasons, prefabricated wooden buildings represent a significant opportunity, although they still need to be further explored [25]. Moreover, it should be noted that the widespread use of modular constructions is influenced by the availability of wood, which increase the preference for off-site construction due to the difficulties associated with the on-site ones [26]. In recent years, interest in prefabricated wooden buildings within the scientific community has grown, as evidenced by the publication of different reviews on this topic [27,28].

However, the existing literature seems to be more focused on the investigation of construction technologies, with particular emphasis on structural and thermal performance, while other aspects still seem to be relatively unexplored. Table 1 presents an overview of the literature reviews found on the subject, revealing that they mainly focus on technological aspects [29,30], such as the building technologies to be used, the types of materials [31], and the connection systems [32,33].

Table 1. Review of studies on prefabricated timber buildings.

Ref.	Title	Year	Focus	Aim
[31]	A Comprehensive Comparison of Insulation Materials for Timber Building Systems	2025	Materials	To assess insulation materials based on thermal, acoustic, fire, environmental, and availability criteria.
[32]	Adaptation of Connection Systems for Integration with Engineered Wood Products in Buildings: A Systematic Review	2025	Connection systems	To assess recent trends in engineered wood products connection research

Table 1. *Cont.*

Ref.	Title	Year	Focus	Aim
[34]	Indoor Volatile Organic Compounds in Prefabricated Timber Buildings—Challenges and Opportunities for Sustainability	2024	Indoor air quality	To evaluate volatile organic compounds (VOCs) studies
[27]	The Potential Contribution of Modular Volumetric Timber Buildings to Circular Construction: A State-of-the-Art Review Based on Literature and 60 Case Studies	2023	Building technology	To review case studies of modular volumetric timber buildings
[35]	Circular economy strategies in modern timber construction as a potential response to climate change	2023	circular economy	To assess circular economy applications and case studies
[33]	Adhesive-and Metal-Free Assembly Techniques for Prefabricated Multi-Layer Engineered Wood Products: A Review on Wooden Connectors	2023	Connection systems	To explore emerging adhesive- and metal-free assembling techniques
[29]	A review of modular cross laminated timber construction: Implications for temporary housing in seismic areas	2023	Building technology	To evaluate features of modular CLT construction, focusing on design, manufacturing, and logistics
[30]	Sustainable Construction—Technological Aspects of Ecological Wooden Buildings	2022	Building technology	To review the feasibility of producing frame buildings in Poland

As shown, the existing review mainly focused on technological factors, while aspects related to user well-being and the quality of the living experience remain underexplored. However, it is worth noting that the acceptance of these building technologies by users may be limited [7]. Indeed, prefabrication has historically been associated with standardization and a perceived lack of design flexibility [36], which can negatively affect the occupants' experience and perception [37]. In this context, human-centered design (HCD) emerges as a perspective that focuses not only on technical performance, but also on the perception, satisfaction, and health of occupants [38], thus emphasizing the relationship between the building (envelope, interior, materials and building services) and its users [39]. For instance, a study by Cabral and Blanchet [40] recognized occupant-related aspects as the most influential criteria for the material selection in prefabricated wood buildings, with particular focus on comfort, satisfaction, well-being, safety, and security of the occupants. Recent studies have demonstrated the importance of integrating human factors into building design, highlighting how research on the topic focuses on six main themes [41]: (i) physical perception of the environment, including visual, acoustic, thermal, and vibrational comfort; (ii) user satisfaction; (iii) information technology for the user experience; (iv) evacuation and accessibility; (v) energy and sustainability; and (vi) indoor air and health. Although not specifically focused on timber buildings, the work provided a comprehensive theoretical basis for understanding user-related dimensions in the built environment, thus laying the foundation of the present review. Indeed, despite there is a portion of the literature that addresses user perception in indoor timber environments [42], it remains unclear how many studies systematically relate user experience to prefabricated timber buildings.

Starting from this literature gap, the present review aims to map existing literature on prefabricated wooden buildings from a user-centered perspective, focusing on the whole building scale. Specifically, the research objectives are as follows:

- To provide an overview of existing literature on prefabricated timber buildings in relation to user experience;
- To identify the key research themes currently addressed on this topic, exploring the main methodologies adopted;
- To outline literature gaps and future research prospects.

The work is structured as follows: Section 2 describes the methodology adopted, Section 3 summarized the results, which are discussed in Section 4, while conclusions and future prospects are presented in Section 5.

2. Methods

With the aim of mapping the current state of the art on user outcomes related to prefabricated timber building, a scoping review was conducted. First, in compliance with established recommendations for scoping reviews [43], a systematic literature search was conducted, based on the PRISMA guidelines [44]. Then, a bibliometric analysis was performed using VOSviewer software (version 1.6.20) [45], to map the co-occurrence of keywords and provide a general overview of the main themes addressed. Building on this, a detailed scoping review of the selected manuscripts was conducted, delving into research topics, methodologies, and gaps in the literature.

2.1. Search Strategies

The present review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines, which provide a framework for systematically searching existing literature based on the predefined research questions [44]. The PRISMA checklist has been provided as Supplementary Materials. Although several other reliable databases exist, such as Web of Science [46], Scopus was selected as the sole database for this study, without compromising the validity or completeness of the sample. This choice was motivated by the following reasons: (1) Scopus offers broader coverage within the construction research field compared to other databases [47]; (2) it provides a wider journals coverage [48,49]; and (3) it features a faster indexing process [50], enabling the identification of a larger number of publications, including the most recent ones.

The first phase of the search involved the identification of the keywords to be combined in the database using Boolean operators. Since the main aim of the review was to retrieve studies that applied user-related approaches to the design and evaluation of prefabricated wooden buildings, two sets of keywords were defined, each corresponding to one of the thematic areas. The keywords were derived from a preliminary review of the literature, based on the keywords adopted in previous review studies focusing on user design [41,51] and supplemented with terminology commonly used in other studies on these topics. In detail, the search query was applied: ((TITLE-ABS-KEY ("solid wood" OR "CLT" OR "cross-laminated timber" OR "glulam" OR "LVL" OR (panelised W/50 timber) OR "volumetric modular" OR "kit-of-parts" OR "prefab* timber" OR (prefab* W/50 timber) OR "modular timber unit*" OR "modular timber" OR "modular timber construction" OR "modular* wood" OR "prefab* wooden" OR "timber unit" OR "3D timber" OR (volumetric W/50 timber) OR (modular building* W/50 wood*) OR (modular building* W/50 timber) OR (manufactured build* W/50 timber) OR (manufactured build* W/50 wood) OR (off-site W/50 timber) OR (off-site W/50 wood) OR (offsite W/50 timber) OR (offsite W/50 wood)) AND TITLE-ABS-KEY ("acoustic" OR "sound" OR "biophilic " OR "human building interaction" OR "human factor*" OR "user centre*" OR "human centre*" OR "perceived control" OR "acceptance" OR "user needs" OR "user-centredness" OR "visual comfort" OR "IAQ" OR "indoor comfort" OR "thermal comfort" OR "acoustic comfort" OR "comfort" OR "air quality" OR "indoor environment" OR "IEQ" OR "indoor environmental quality"

OR “human factor” OR “user experience” OR “human centered design” OR “human centric design” OR “user cent* design” OR “wellbeing” OR “perception*” OR “occupant*” OR “subjective evaluation” OR “well-being” OR “human-in-the-loop” OR “health” OR “people” OR “post-occupancy” OR “satisfaction”)).

It is important to note that keywords related to human-centered design were combined with specific terms referring to comfort and indoor environmental quality (e.g., thermal comfort, acoustic comfort, indoor environmental quality). This choice reflects the terminology observed in the preliminary literature search, where studies addressing occupant well-being and user perception often do not explicitly mention “user-centered design,” yet focus on aspects related to the building users. Therefore, the inclusion of these keywords ensures a more comprehensive coverage of the literature on human-centric theme applied to prefabricated timber buildings, although resulting in a subsequent need for a more extensive screening process.

As a result of the search query, 1891 articles were retrieved and then refined according to the established inclusion criteria. Specifically, only articles written in English, published within the last 15 years (2010–2025), and assigned to the subject areas of Engineering, Environmental Science or Energy, were included. The application of these criteria reduced the sample to 751 articles, which were then screened based on title and abstract, excluding manuscripts out of the scope of the review. This initial screening process narrowed the sample to 116 articles, which were then subjected to a second screening process based on full-text reading. At this stage, 79 articles were excluded, primarily because they focused on material performance, individual building components rather than whole-building scale, construction technologies, thus do not provide data or insights on occupant-related outcomes. A double independent screening process was employed, with each article assessed independently by two authors: any disagreements were first addressed through discussion and, if consensus could not be reached, the third author was consulted to make the final decision. Finally, a forward citation search was conducted on the remaining manuscripts, to identify further studies on the same topics, resulting in the inclusion of another 2 articles. Therefore, the total number of papers included in the review was 39, as shown in Figure 1.

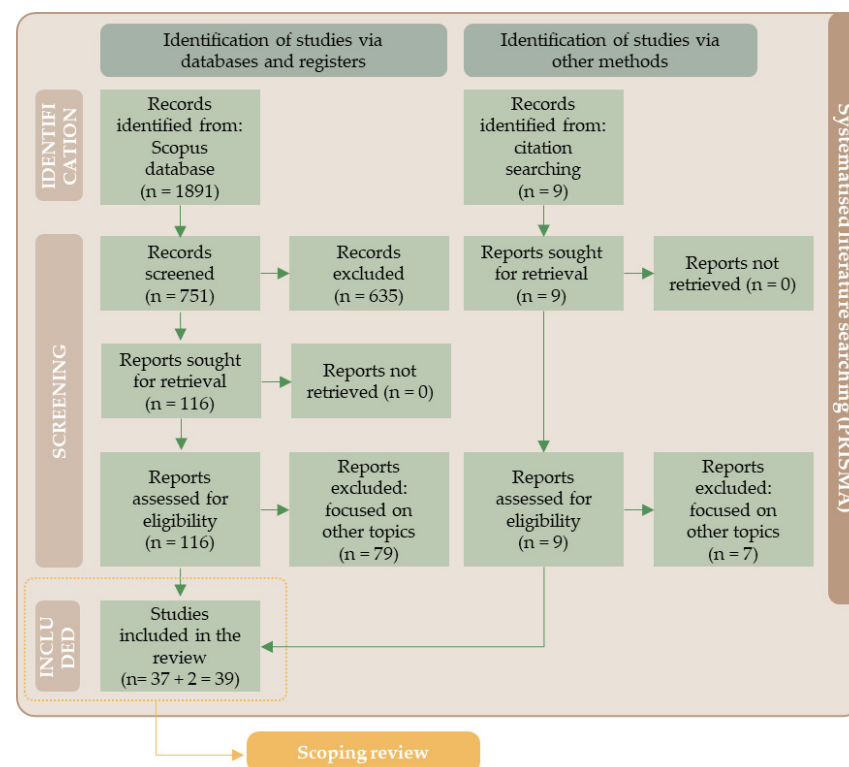


Figure 1. Prisma flowchart, adopted from [44].

2.2. Content Analysis

First, to map the research landscape, the selected manuscripts were subjected to a bibliometric analysis using VOSviewer software (version 1.6.20) [45], which allows bibliometric networks to be visualized based on a distance-based approach [52]. The networks are made of multiple nodes positioned within in a two-dimensional space based on the similarities. Accordingly, the closer the nodes, the stronger their relationship. In this work, the default association strength is adopted as the normalization approach to account for variation in node connections. Finally, each node is assigned to a cluster, marked with a different color in the map. Among the tool's features, the keyword co-occurrences across the reviewed papers were displayed, offering an overview of the main research themes, which were subsequently examined through the scoping analysis [53]. In this regard, it should be noted that a quality assessment of the reviewed manuscripts was not performed, since the scoping analysis does not aim to critically evaluate the studies. Indeed, the purpose of a scoping review is to map a research field by exploring its key theme, thus offering a comprehensive breadth of the available literature [43].

3. Results

3.1. General Overview

As outlined in the methodology section, the adopted research strategy resulted in the selection of a sample of 39 articles. On the one hand, this limited number reflects the specific research criteria, which were established to cover a narrow research topic: the study of prefabricated wooden buildings related to user-related aspects. On the other hand, the aim of studying this topic at the whole-building scale led to the exclusion of a large number of articles focused on individual building components (e.g., studies on the vibrational behavior of timber floors or on user perception of wooden finishes), since they were not aligned with the objective of the study. The resulting sample thus reflects the scarcity of contributions addressing occupant-related outcomes in this field.

The number of publications over time, illustrated in Figure 2, does not show a clear evolution pattern. Indeed, a limited number of publications occurred in the early years of study (2010–2013), which then tends to increase over time, despite annual fluctuations. Accordingly, no specific trend can be identified, although the number of publications appears to be growing. As for the research impact, the analysis of citations by year shows an overall increase in the research interest, with citations exhibiting a steady growth trend over the analyzed period. The peak in citations occurred in 2023 with 74 citations, followed by a slight decrease in 2024 and 2025, which account for 63 citations each.

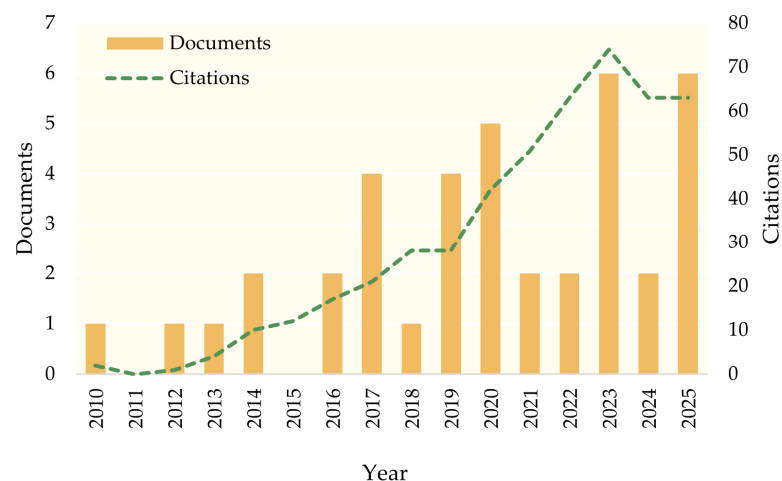


Figure 2. Trend of publications and citations for the 39 articles included in the review.

From a geographical perspective, there is an uneven distribution of studies, with research production primarily concentrated in Germany and France, followed by China, Chile, United Kingdom, Norway and the United States, as depicted in Figure 3. These results are based on fractional counting, meaning that each country receives a proportional share of an article according to the number of authors affiliated with that country. This distribution likely reflects the countries where prefabricated timber construction technologies are more widely adopted.

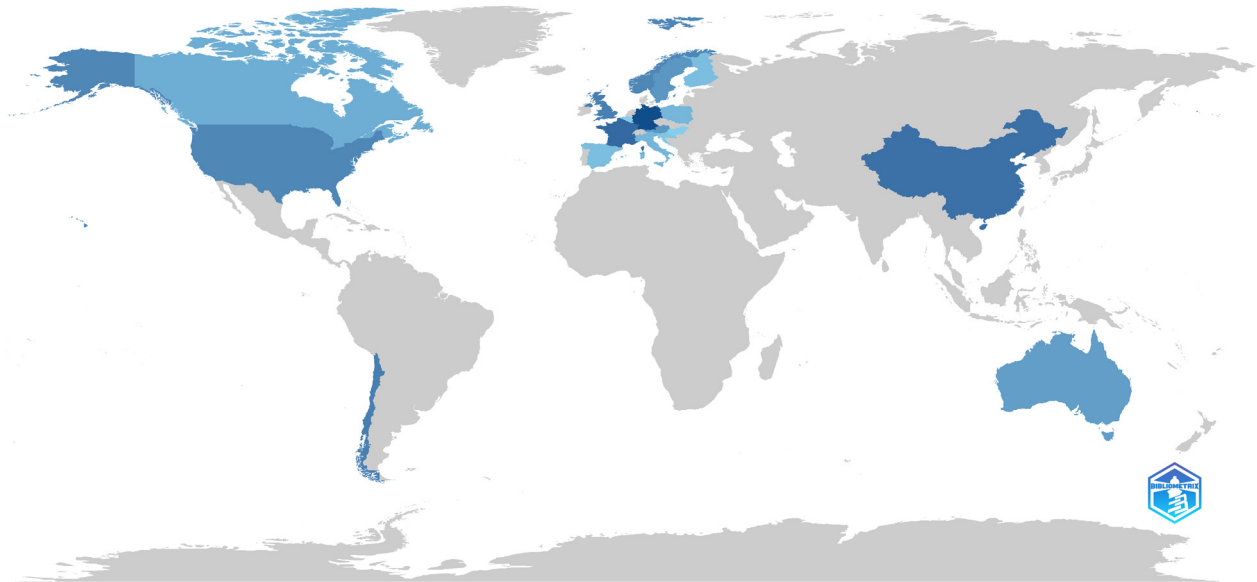


Figure 3. Distribution of publications per country, darker blue indicates countries with higher research production. Created with Biblioshiny.

3.2. Bibliometric Overview

The keywords co-occurrence analysis conducted using VOSviewer provided an early overview of the main research topics addressed by the retrieved manuscripts. On one hand, the keywords indicate the topics addressed, while on the other hand, the co-occurrence map reflects the semantic proximity of topics. More in detail, the size of both keywords labels and circles depends on their frequency of occurrence, indicating their relevance within the field. In addition, the thickness of the link between two keywords indicates the strength of their co-occurrence, which is defined as the number of publications in which both keywords occur together in the title, abstract, or keyword list [52]. Based on co-occurrence, keywords are grouped into clusters, where the proximity of clusters reflects the strength of the relationships between topics.

The co-occurrence analysis, depicted in Figure 4, revealed three main thematic clusters, which can be summarized as follows:

- Comfort and users' perceptions (purple cluster);
- Indoor air quality (orange cluster);
- Structural and architectural design (blue cluster).

The largest cluster is the purple one, which includes keywords mainly related to thermal comfort, with particular emphasis on the risk of overheating, as well as keywords commonly associated with post-occupancy evaluations. The orange cluster, which is related to indoor air quality, contains keywords related to environmental pollution and emissions of materials potentially harmful to human health. Finally, the cluster on structural and architectural appears to be the smallest, characterized by more generic keywords that do not allow for a clear identification of the topics addressed.

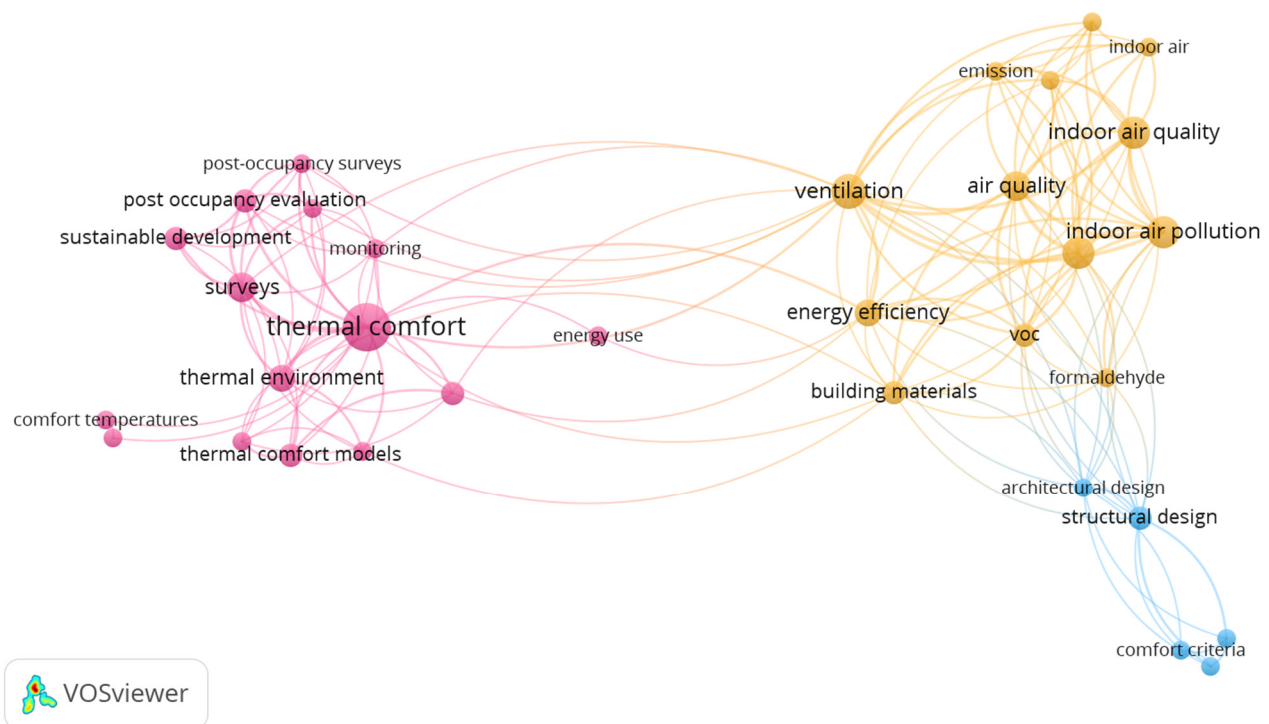


Figure 4. Co-occurrence map.

These themes partially overlap with the six main areas identified in a previous review of user-centered design in the built environment, namely: (i) physical perception of the environment, including visual, acoustic, thermal, and vibrational comfort; (ii) user satisfaction; (iii) information technology for the user experience; (iv) evacuation and accessibility; (v) energy and sustainability; and (vi) indoor air and health [38].

However, compared to this broader categorization, the literature on prefabricated timber buildings seems to converge on a narrower set of priorities, mostly related to environmental performance (sustainability) and occupant well-being (comfort and IAQ), including users' perception of the indoor environment. In contrast, topics such as evacuation and accessibility, Information and Communication Technology (ICT) for user experience, and broader aspects of user satisfaction do not appear to emerge from the keyword map.

The co-occurrence map by year (Figure 5) revealed different mean publication year depending on the cluster. For instance, the comfort cluster seems to be the most traditional, since its average publication year is 2017 (with a standard deviation of about 1.8 years). In contrast, the other two clusters seem to include more recent publications, with average publication years of 2019.4 and 2019.8, respectively. However, these clusters exhibit different variability, with standard deviations of 1.8 for IAQ cluster and 0.9 for structural/architectural design cluster, likely reflecting the size of the cluster itself, as the latter includes only four keywords.

3.3. Scoping Review

Starting from the results of the keyword co-occurrence analysis, which offered an initial overview of the aspects most frequently addressed in the manuscripts, the scoping review enabled a more detailed examination of the selected papers, allowing for a clearer identification of the key concepts investigated. In detail, the full texts of the selected papers were analyzed to identify the main themes and research objectives, allowing their classification into four main groups, illustrated in the pie chart in Figure 6. These groups largely correspond to the clusters previously identified through the keyword co-occurrence

analysis. However, a further topic related to architectural building design was identified. As shown in the chart, indoor comfort clearly emerges as the most frequently investigated user-related aspect, accounting for about half of the analyzed papers, including studies on thermal, acoustic and vibrational comfort. The second most addressed topic concerns indoor air quality, whereas energy efficiency and sustainability, in relation to user aspects, appear to be less extensively addressed. Finally, only a limited number of papers were found to span multiple clusters, highlighting the scarcity of multidisciplinary research in this field.

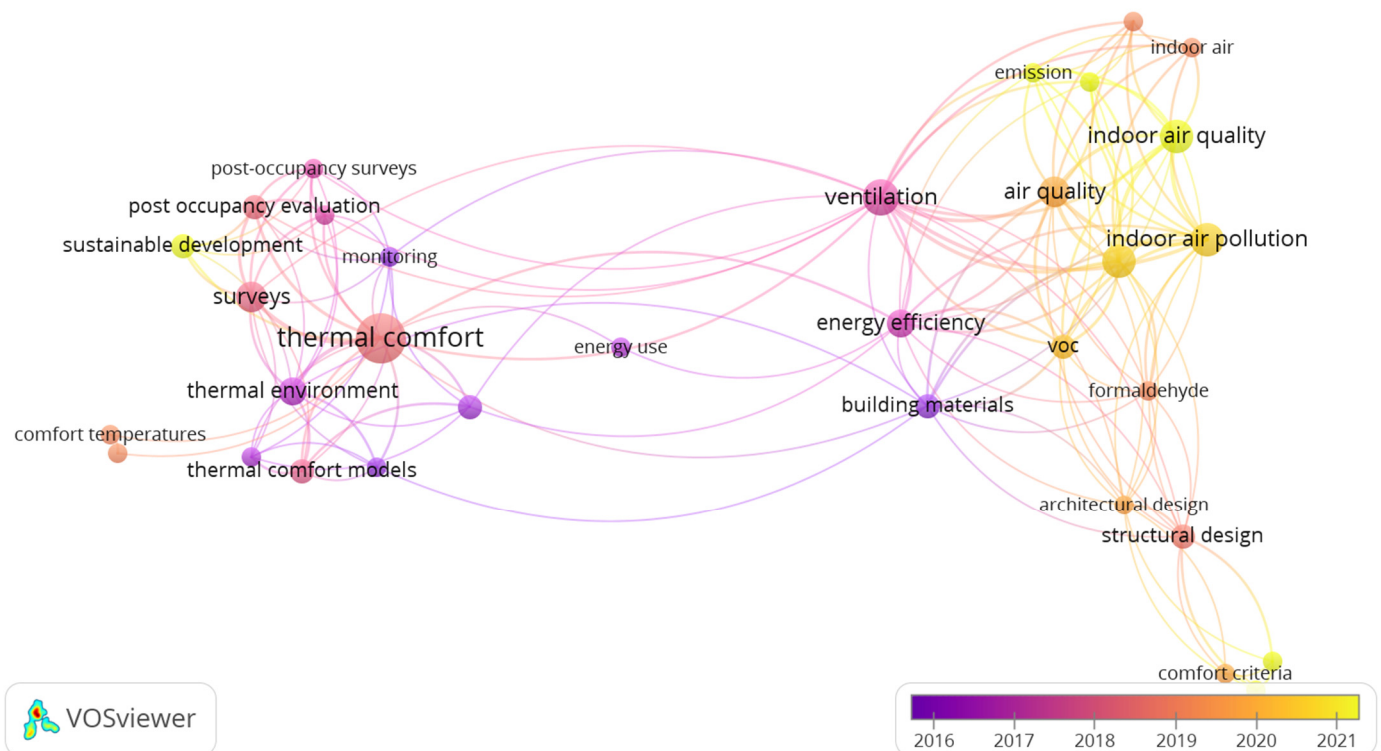


Figure 5. Co-occurrence overlay visualization.

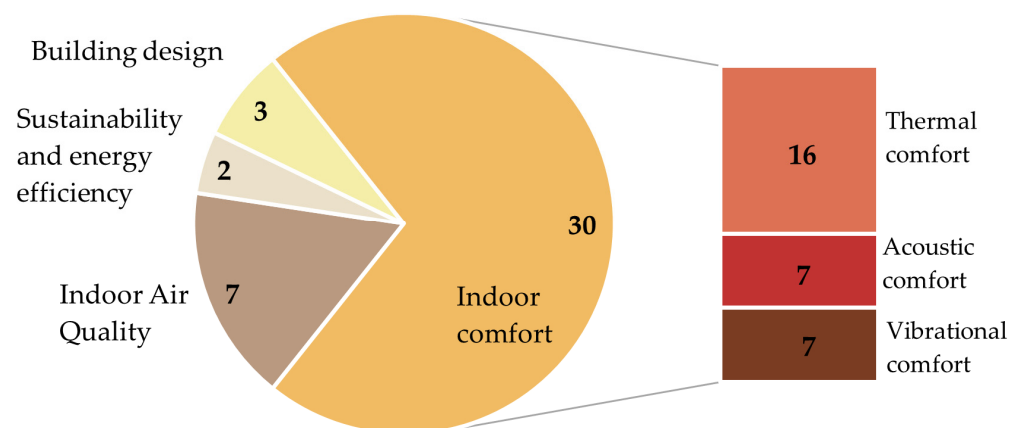


Figure 6. Distribution of the analyzed papers by main thematic areas.

An overview of each of these themes is provided in the following paragraphs, with a focus on research objectives, adopted methodologies, and identified knowledge gaps.

3.3.1. Indoor Comfort

Analyzing papers belonging to the indoor comfort cluster, it emerges that the majority of them focuses on the assessment of thermal comfort, while only a limited number addresses other aspects, like vibrational comfort or acoustic comfort.

Thermal Comfort

Thermal comfort is evaluated through different methodological approaches, including in situ monitoring, building energy simulations, occupant surveys, or a combination of them, as summarized in Table 2. The case studies analyzed range from real buildings (either occupied [54] or unoccupied [55,56]), to experimental test units [57], up to building models [58]. In situ monitoring is mainly aimed at measuring indoor air temperature to assess overheating risk [59], but also evaluating the performance of building components [56,57], or applying indoor comfort models [60]. Among these, different models are employed, including both PMV theories [61] and adaptive comfort models [60,62]. Another approach involves energy simulations, which reproduce the behavior of buildings under investigation. These simulations typically focus on indoor air temperatures to estimate overheating risk [59]. The assessment of thermal comfort during the summer season clearly emerges as the most critical concern, which is recognized as a key factor to be addressed from the earliest stages of design [58]. Indeed, it is often integrated into multi-objective optimization studies that aim to improve the building overall energy efficiency, as a factor that can significantly affect the design strategies [63]. Moreover, thermal comfort assessment is often employed not only to evaluate different design solutions, but also to perform comparative analyses, either among different timber construction systems [64] or with building typologies constructed using alternative materials [65].

Examining the findings of the reviewed studies, it emerges that prefabricated wooden buildings present significant challenges in terms of summer thermal comfort, mainly due to overheating. Among the mitigation strategies evaluated, enhanced natural ventilation proves to be more effective than solar shading devices, as pointed out by a study conducted in Luxembourg, which also highlights the importance of improving thermal mass to mitigate overheating [59]. The importance of thermal mass is also confirmed by other studies, which highlight how this deficiency can lead to a risk of overheating even in places with mild summer weather conditions, such as the United Kingdom [54,60,62], to the extent that massive constructions are often preferable in hotter climates such as Spain [65]. In fact, even within the same wooden buildings, there are differences based on the building thermal mass: when outdoors drop, indoor temperatures are found to decrease faster in the timber-frame than in the CLT apartment [64]. Not surprisingly, some studies show that summertime overheating occurs, exceeding acceptable limits, although in different ways depending on the environment—for example, more in bedrooms than in living rooms [54], but also depending on the characteristics of the building [58]. Considering the entire year, temperatures seem to remain within acceptable comfort limits, even when different comfort models are considered [61]. However, the literature indicates that simulations tend to underestimate the occurrence of overheating compared to in situ monitoring, revealing a methodological gap between predictive models and the actual behavior of buildings [60]. Despite this risk of overheating, the studies analyzed report an overall level of satisfaction among occupants within this type of building. Several studies based on occupant satisfaction surveys show that, although there is a slight perception of heat in summer [54,60] or in both seasons [61,64], overall users report being satisfied throughout the year, especially when they have the opportunity to interact with the environment by opening windows, doors, fans, and blinds [60,66]. Specifically, nearly all studies examine the users' perception of thermal comfort, also addressing aspects related to thermal satisfaction or thermal

preference [54,64]. It is worth noting that almost all the studies employ both objective and subjective approaches, thus combining questionnaires with in situ measurements. These measurements primarily focus on indoor air temperature, providing an empirical basis to support the assessment of thermal comfort. However, in some cases, the perception of dissatisfaction is slightly higher than would be expected from objective measures [67]. Overall, most studies report higher thermal satisfaction during winter [68], whereas in summer occupants tend to experience overheating [69], although satisfaction levels generally remain acceptable [64]. A completely different perspective on the topic is provided by a study conducted in a test chamber, which analyzed how the visual appearance of interior materials—wood versus white walls—can influence that thermal perception. Although people in the room with wooden walls said they felt closer to “neutral”, the result was found to be not statistically significant [70].

Table 2. Manuscripts focused on the evaluation of thermal comfort.

Ref.	Title	Building Type	Location	Methodology
[59]	Summertime overheating risk assessment of a flexible plug-in modular unit in Luxembourg	Building model	Luxembourg	simulation
[57]	Passive room conditioning using phase change materials—Demonstration of a long-term real size experiment	Test unit	Germany	in situ monitoring
[56]	Temperature stabilization using salt hydrate storage system to achieve thermal comfort in prefabricated wooden houses	Real building	Germany	monitoring and simulation
[54]	A study on the evaluation of thermal comfort of occupants, summertime and wintertime temperatures in a single prefabricated structural timber dwelling	Real building	UK	monitoring and survey
[60]	Thermal comfort, summertime temperatures and overheating in prefabricated timber housing	Real buildings	UK	post-occupancy evaluation, surveys, monitoring and simulation
[62]	Thermal performance of indoor spaces of prefabricated timber houses during summertime	Real buildings	UK	monitoring and simulation
[58]	New chilean building regulations and energy efficient housing in disaster zones: The thermal performance of prefabricated timber-frame dwellings	Building model	Chile	simulation
[65]	Study of thermal environment inside rural houses of Navapalos (Spain): The advantages of reuse buildings of high thermal inertia	Real building	Spain	monitoring
[64]	Comparison of thermal comfort conditions in multi-storey timber frame and cross-laminated residential buildings	Real buildings	Italy	monitoring, simulation, post-occupancy evaluation

Table 2. *Cont.*

Ref.	Title	Building Type	Location	Methodology
[61]	Thermal performance and apparent temperature in school buildings: A case of cross-laminated timber (CLT) school development	Real building	US	monitoring
[55]	Experimental Analysis of Thermal Performance and Evaluation of Vibration and Utility Function for the Readaptation of a Residential Building in an Experimental Housing Complex	Real building	Poland	monitoring
[70]	Impact of Wood on Perception of Transient and Steady-State Indoor Thermal Environments	Test chamber	-	surveys
[66]	Post-occupancy evaluation on people's perception of comfort, adaptation and seasonal performance of sustainable housing: a case study of three prefabricated structural timber housing developments	Real buildings	UK	post-occupancy survey
[68]	Winter performance, occupants' comfort and cold stress in prefabricated timber buildings	Real buildings	UK	monitoring, post-occupancy survey
[69]	Post-occupancy and indoor monitoring surveys to investigate the potential of summertime overheating in UK prefabricated timber houses	Real buildings	UK	monitoring, post-occupancy survey
[67]	Comfort assessment of two nzebs in Norway	Real buildings	Norway	monitoring, post-occupancy survey

Vibrational Comfort

Despite most studies focuses on thermal comfort issues, a small portion of research has addressed vibrational comfort in prefabricated timber buildings, although this remains very limited. The issue of vibrational comfort is particularly relevant in timber buildings, as a significant body of literature deals with the vibration serviceability of wooden floors, that is, the evaluation of their performance in controlling vibrations perceived by occupants, with the aim of keeping them within acceptable thresholds [71,72]. Nevertheless, the review revealed that studies explicitly focusing on users' comfort remain limited: in situ monitoring is relatively scarce, and direct assessments of occupants' perceptions on this matter are even more sporadic. Recent literature distinguishes between two main areas of analysis: wind-induced vibrations and floor vibrations. Although there is extensive literature on the study of floor vibrations, this review focuses on this topic from the user's point of view. Therefore, only those papers that evaluate these aspects in relation to the comfort perceived by users, rather than the structural performance itself, have been selected. The literature often evaluates this topic according to ISO 10137 [71], which defines the serviceability of buildings with vibrations, defining the acceptable limits for human comfort.

As for wind-induced vibrations, several studies have focused on multi-story buildings made of CLT and glulam. Numerical analyses conducted using finite element (FE) models

on 12–14-story residential buildings show that, even at moderate heights, the comfort criteria defined by ISO 10137 are not always met [73]. However, studies of real-world cases, such as the “Treet” wooden skyscraper in Bergen (Norway), indicate that the vibrations perceived by occupants on the upper floors generally remain within regulatory limits and do not cause discomfort [74]. An analysis of three CLT buildings in the United Kingdom and Norway confirmed that, although the natural frequency of the system may meet the comfort criterion, estimation errors in the model and factors such as damping and modal shape affect the actual behavior, sometimes leading to non-compliance with the ISO limit in the actual building, even though it is theoretically satisfied at the design stage [75].

In the case of floor vibrations experimental tests on glulam and CLT floors have shown that actual vibration performance is often better than that predicted by equations provided by technical codes [76,77]. Continuous monitoring of an eight-story building in France has also shown that measured accelerations remain well below the ISO 10137 sensitivity threshold, with no reports of discomfort from building users [78]. Finally, experimental studies using virtual reality (VR) have explored the influence of the visual environment on the perception of vibrations, suggesting that the spatial context can modulate tolerance to floor movement, highlighting a lower tolerance to vibration in bedrooms than in gyms [79]. Accordingly, current limit values of the response factor in ISO 10137:2007 appear to be conservative for timber floors in both the bedroom and gym environments.

Acoustic Comfort

While the majority of the literature seems to be focused on thermal comfort, some manuscripts deal with acoustic comfort, which represents one of the main challenges for prefabricated timber buildings. Indeed, although these constructions generally offer good thermal performance, they exhibit different sound transmission characteristics compared to traditional systems, which often result in acoustic issues. The reviewed studies show a growing interest in evaluating the acoustic behavior, particularly of cross-laminated timber structures, with the aim of improving airborne [80] and impact noise insulation [81], but also in assessing overall acoustic comfort [82].

The main methodologies include sound insulation measurements between floors or adjacent rooms as well as vibration analysis, evaluating in particular the influence of different types of joints. For instance, some studies have investigated the effect of building height and joint details on the vibration reduction index (VRI) [81] and airborne sound insulation [80], highlighting that an increased vertical load and the presence of flanking paths can reduce acoustic performance, especially on lower floors [80,81]. Research on test buildings and mock-ups has also highlighted the importance of elastic joints and fasteners, which can significantly improve impact sound attenuation [83,84]. More in detail, the use of angle brackets has been shown to be effective in reducing the dampening effect of the elastic interlayers [84]. Moreover, a recent study conducted in China on a high-rise glulam building floor structure showed that the impact sound insulation of this kind of floors is generally better than its airborne sound insulation performance [77]. A further study was conducted in a CLT church in Viareggio, where geometric acoustic models were applied to correlate the architectural form with speech intelligibility, demonstrating how the ceiling configuration affects the auditory comfort of the occupants [82].

Although the assessment of acoustic performance is crucial for ensuring occupants well-being in this building types, the reviewed studies revealed several limitations. For instance, it has been found that predicted performance tends to underestimate actual measurements, not always providing a reliable estimate [83]. Furthermore, many studies focus on a single level of the building or on specific structural configurations, neglecting the variability between floors and between different construction systems [80,81]. Overall,

the literature still seems to focus on the study of sound transmission through individual building elements, resulting in a lack of building-scale data that limits the generalizability of the results and makes it necessary to expand experimental campaigns.

A different perspective is provided by a study conducted in Norway, which evaluated user satisfaction in a student housing building in relation to noise, revealing that 28% of the users were dissatisfied, thus confirming that acoustic comfort requires further investigation [67].

3.3.2. Indoor Air Quality

Another user-related topic that appears to be studied is indoor air quality (IAQ). In particular, the assessment of indoor organic volatile compounds (VOCs) appears to be a particularly relevant, as highlighted in a literature review by Goodman et al., which analyzed 24 years of research on the subject [34]. Their review, covering eight studies, revealed the limited number of investigations available on this topic, while also highlighting its importance for human health. As expected, most studies on VOCs rely on field measurements, either in real buildings [85] or in test chambers [86], sometimes combined with assessments of occupant perception [87].

The analyzed studies show that even natural wood materials can be a source of VOC emissions, although generally to a lesser extent than other building materials [34]. More in detail, investigations conducted on new prefabricated timber houses have shown some VOCs (aldehydes, acetaldehyde, and carboxylic acids) exceeding guideline thresholds, especially in the early stages of use, thus suggesting that attention should shift from formaldehyde to new categories of emerging compounds [88]. A study conducted in France used a chemical mass balance model to estimate VOC sources in new timber-frame houses, showing that turning off the ventilation systems can significantly increase the concentration of indoor pollutants, particularly those derived from furnishings and surface finishes [86]. Actually, good indoor air quality cannot always be guaranteed even when a mechanical ventilation system is present [88], although controlled ventilation systems limit VOC concentrations compared to window ventilation [89].

Other studies have investigated both measured air quality and that perceived by users. On the one hand, a study conducted in Finland on three experimental buildings revealed that subjective perception of air quality improves with higher ventilation rates, although the tests were carried out in unfurnished rooms with untreated materials, limiting the representativeness of the results [87]. Despite this, terpene emissions seem to remain relatively high for several years [87], depending also on the construction type (with differences between timber frame and solid wood [89]), thus requiring further investigation into their effect on the health of occupants. On the other hand, in Norway, analyses during the construction of wooden dormitories found VOC concentrations below risk levels [90]. Overall, VOC concentrations appear to decrease as early as 6 [91] or 8 months [89] after construction, allowing users to be generally satisfied with IAQ.

3.3.3. Energy Efficiency and Sustainability

The full-text analysis revealed that only two papers can be strictly classified within this cluster, examining occupant behavior in relation to building energy efficiency. Specifically, post-occupancy questionnaires were used to gather information on residents' habits, showing that most occupants ventilate their homes daily during the winter, despite low indoor temperatures, reporting limited perceived control over indoor air quality [92]. Energy efficiency is also examined in relation to occupant comfort in the study cited in the previous paragraph, highlighting the importance of accounting for limitations related

to summer overheating when selecting construction technologies aimed at improving building performance [63].

3.3.4. Building Design

A further topic related to the architectural design of buildings was identified, which was the focus of only three papers. It is noteworthy that only few manuscripts focus on the architectural design of prefabricated timber buildings driven by user needs, as it is a core aspect of user-centered design. A study conducted in Croatia employed both questionnaires and informal interviews to identify users' requirements regarding social spaces, thus defining the design criteria for a modern modular prefabricated timber building [93]. However, two studies diverge from this framework, aiming to explore broader aspects of Indoor Environmental Quality (IEQ) in prefabricated timber buildings, based on users' perceptions. The former investigates occupant satisfaction, productivity, and health in mass timber office buildings using pre- and post-occupancy questionnaires, which were combined with in situ measurements in an attempt to identify a relationship between environmental variables and user satisfaction [94]. The latter presents a multi-scale evaluation, exposing elderly users to mock-up environments and analyzing their feedback on indoor comfort (including thermal sensation, acoustic satisfaction and tactile feedback), safety (evaluating perceived slip resistance, edge sharpness and emergency egress clarity) and esthetics (investigating color harmony and texture appeal) [95].

4. Discussion

The literature review highlighted that, although research on prefabricated timber buildings is attracting increasing attention, investigations addressing user-related aspects remain scarce. In general, user-centered design emerges as an evolving topic, with studies from the user's perspective significantly limited. This appears even more pronounced in the field of prefabricated timber buildings, where the focus on user experience is still underexplored, compared to the predominance of studies addressing technological aspects. With regard to users' perceptions of prefabricated timber buildings, only few references have been identified. Although one study reports a high level of satisfaction among building occupants, the available literature remains extremely limited, making it difficult to draw solid conclusions about user satisfaction in this type of building.

Compared with the broader literature on the topic [41], results indicate that only a few research themes have been addressed, including studies on spatial design (closely related to user-centered design), indoor comfort, indoor air quality, and energy efficiency. Among these, thermal comfort clearly dominates, with nearly all studies investigating this topic through both theoretical analyses and post-occupancy evaluations. These findings highlight that prefabricated timber buildings—especially lightweight frame buildings—may experience discomfort during the summer months due to overheating. However, thermal comfort is mainly evaluated based in indoor air temperature, whether simulated or measured, neglecting other influencing parameters such as humidity or air velocity. In contrast, vibrational comfort represents an important yet less explored topic. Overall, studies directly linking vibrational performance to occupant well-being are scarce, with most research focusing on theoretical assessments based on reference thresholds provided by standards, rather than users' perceptions. The scarcity of experimental data at the building level, especially in high-rise buildings, appears to be one of the main limitations in this research area. Likewise, as for acoustic comfort, most studies analyze sound transmission between individual building elements, which limits building-scale understanding and the generalizability of results, thus highlighting the need for broader experimental campaigns. Also in that case, only one study deals with the users' perception, revealing a

dissatisfaction with acoustic comfort. This absence may be partly attributed to the focus of this review on the building scale, which excluded the extensive body of component-scale research available on these topics. Moreover, it should be noted that other comfort aspects, such as visual comfort, are largely absent from the literature. Similarly, indoor air quality appears to be of growing interest, but research mainly addresses pollutants that may affect occupant health—such as VOCs—while other IAQ aspects, including CO₂ concentration or bacteria presence, are less frequently investigated. However, the main limitations concern the scarcity of long-term measurements, the use of test buildings, and the uncertainty in identifying emission sources.

Although the number of studies is limited, all of them consistently highlight aspects that require careful consideration in the design of prefabricated timber buildings (thermal and acoustic comfort, indoor air quality, spatial layout, and vibrational performance). Accordingly, inadequate attention to user needs can result in buildings that fail to provide satisfactory occupant experiences, albeit being environmentally sustainable. Furthermore, the limited number of studies suggests that many human-related aspects remain unexplored, making it difficult to predict their relationship with user experience. Lastly, the majority of the reviewed studies remain confined within a single disciplinary perspective, while user-oriented design required an integrated, multidisciplinary approach, which is still lacking.

5. Conclusions

Prefabricated timber buildings are a topic of growing interest within the scientific community, as they are considered a sustainable construction approach. In recent years, the body of literature on this topic has increased, although it still predominantly addresses technological aspects, while users' perceptions within such buildings remain unclear. The present review aims to address this literature gap, in an attempt to provide a comprehensive overview of the literature, focusing on studies that examine user-related dimensions rather than construction technology itself.

To this end, a literature review was conducted in accordance with the PRISMA guidelines, firstly analyzing the results using a bibliometric analysis and then further exploring them through a scoping review. In response to the initial research question, the review shows that studies addressing user-related aspects are extremely limited, concentrating on a narrow set of issues while neglecting others. Among these, thermal comfort—particularly in lightweight prefabricated structures—emerges as the most extensively investigated aspect. By contrast, other dimensions of user comfort, such as vibrational, visual, and acoustic comfort, remain largely unexplored. Similarly, indoor air quality has received some attention, with studies often focusing on VOC emissions, while fewer investigations consider CO₂ concentrations, microbial presence, or a broader set of parameters. By contrast, aspects related to energy efficiency and sustainability in connection with user behavior remain underexplored, as do post-occupancy evaluations, which once again tend to focus primarily on thermal comfort.

However, some limitations can be highlighted in this work. Firstly, the analysis specifically focused on prefabricated timber buildings, thus excluding studies that address wooden architecture from a broader perspective. For instance, articles addressing users' perception of wooden interiors were not included, even though this topic could be related to prefabricated timber buildings as well. Similarly, articles focusing on individual wooden assemblies rather than on the whole building scale were also excluded, since they mainly investigate technical performance rather than user experience, even though they represent an intensive research area.

Overall, the results clearly underscore the need for further research. On the one hand, topics already investigated require deeper exploration to address current limitations. On the other hand, it is essential to expand the breadth of investigation to encompass new occupant-related dimensions, to ensure a more comprehensive and satisfactory experience within the built environment. This could also improve users' perceptions of these construction types, increasing their level of acceptance and, consequently, promoting their wider implementation. As for thermal comfort, future works should include all the influencing factors, taking into account, for example, relative humidity and air velocity, to provide a more comprehensive and reliable understanding of users' thermal comfort. Regarding acoustic comfort, future research should involve measurement campaigns in real multi-story buildings, further analyses comparing different structural configurations, as well as more occupancy evaluations on this topic. Also, vibrational comfort studies have significant potentials in terms of research development, through monitoring campaigns which could help in validating numerical models, as well as occupants' evaluations which could help update comfort thresholds with more realistic limits. Finally, future studies on IAQ should focus on long-term monitoring in occupied and fully operational buildings, improving measurement accuracy and identifying emission sources more precisely, while also enhancing knowledge on the specific toxicity of wood-emitted compounds. Overall, there is a clear need for more multidisciplinary studies, integrating perspectives from architecture, building physics and social sciences, to fully capture the complexity of user experiences in prefabricated timber buildings, a field that remains largely unexplored.

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