

Advancing Timber for the Future Built Environment

OCCUPANT OUTCOMES IN TIMBER-RICH ENVIRONMENTS: A REVIEW

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ABSTRACT: Occupant outcomes are an important area of research that seeks to understand the effects of building design and material selections. Views to the outside and natural materials such as timber are associated with numerous benefits for occupants, including increased productivity, the experience of biophilia, and other indicators of positive feelings. These benefits point to the importance of well-designed buildings for human psychological well-being and workplace productivity. However, few studies focus specifically on occupant outcomes from timber as a visible material in the interior, and even fewer highlight how the design of a space impacts or modulates those outcomes. This paper presents a robust literature review methodology used to seek, select, and review existing literature on occupant outcomes in timber spaces. Results indicate three themes in existing research: (i) studies focusing on material performance, (ii) reviews and case studies addressing spatial environments, and (iii) human responses to timber environments. The literature review reveals an important lacuna in linking how the design of timber spaces impacts these identified themes.

KEYWORDS: timber, occupant outcomes, literature review, design, human experience

1 – INTRODUCTION

Timber is emerging as an attractive alternative material to the concrete and steel so often used in the structure and finishes of buildings [1]. One major benefit of building with timber is its ability to sequester carbon, providing a positive environmental benefit for buildings [2]. Another benefit is the materials' biophilic qualities, with positive impacts for occupant well-being and productivity. Reports sponsored by the timber industry highlight potential positive occupant benefits to building with timber, including linking timber to biophilia (generally understood as humans' affinity for life and living things) and therefore well-being [3], and to satisfaction and therefore workplace productivity [4]. Other research studies have shown that people can have measurable positive psychological responses to timber environments [5].

2 – BACKGROUND & DESCRIPTION

Building design generally has been shown to have the ability to increase feelings of biophilia and a connection to nature [6], [7]. Biophilia has even been considered an

important design element to improve the mental health of astronauts [8]. Additionally, building design and material decisions have been shown to have other social outcomes for occupants as well, including productivity, [9] comfort, [10] behaviour, [11] and other factors [12]. Buildings have also been shown to have the potential to communicate and educate about sustainability [13], [14].

However, previous research focusing on occupant outcomes in timber buildings often concluded that further research is needed to fully understand the impact of timber use on building occupants [15], [16]. Additionally, previous reviews have focused on experimental data from narrowly defined fields and have overlooked spatial and design elements.

This paper aims to increase understanding of how design choices can improve occupant outcomes from visible timber in indoor environments. To that end, the authors present their methods for a rigorous literature review and the themes that emerged from their analysis.

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The literature review considered the reported physiological and psychological effects of exposure to architectural timber finishes in indoor environments – particularly in relation to the use of timber in workplaces and associated environments, and experiential effects that impact work (such as well-being and productivity). The authors were interested in determining to what extent these studies focused on spatial elements, along with factors of study design such as the consideration of time (as long- or short- term exposure) and how data was obtained.

3 – METHODS

3.1 SEARCH STRATEGY

A search strategy was drawn up centred on the following search concepts:

- Effects (a. General; b. Well-being; c. Productivity)
- 2. Timber
- Indoor (a. General; b. Exposed structure; c. Surface treatment)
- Exposure (a. General; b. Visual; c. Tactile; d. Olfactory; e. Acoustic).

Given the broad and multidisciplinary nature of the search query, Web of Science and ProQuest (Art and Architecture) were chosen as appropriate databases to perform the search. Searching occurred in November 2024 using an iterative search design to limit results that did not respond to the search statement.

Inclusion criteria were:

- discussion of human/occupant interaction with timber components
- discussion of the architectural/spatial use of timber components
- discussion or testing of the material properties of timber components that affect atmospheric comfort; and/or
- discussion of the subjective meanings of timber as a material.

The search results were pooled, and summary information and abstract text were extracted for each record to yield a total of 1152 results. Results were manually screened by the authors using abstract and summary information against the inclusion criteria. Exclusion criteria that surfaced as part of the screening process were:

- Erroneous results (such as one of the search terms appearing as an author name or citation)
- Results discussing or testing material properties influencing structural behaviour (including fire resistance and decay)
- Results discussing historical structure restoration and rehabilitation techniques or case studies
- Results discussing OHS considerations for timber processing industries
- Descriptions of residential projects
- Results detailing the workflows of educators, architects, designers and builders, including how they make decisions regarding the use of timber in buildings
- Results detailing the working process of developing timber products or treatment processes
- Results discussing the use of wood for cooking and heating (including air quality studies relating to the burning of biomass)
- Results discussing or testing timber coatings (such as varnishes and paints, including their effect on air quality)
- Energy analyses.

After this screening, a total of 132 results remained and were included in analysis.

3.2 CODING OF RESULTS

The authors used the inclusion criteria to develop codes that addressed three important factors of the research focus.

First, the authors considered the way in which the data generated by the study was connected to inhabitation of timber environments. Categories developed here describe whether data was collected: (i) *in situ* (as the result of testing an inhabitable timber environment), (ii) by contact with a sample (involving participant contact with a physical sample of timber and its material qualities); (iii) through participant exposure to image (involving participants viewing simulations or images of timber environments); or (iv) through no *in situ* elements (where data is the result of review or discussion only, or data is collected by material testing outside of a normally inhabited environment).

Second, the authors considered the way in which spatial characteristics were linked to timber use by the study. Categories developed here describe whether the study investigated: (i) design elements of timber use (such as the amount and positioning of timber in an environment), (ii) the material properties of timber; or (iii) if spatial characteristics were not detailed.

Third, the authors considered the degree to which the study considered occupant outcomes. Categories developed here described whether the abstract: (i) generated qualitative data about occupant outcomes, (ii) discussed occupant outcomes alongside quantitative testing, (iii) considered occupant outcomes as background context only; or (iv) did not discuss occupant outcomes.

After coding, the authors removed 26 results that did not collect data using *in situ* elements, did not detail spatial characteristics, and either only considered occupant outcomes as background context or did not discuss the occupant outcomes. These results were concerned with decision-making in design and construction, the development of novel products, and quantitative testing of the material properties of samples, and were thus outside of the scope of this research.

An initial blunt statistical analysis revealed code distributions presented in figure 1. The abstracts of the remaining 106 results were analysed to reveal specific existing research foci within the broader field.

4 – RESULTS

Three main clusters of topic areas emerged from the subsequent analysis, each with a specific focus regarding our research question. The details of the code distributions in each cluster are presented in figure 2.

4.1 MATERIAL PERFORMANCE OF TIMBER AND TIMBER ENVIRONMENTS

A first cluster of studies concerned with the material performance of timber and timber environments (n=46, 43.4%) presented various findings on the properties of

timber by testing material samples and by measuring inhabitable environments *in situ*. This set of studies provided valuable evidence for the impact of timber on different aspects of spatial experience.

The majority of these studies (n=37, 80.4%) used material engineering methodologies to produce quantitative data that was linked to, or mentioned in terms of, aspects of spatial experience. They provided a data bank reporting on different testing scenarios: the structural (n=11, 29.7%), thermal (n=9, 24.3%), acoustic (n=8, 21.6%), or visual (n=3, 8.1%) properties of timber and timber environments; and the indoor air quality effects of timber and timber environments (n=5, 13.5%). Half of these studies involved measurement in-situ (n=23, 50.0% of this focus set), while the remainder had no *in situ* environmental component.

Nine of these studies included a qualitative component. Four assessed material properties without participant involvement [17], [18], [19], [20], all of which focused on the interactions between timber and daylight in different spatial conditions. The other five studies focused on thermal comfort [21], [22], indoor air quality [23], [24], or both [25] and used surveys to register participant comfort to correlate with quantitative measurements of in-situ environments.

4.2 REVIEWS OF THE IMPACTS OF TIMBER ON SPATIAL EXPERIENCE

A second cluster of studies were reviews concerned with the impacts of timber on the experience of spatial environments (n=16, 15.1%). The authors classified these broadly as literature reviews, case studies, and design philosophy reviews. These reviews offered understanding around the role of timber in the human experience of space.



Figure 1: Result distribution across three coding sets.



Figure 2: Code distribution within the three clusters. Coding categories are presented as areas corresponding to the percentage of results carrying the code within the result cluster. Areas of each code set overlap to show percentage of results carrying both codes.

Four case studies discussed the use of timber in particular buildings and architects' works. These studies used methodologies from the design disciplines to connect timber as a material to the tectonics and spatiality of specific buildings, looking at the articulation of structural timber components and the way they order, express and connect space [26], [27], [28]. One case study explored the structural identities, spatial applications and spatial experience of timber in context to explore the perceptual and psychological impacts of timber environments [29].

Five design philosophy reviews explored material meaning and context in more general ways. These discussions acknowledged timber's renewed popularity or importance for sustainability in tension with reduced acoustical performance [30] and required changes to form and structure [31]. They also addressed the tectonics and visual qualities [32], meaning [33], and aesthetics [34] connected to timber. These studies contributed to the understanding of how timber can be used in spatial environments, and the impact that design decisions about how and where to use timber can have on sensory and symbolic meanings.

Of the remaining seven literature reviews, the majority explored the psychological and physiological impacts of using timber as a building material with slightly different foci. Three reviews [35],[36],[37] compiled a set of resources discussing human responses to timber environments, showing that timber interiors provoke positive psychological and physiological reactions amongst occupants, and in one case [35] introducing a range of theories for explaining these reactions. Two reviews [15], [38] focused on visual contact with wood and wood-like surfaces, exploring the nuances of these contacts. One review [39] explored which material properties are associated with the reported psychological and physiological impacts of coming into contact with timber.

One outlier within this cluster instead explored the interactions of material and space in the architecture disciplines, reviewing design texts using big data mining. This review found that material properties, material interactions, and material presentation were important and resurfacing concerns in the field of architecture [40].

4.3 HUMAN RESPONSES TO TIMBER AND TIMBER ENVIRONMENTS

A third cluster of studies concerned with human responses to interacting with timber and timber environments (n=44, 41.5%) presented findings on the physiological and/or psychological effects of encountering timber.

These studies followed experimental psychology, neurobiology, and post-occupancy evaluation methodologies to produce quantitative and/or qualitative data sets related to measured and/or reported responses to smelling, touching, looking at, or inhabiting with timber. Experiment design in these studies was split between contact with samples (n=14, 31.8% of this focus set) exposure to images and digital models (n=12, 27.3% of this focus set), and in situ experiments (n=18, 40.9% of this focus set). The majority of the studies were concerned with design elements of the experimental object (n=33, 75.0% of this cluster)—with the exception of the contact-with-sample experiments, which focussed more strongly on particular properties of materials that affect spatial experience (n=9, 64.3% of results that involved contact with samples). The studies in this cluster considered a range of sensorial exposures to timber, including tactile (n=8), visual (n=20), olfactory (n=4) and immersive (n=16). A large majority of the studies in this set produced qualitative data - either in isolation or alongside quantitative data - and analysed these in terms of impacts on occupants (n=37, 84.1%).

The findings of the studies in this cluster agree that timber environments are beneficial to well-being, with different nuances amongst the studies. Nine studies found that being or working in timber environments generally had positive effects such as an increase in cognitive performance, mood and comfort and a reduction fatigue and physiological stress indicators [41], [42], [43], [44], [45], [46], [47], [48]. Further studies linked similar effects to specific aspects of interacting with timber, including smell [49], [50], [51], sight [52], [53] and touch [54].

Eleven studies discussed the preferences among study participants for particular aspects of the tactility of timber, such as its visual or tactile warmth [55], [56], [57], [58], [59], [60], [61], the way it feels on touch [62], [63], [64], and how it weathers [65]. Visual characteristics were also presented as affecting preference [66], [67].

The work above details the qualities of timber and its effects on people and reveals a variety of potential benefits for human physiology and psychology. Two studies contradicted these results in specific cases, showing that walking on carpeting induces less stress than walking on timber floors [68] and that there was no correspondence between psychological evaluations and physiological responses on entering timber rooms [69]. Two more studies showed timber use as only one of many spatial factors affecting restorative qualities [70], [71].

These contradictions and contexts hint that the experimental data produced, whilst highly valuable in describing the physiological and psychological effects that timber can have on people, might not tell the whole story regarding the design impacts of timber. Extrapolating from interactions between people and timber to interactions between people and timber *environments* is not straightforward. Two concepts can help emplace studies in environments: the spatial context (where and how the material is used) and program or use context (what a person is trying to do in a space, its purpose).

Two groups of studies in this cluster investigated the spatial and use contexts of timber environments more fully. These studies are particularly of interest to our research as they establish a relationship between human response, exposure to timber, and design aspects of creating timber environments.

Six studies focused on the spatial context of timber and its psychological and physiological effects. The spatial contexts considered were the saturation of timber within the environment [72], [73], [74], and whether the timber was part of the structure or surface treatment of the space [75], [76]. The specifics of the results of these studies varied, but it was generally found that particular ranges of timber saturation within a room corresponded with different attention levels and physiological responses, and that exposure of timber structural components contributed to beneficial psychological and physiological effects.

Two studies discussed the placement of timber elements and their effects on attention [77], preference and satisfaction [78]. These studies indicated that finishes or timber elements may be more beneficial when used in particular places in buildings.

A further group of four studies focused on the participant use context (the task or level of activity being performed) and how the preference for particular qualities or features of timber was affected by this context. These studies linked preferences for different timber features and qualities to different levels of activity and cognitive task [79], [80], [81]. One study [82] introduced symbolic dimensions to these preferences, showing that people prefer to work for companies that use timber products in their interiors; another [83] found that architectural program (the intended use of a space) influenced whether people preferred high-feature timber.

The studies discussed in this section, though they used different methodologies from a range of disciplines, primarily used a short time scale in their experimental design. Only four studies [16], [48], [70], [78] were identified in as collecting data over a longer experimental period.

5 – CONCLUSIONS

The existing literature on occupant outcomes offers a net positive assessment. However, contradictory findings and complicating factors litter the literature, confounding an easy summary of findings that would hold across all cases. Future research could focus on considering the factors that modulate results. Robust comparative studies could contribute to that agenda.

Additionally, there is a noted lack of long-term studies *in situ*. The places where people live and work, where the effects of timber are most important and most felt, are also places where people spend extended periods of time, well beyond what is typically studied. This is true for any given day (e.g., people might work for over seven hours in the same room) and more longitudinally (where people might work in the same office for multiple years). Future research could begin to address this lacuna by utilizing longitudinal research designs, especially when studying timber *in situ*.

Fundamentally, there is agreement that timber has important and unique qualities that are worthy of study, and that one of its qualities is a generally positive impact on people inhabiting timber spaces. An important next step is teasing out the nuances of exactly how design matters to that impact.

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