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GREY ZONES: UNVEILING CHALLENGES AND SOLUTIONS IN DESIGNING, PLANNING, AND CONSTRUCTING WOODEN BUILDINGS FOR DEVELOPING COUNTRIES.

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ABSTRACT: This article is the result of the systematic registration and identification of the so-called “grey areas”, understood as sectors of an ambiguous nature in the face of the challenges and solutions in the design, planning and construction of wooden buildings for developing countries and which prevent the initiation and development of this type of projects in developing countries such as those in Latin America. Through recent architectural and engineering design work - Tamango Building, a 12-story building in wood not yet built and Piloto Tamango, a 1-story building with a LVL load-bearing structure already built in the far south of Chile - and consulting work - Roadmap for Social Housing in Wood in Uruguay and evaluation of new projects for an important local mass timber industry - it was possible to carry out a survey of current practices in this region of the planet - with problems regarding construction productivity and strong challenges around sustainability goals for the coming years - delivering a diagnosis that identifies key actions and a realistic path to be followed specifically by professional offices, through the development of the so-called "Digital Twin".

KEYWORDS: Wood Buildings, Real Estate Development, Design for Manufacturing and Assembly.

1 – INTRODUCTION

Over the past two decades, timber construction has experienced steady global growth, driven by the urgency to meet sustainability goals and improve productivity in the building industry. Regions such as Europe and North America have made significant progress in incorporating technologies such as cross-laminated timber (CLT), glued laminated timber (glulam), and laminated veneer lumber (LVL) in mid- and high-rise buildings [1]. However, in Latin America and other developing countries, this progress has been considerably slower, despite the availability of natural resources, emerging technical capacities, and a clear need for sectoral transformation.

In this context, the use of advanced digital models—or “digital twins”—has proven to be a crucial strategy for efficiently integrating design, manufacturing, and assembly decisions, maximizing the benefits of industrialization. As Ott et al. state, the dynamic visualization of material flows from forest to building improves not only product traceability but also reduces environmental impact and enhances cross-disciplinary coordination [2].

International experience shows that prefabrication methods applied to timber construction can increase productivity by up to 30% and significantly reduce construction timeframes, as seen in Swedish projects executed between 2014 and 2018. These figures are especially relevant in contexts where the inefficiencies of traditional linear design–bid models compromise the economic viability of projects (fig 1) [3].

Cases like the SporX building in Norway illustrate the tangible benefits of integrating high-resolution BIM models (LOD400) with digital twins from the early stages. In this 10-story timber building, construction quality was improved, on-site errors were reduced, and high efficiency standards were met, demonstrating the

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effectiveness of "building before building" through comprehensive digital simulations [4].

In light of this, key questions arise for Latin American countries: What factors are delaying the adoption of these models in our region? Why, if the technological challenges are similar, are the outcomes so different? What regulatory, technical, and management gaps must be addressed to make medium- and high-rise timber buildings a reality?

This article proposes a structured response to these questions by systematizing the obstacles as "grey zones" and offering strategies to overcome them. The objectives are:

- To identify and classify the grey zones that hinder the design and construction of timber buildings in developing countries.
- To propose action strategies for architectural offices and real estate developers interested in effectively incorporating timber technologies.
- To assess the potential of the "Digital Twin" as an enabling tool to anticipate and resolve complex issues in industrialized construction.

The work is based on real-world projects led by the authors: the Tamango Building (12 stories, in design stage), the Tamango Pilot (1-story structure built in southern Chile using structural LVL), the Roadmap for Timber Social Housing (consultancy in Uruguay), and technical advisory for mass timber companies in Chile. These experiences reveal that the barriers are not only technological but also cultural, institutional, and contractual. Overcoming them requires not only technical innovation but also a reconfiguration of real estate development models toward collaborative, traceable, and digitalized frameworks.

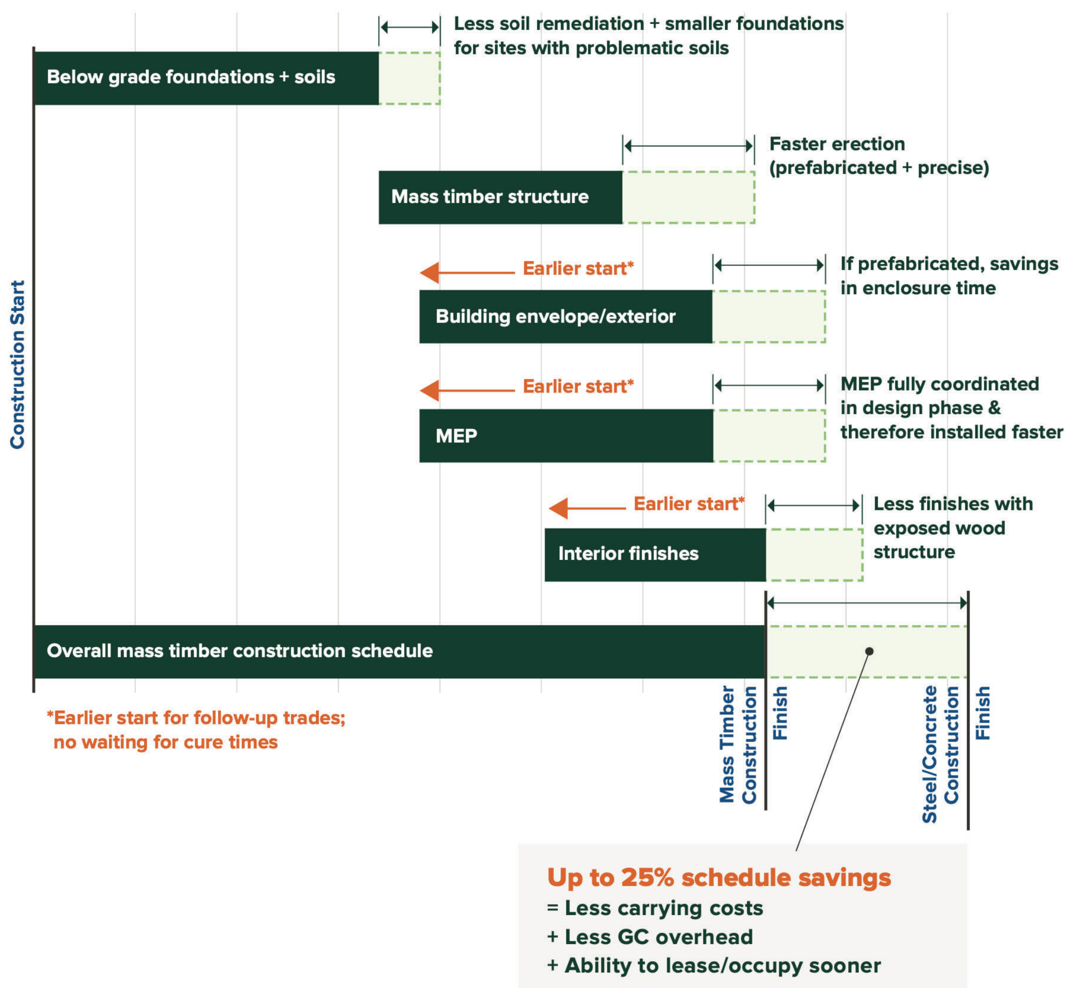

Figure 1. Compressing the Typical Construction Schedule with Mass Timber. Wood Works

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2 – METHODOLOGY

This research adopts a qualitative applied approach, based on the analysis of real-world experiences in design, consulting, and construction of timber projects in Latin America. The methodology combines three main components:

- Empirical fieldwork: through the direct participation of the authors in key projects: Tamango Building (12 stories, Chile), Tamango Pilot (1 story, southern Chile), Roadmap for Timber Social Housing (consultancy, Uruguay), and advisory work for an industrial timber company in Chile.
- Systematization of practices, barriers, and opportunities: through document review of regulations and contractual models, and analysis of developed BIM models.
- Comparison with international guidelines: particularly the design and cost optimization checklists for industrialized timber structures developed by WoodWorks, as well as references to benchmark international projects.

The intersection of these three dimensions—professional practice, technical analysis, and international comparison—enables the construction of a comprehensive view of the structural challenges affecting timber construction in developing countries and the proposal of viable recommendations based on real case studies.

The relevance of this strategy is reinforced when compared to international benchmarks. Projects such as Ascent (USA), Brock Commons (Canada), Mjøstårnet (Norway), or social housing developments in Barcelona show how the articulation of design, engineering, and manufacturing can translate into time savings, CO_2 emissions reductions, efficient use of local resources, and near-zero waste. In all these examples, early integration (fig 2) was key to making timber construction technically and economically viable in complex urban settings.

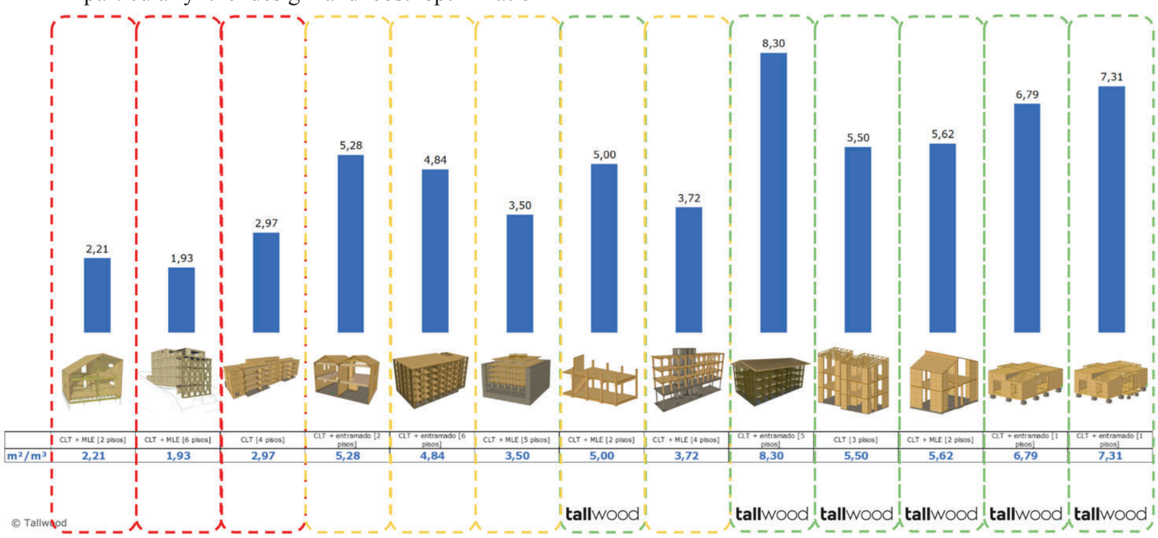

Figure 2. Structural efficiency resulting from the early integration and joint work between architecture and engineering.

3 – CASE STUDIES: REAL PROJECTS AND CONSULTANCIES

The joint work between architects, structural engineers, and technical advisors—both national and international—has enabled the systematization of specific processes and typologies across diverse contexts, from single-story rural housing to six-story office buildings. This approach led to a key distinction: "timberizing" a pre-existing design is not equivalent to "designing in timber." The former involves adapting conventional solutions to a new material, while the latter requires embracing the structural logic, modulation, connection systems, and prefabrication strategies inherent to Mass Timber from the outset.

The development of multiple projects—such as the Tamango Building in Coyhaique—has created a valuable empirical foundation for evaluating structural combinations (CLT, MLE, light-frame) and defining optimal height ranges for each. Simultaneously, a technical catalog of connectivity solutions (wood-wood, wood-concrete, wood-steel) has been consolidated, enabling precise structural and construction-oriented design.

3.1 TAMANGO BUILDING (12 STORIES)

This project, currently in development in Chile, proposes a mixed CLT and LVL structure to reach 12 stories in height, which would make it one of the tallest timber buildings in Latin America. The case has highlighted key

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constraints: the lack of national technical regulations for tall timber buildings, the shortage of suppliers with continuous industrial production capacity, and the urgent need to establish contractual models that fairly compensate early investments in digital coordination and advanced design [5].

3.2 TAMANGO PILOT (1 STORY)

Executed in southern Chile, this prototype module validated critical variables: assembly times, LVL structural behavior, specialty coordination, construction tolerances, and finishes. The project demonstrated that prefabrication is feasible, but it requires detailed BIM modeling from early stages and rigorous coordination between architecture, engineering, and manufacturing (fig. 3).

3.3 ROADMAP FOR TIMBER SOCIAL HOUSING IN URUGUAY

As part of a consultancy for the Uruguayan government, a national diagnosis was carried out to determine the conditions required to scale up timber social housing. Significant barriers were identified in the areas of regulation, certification, industrialization, and technical training. The study proposed a sequence of strategic actions, including pilot projects, regulatory adaptation, and the strengthening of institutional capacities [6].

3.4 ADVISORY FOR INDUSTRIAL TIMBER COMPANY IN CHILE

This effort involved the technical and strategic evaluation of timber building projects developed abroad, aiming to adapt them to Chile's production capacities and current regulations. The experience revealed challenges in component standardization, early-stage alignment between design and manufacturing, and the need to adjust commercial strategies to local regulatory frameworks

Figure 3.Tamango Pilot.

4 – RESULTS: IDENTIFICATION OF GREY ZONES.

The analysis identified four main categories of grey zones that hinder the development of industrialized timber projects in developing countries:

4.1 EARLY INTEGRATION

One of the main contributors to grey zones is the disconnect between architectural design and engineering development. When these disciplines operate sequentially or in isolation, the resulting solutions tend to be inefficient, costly, or incompatible with the advantages offered by Mass Timber.

In response, Tallwood’s experience in the Chilean context proposes a clear methodological strategy: bring architecture and engineering together from the early stages, establishing sustained interdisciplinary collaboration oriented toward execution. Integrated design is a condition for reducing grey zones.

4.2 PRODUCTIVITY

These limitations result in inefficient processes, higher costs, and a loss of competitive advantage:

- Lack of integration between design, manufacturing, and assembly phases.
- Absence of collaborative planning from early project stages.
- Lack of coordinated digital models to anticipate errors and precisely plan construction processes.

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recognize the value of digitally intensive design, and transfer time savings to developers:

- Misalignment between those who invest in detailed design and those who reap economic benefits (e.g., in time and assembly savings).
- Contractual models that do not recognize or compensate the complexity of design for prefabrication.
- Financial risk for professionals who develop advanced models without guaranteed returns.

The development of a Digital Twin becomes essential: it integrates architecture, engineering, manufacturing, and assembly by generating all plans and files from a coordinated 3D model (Fig. 4).

Ultimately, implementing industrialized timber projects in emerging countries requires transforming not just technical tools, but also incentive structures, contractual frameworks, and project culture

4.3 SUSTAINABILITY

The following limitations prevent the full use of timber's advantages in embodied carbon, energy efficiency, and material traceability:

- Poor incorporation of life-cycle criteria in architectural design.
- Difficulties in quantifying the environmental benefits of structural timber.
- Lack of economic or regulatory incentives to promote low-impact solutions

4.4 BUSINESS MODEL

The traditional "Design–Bid–Build" model does not align with industrialized construction logic, which requires early decision-making. New business models must ensure a fair and traceable distribution of benefits,

Figure 4. Digital Twin of Tamango Building

5 – CONCLUSION

The systematized experience from the design of the Tamango Building, the execution of the Tamango Pilot, and various advisory projects in Chile and Uruguay confirms that the benefits of industrialized timber construction—productivity, sustainability, and quality—only materialize through structural transformation of the project process. This transformation involves adopting advanced digital tools (such as the Digital Twin), engaging all stakeholders early, and redefining business and contractual models.

Closer integration between architecture and engineering not only improves efficiency and quality in Mass Timber projects but also acts as a critical tool for reducing grey zones in construction. Establishing collaborative workflows from the project's inception becomes a structural condition to consolidate timber construction as a sustainable, repeatable, and technically robust solution in developing countries.

Another key element is the principle of "building before building," understood as a practice combining advanced modeling (BIM), digital machining, and industrial prefabrication. This approach was exemplified in the Tamango Building, whose development involved over 6,000 metal connectors, 339,000 screws, and nearly 3,000 structural timber elements—all defined and coordinated before construction began. Technical anticipation shortens timelines, reduces errors, and ensures project traceability.

At the same time, it becomes evident that the barriers to advancing such systems in Latin America are not merely technical. Regulatory gaps, lack of specialized technical training, cultural resistance to innovation, and inadequate contractual models all hinder effective collaboration between design, manufacturing, and construction.

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The following recommendations are proposed:

- Promote pilot projects that validate the technical and economic feasibility of tall timber or modular systems to build institutional and public trust.
- Develop specific regulations that enable and govern the design, calculation, and execution of mass timber structures, incorporating performance, life-cycle, and traceability criteria.
- Reform procurement models to favor collaborative and early investment schemes, such as Integrated Project Delivery (IPD), that fairly compensate coordinated design work.
- Encourage professional training focused on digitalization, prefabrication, and sustainability applied to timber.
- Promote the use of Digital Twins, not only as a technical tool but as a basis for traceability, transparency, and coordination throughout the construction process.

In short, developing countries have a strategic opportunity to innovate and lead from within by adopting sustainable technologies such as industrialized timber. However, this transition requires political will, investment in knowledge, and a deep redesign of the building ecosystem. Only then will it be possible to close the gaps that today constitute the "grey zones" of timber development.

The collaborative process, where architecture proposes a framework of possibilities and engineering defines the feasibility of each scenario, helps narrow down the universe of options to those that are both technically and economically viable.

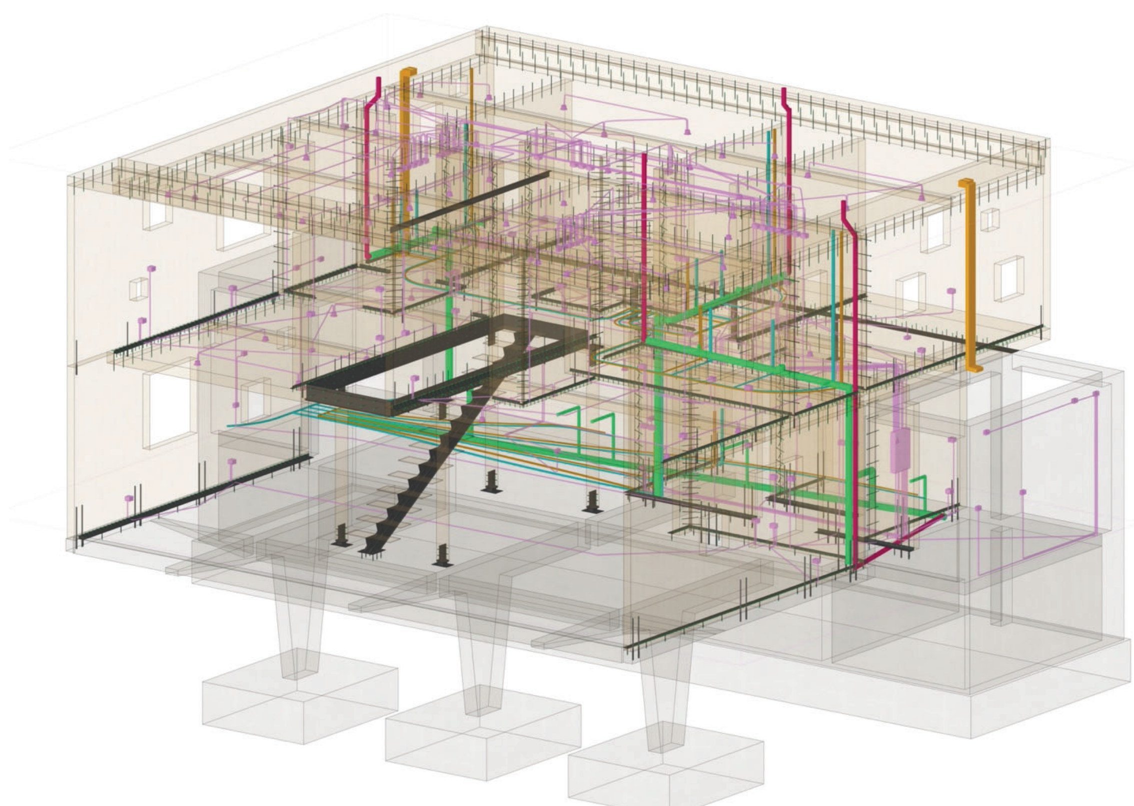

Figure 5 Example of Digital Twin with coordination of specialities developed in Tallwood.

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