How Long Can Timber Buildings Last? Strategies for Service Life and Sustainability

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Abstract. Lifecycle assessments (LCA) often estimate the service life of taller timber buildings at 50 years, but how long can they realistically last? More importantly, how can their lifespan be extended? This chapter addresses these questions by exploring strategies to extend service life and methods to predict durability during the planning phase. A survey of over 120 experts in timber construction was conducted to define the actual service life of medium-rise and tall timber buildings. The survey results highlight key measures for extending service life, including material selection, climate-adaptive design, proactive maintenance, and principles of circular construction. These findings serve as the foundation for refining service life prediction models and establishing sustainable design guidelines. This chapter provides actionable insights and expert-driven strategies to ensure the longevity and resilience of taller timber buildings, contributing to their role as a sustainable alternative in the global construction industry.

Keywords: environmental impact · GHG emission · carbon modelling · High-rise construction · end-of-life · engineered timber

1 Introduction

In Europe, over 75% of timber waste is either incinerated or sent to landfills, while most cascading recycling efforts result in material downgrading rather than high-value reuse [1, 2]. This inefficiency underscores the need for innovative strategies to maximize timber's lifecycle value. Simultaneously, there is an urgent demand for low-carbon construction solutions, particularly for buildings with a carbon intensity below 12 kg CO_2e/m^2/year across their entire lifecycle [3]. Engineered timber has emerged as a renewable material that not only meets these environmental goals but also facilitates the construction of taller buildings, such as HAUT in Amsterdam [4] and the Wood Hotel in Mjøstårnet [5], which serve as benchmarks for sustainable urban development.

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While engineered timber offers significant environmental advantages, including lower greenhouse gas emissions and circular economy potential, its application in high-rise buildings faces several challenges. Existing research has largely focused on mid-rise or low-rise structures, leaving a critical gap in understanding the durability and service life of taller timber buildings. Additionally, current end-of-life practices for timber often fail to capitalize on their full potential, emphasizing the need for systematic approaches to extend material utility [6]. Understanding and improving the service life of tall timber buildings is vital for advancing their role as low-carbon alternatives to traditional materials like steel and concrete. Accurate predictions of service life and robust strategies for maintenance and reuse are essential to optimize the lifecycle carbon intensity of these structures. This study, conducted between 2023 and 2025 under COST Action HELEN, addresses two critical questions:

- How long is the lifespan of tall timber buildings?
- How can the service life of these buildings be accurately predicted during the planning process?

A survey of over 120 industry experts was undertaken to collect data on the lifecycle and durability of medium- and high-rise timber structures. The survey remains open until 2026 to ensure a comprehensive dataset and meaningful conclusions.

Combined with literature review and the creation of a dataset of building connections and case studies, the results will inform strategies to extend the service life of timber buildings by at least 150 years and reduce their lifecycle carbon intensity. This research aims to redefine timber's role in sustainable construction, offering practical guidelines for long-lasting, low-carbon timber buildings while addressing the environmental inefficiencies of current practices.

2 Challenges of Extending the Service Life

Tall timber buildings symbolize a paradigm shift in sustainable urban construction. Prominent examples include HAUT in Amsterdam, a 21-story hybrid timber structure, and Mjøstårnet in Norway, an 18-story glulam tower, both of which highlight the viability of engineered timber in achieving ambitious height while minimizing environmental impact. These buildings serve as benchmarks for sustainable design, leveraging engineered timber's lower carbon footprint compared to traditional materials like steel and concrete. These structures serve as benchmarks, yet ensuring their long service life and addressing their end-of-life (EoL) scenarios are vital to realizing timber's full environmental benefits.

2.1 Load-Bearing Capacity Over Time

Tall timber buildings endure higher vertical and lateral loads due to increased height and mass. Over time, these stresses can cause structural creep and deformation in timber components. Hybrid construction, such as the use of concrete cores in HAUT, mitigates these challenges by enhancing stability and load distribution. Also, tall structures are more exposed to strong winds, requiring advanced lateral bracing and connection systems.

In seismic regions, earthquake resistance must also be considered in the structural design of tall timber buildings. While engineered timber systems like CLT and glulam perform well in absorbing seismic energy due to their flexibility and low mass, seismic loads introduce complex lateral forces that require robust connection detailing, ductility, and energy dissipation capacity. Hybrid designs with concrete cores or steel reinforcement can improve seismic performance, but they may also affect circularity and end-of-life strategies.

2.2 Environmental Exposure and Fire Safety

Timber's susceptibility to moisture and water ingress can lead to swelling, shrinkage, and decay. Effective detailing, such as moisture barriers and well-sealed joints, is critical to preventing degradation. A moisture management plan is essential in timber buildings. A moisture management plan integrates design, material selection, construction, and maintenance to control moisture ingress and accumulation. Architectural strategies include overhangs, rain screens, and site drainage, while pre-dried, treated timber and vapor-permeable membranes enhance durability. Construction best practices, such as weather protection and sealed joints, minimize exposure. HVAC systems, dehumidifiers, and sensors regulate indoor humidity, preventing mold and swelling. Routine inspections, sealant reapplications, and moisture testing ensure long-term performance, mitigating decay and structural risks.

Prolonged exposure to sunlight and UV Radiation accelerates weathering and weakens timber surfaces. Protective coatings and regular maintenance are required to counteract this issue.

Fire safety is a critical concern for tall timber buildings. Products like cross-laminated timber (CLT) exhibit predictable charring behavior, but achieving compliance with stringent fire codes necessitates additional fire-resistant layers or encapsulation.

2.3 End-of-Life Scenarios

In Europe, over 75% of timber waste is incinerated or landfilled, and most recycling efforts result in material downgrading rather than high-value reuse [2]. A timber building designed with poor disassembly potential will have higher embodied GHG emissions than a design optimized for recovery and reuse [7]. This highlights the need for improved end-of-life strategies to maximize the utility and carbon sequestration potential of timber. Designing for deconstruction (DfD) with reversible connections and modular components enables the reuse of timber compnents in new construction, reducing environmental impact and promoting circularity [8]. Advanced lifecycle assessments (LCA) that include deconstruction and recycling pathways can better inform planning and design phases.

2.4 Importance of Addressing these Challenges

Extending the service life of tall timber buildings is crucial to their sustainability and lifecycle performance. Current lifecycle assessments often limit predictions to 50 years, yet evidence suggests that with proper interventions, timber structures can surpass 150 years of service life. Key strategies include:

- **Monitoring and Maintenance**: IoT-enabled sensors, such as the WM1 moisture monitoring system, provide real-time data to address structural risks preemptively [9]. See Sect. 2.2.
- **Circular Design**: Incorporating end-of-life scenarios into the initial design phase, such as modular construction and material recovery strategies, ensures that timber components retain value beyond their initial use.
- **Policy and Guidelines**: Clear standards for durability, fire safety, and deconstruction will drive adoption and ensure the long-term viability of tall timber buildings.

By addressing these technical and environmental challenges, tall timber buildings can achieve the durability and low carbon intensity needed to meet the demands of modern urban development. This research under COST Action HELEN contributes to identifying practical, scalable solutions for sustainable timber construction.

3 Survey Methodology and Results

The research employed a mixed-methods survey approach, integrating closed-ended and open-ended questions to comprehensively collect data on the service life of components used in medium-rise (3–8 stories) and tall (above 8 stories) timber buildings. The survey aimed to define the actual service life of key building components, including structural components, envelope components, and connection systems.

3.1 Survey Design and Objectives

A pilot study involving 12 timber construction experts was conducted in September 2023 to ensure clarity and relevance. The pilot validated the survey's design, ensuring that the questions were appropriately formulated and aligned with the study's objectives. Based on the feedback, minor adjustments were made before the full-scale launch.

The finalized survey, designed to be concise and accessible, was distributed in English and targeted architects, engineers, and industry professionals globally. Recruitment leveraged the COST Action HELEN network, employing snowball sampling techniques and LinkedIn announcements to reach potential participants. Specific outreach included professionals attending the Holzbau conference and experts familiar with timber construction across Europe, North America, and Australia. The survey featured a detailed questionnaire asking participants to estimate the lifespan range (minimum and maximum years) for various timber components without differentiating between specific timber materials (https://form.jotform.com/232473794563365). Assessed components included structural components such as timber columns, beams, and panels; envelope components like wall claddings, waterproofing layers, and insulation materials; and interior finishes such as plasterboards, floor finishings, and glazed products. Participants could leave fields blank for components they lacked experience or knowledge about, ensuring the data collected was both accurate and focused.

3.2 Key Findings

The survey, completed by over 120 participants from Europe, North America, and Asia, revealed significant insights into the service life of tall timber building components. The aggregated responses suggest that taller timber buildings can achieve a lifespan exceeding 150 years, with some components potentially lasting up to 300 years under optimal conditions, as shown in Fig. 1. Timber columns, beams, and solid panels demonstrated high durability, with life expectancy often surpassing 150 years when properly maintained. External timber claddings and coatings showed shorter lifespans, typically ranging from 50 to 75 years due to environmental exposure, while the performance of waterproofing layers and insulation materials varied depending on material type and maintenance practices. Interior finishes, such as plasterboards and floor finishes, were identified as requiring periodic replacement, with average lifespans between 50 and 70 years. The survey also highlighted region-specific challenges, including climate-related impacts in humid or arid regions, underscoring the critical importance of regular maintenance to extend the service life of these components.

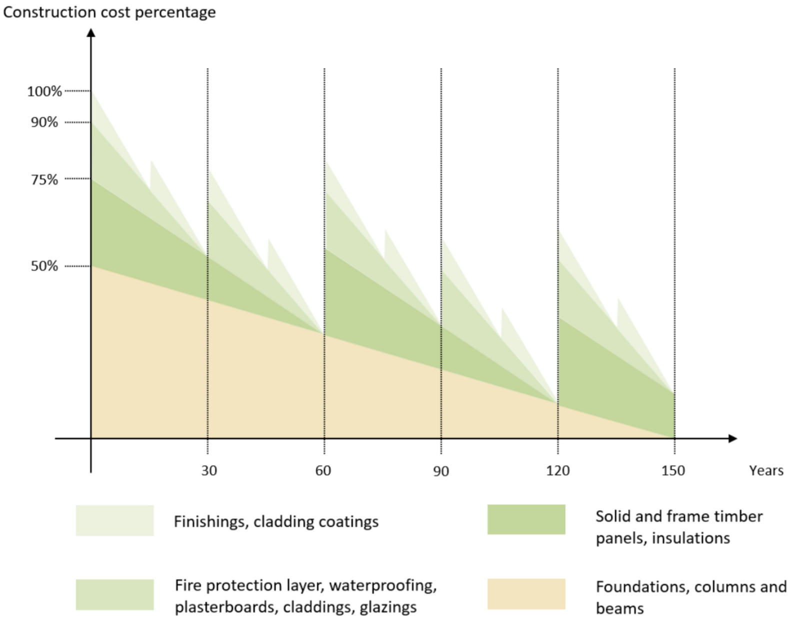

Fig. 1. Tall timber building components expected life span

3.3 Validation and Dissemination

Eight timber construction experts were interviewed in-depth to validate the findings, focusing on their interpretations of the survey data and practical implications for design and maintenance. Additionally, the initial results were shared during an international webinar in October 2023 [10], where industry professionals provided further feedback and discussed the potential applications of the findings.

4 Strategies for Achieving a 150-Year Lifespan in Tall Timber Buildings

4.1 Material Innovations

Engineered timber products such as Cross-Laminated Timber (CLT) and Glued Laminated Timber (glulam) are revolutionizing the construction of tall timber buildings. These materials are designed to provide exceptional structural performance, enabling timber to replace carbon-intensive materials like concrete and steel in high-rise applications. CLT, for instance, combines layers of wood arranged perpendicularly and bonded with adhesives, offering high strength and stability, even for tall structures.

Despite these advancements, challenges remain in achieving long lifespans for timber in demanding environments. Timber's susceptibility to fire, moisture, and decay necessitates innovative treatments. Protective coatings enhance fire resistance by slowing charring rates, while moisture barriers and UV-blocking finishes mitigate environmental degradation. However, as building heights increase, hybrid systems integrating concrete or steel become essential. While these materials improve load-bearing capacity, fire resistance, and stability under lateral forces, they also offset some of timber's environmental advantages, posing a trade-off in lifecycle carbon intensity.

4.2 Structural Design Strategies

Modular and prefabricated construction methods enhance the precision and efficiency of tall timber projects. Prefabricated components, such as CLT panels, can be manufactured off-site to exact specifications, reducing construction waste and time. Modular systems also facilitate adaptability, allowing easier maintenance and potential reuse of timber components. However, taller buildings face unique structural challenges. Increased exposure to wind and seismic forces requires robust design solutions. Hybrid systems combining timber with concrete or steel cores are critical for ensuring lateral stability and mitigating vibrations. While these approaches enhance structural integrity, they introduce higher embodied carbon compared to all-timber designs. Projects like HAUT in Amsterdam demonstrate how balancing these trade-offs can achieve both performance and sustainability goals.

In conclusion, the integration of material innovations and hybrid systems addresses the limitations of timber in tall structures, ensuring longer lifespans and enhanced safety. However, the environmental trade-offs of incorporating concrete and steel highlight the need for ongoing research and innovation to optimize sustainability in tall timber construction.

5 Circularity and End-of-Life Strategies for Tall Timber Buildings

The design of tall timber buildings must prioritize circular construction principles to maximize material reuse and minimize waste. Reversible connections and modular components facilitate disassembly, preserving timber's value for repurposing in future projects [11]. However, not all timber buildings and connections can be dismantled in practice. Demolition contractors report that screw, nut, and bolt connections frequently deform, making disassembly difficult and limiting material recovery. Our database on demountable connections supports this finding, indicating that most timber connections are not easily reversible, emphasizing the need for improved fastening systems and alternative connection methods to enhance reuse potential [12]. While residual materials can support energy recovery, optimizing connection design remains crucial to reducing reliance on virgin materials and lowering lifecycle emissions. Lessons from projects like HAUT demonstrate the economic and environmental advantages of integrating circularity in tall timber construction [13] reinforcing timber's role in sustainable building practices aligned with global carbon reduction goals [14].

6 Conclusion

Tall timber buildings represent a promising solution to the environmental challenges of urban construction. Achieving a 150-year lifespan requires integrating durable materials, advanced structural designs, proactive maintenance, and predictive planning. Interdisciplinary collaboration and the adoption of circular principles are essential for maximizing the environmental and economic benefits of these structures. The findings from this research emphasize the potential of tall timber buildings to serve as long-lasting, low-carbon alternatives to traditional construction methods. By prioritizing sustainability at every stage, the construction industry can redefine its approach to urban development and pave the way for a greener future.

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