

FROM WASTE TO WORTH: FEASIBILITY OF REPURPOSING CONSTRUCTION TIMBER WASTE INTO CLT-INSPIRED SUSTAINABLE PANELS IN DEVELOPING COUNTRIES

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Abstract : This study examines the feasibility of repurposing construction timber waste into Cross-Laminated Timber (CLT)-inspired sustainable panels in developing countries with an objective of transform discarded wood materials into value-added construction products. Despite the global reputation of the CLT system for their structural performance, environmental advantages, and adaptability to modern building practices, their adoption in developing regions remains minimal due to high production costs, limited local manufacturing capacity, and low awareness of engineered timber technologies. A comprehensive review of CLT manufacturing principles, structural properties, and international adoption trends is undertaken alongside an assessment of timber waste generation practices in developing countries. Potential of repurposed timber waste, such as plywood and other wood-related products, as an alternative raw material to CLT-inspired panels is critically reviewed. This paper also examines the technical, environmental, and practical conditions that constitute the viability of such initiatives, with a focus on their adherence to the principles of the circular economy and sustainable development of construction objectives. The results show that timber waste can be reformed into engineered panels through proper processing, including material selection, quality standardization, and policy support. This approach will lead to significant environmental, economic, and social benefits for the construction industry in developing countries.

Keywords: *Plywood waste, Cross-laminated timber (CLT), Developing Countries, Circular economy, Waste reuse*

1. Introduction

The construction industry is one of the most significant consumers of natural resources and a significant generator of timber waste, which is mostly disposed of in landfills or downcycled into low-value products which accelerates the environmental and economic challenges in developing countries (Ghobadi & Sepasgozar, 2023; Vamza et al., 2021). According to Ahn et al. (2022), Addressing this issue requires innovative approaches that align with sustainable development goals and Circular Economy (CE) principles which focus on the reuse, recycling, and reintegration of materials into production cycles. Moreover, CE enhances resource efficiency and reduces environmental impacts with the help of material loop closure, as well as promoting sustainable development (Ahmed et al., 2022; Ngan et al., 2019).

Cross-laminated timber (CLT) is one of the brightest engineered wood products of the construction industry since it is strong, versatile, and sustainable (Harte, 2017; Jahedi et al., 2024). Moreover, CLT has emerged as a sustainable construction material that has proven to provide advantages such as structural strength, low carbon footprint, and design flexibility (Vamza et al., 2021). However, adoption of CLT is limited in developing countries due to the high cost of production, lack of manufacturing infrastructure and lack of technical expertise and awareness about engineered timber solutions (Ahn et al., 2022; Benedetti et al., 2022; Ilgin et al., 2023; Ilgin & Karjalainen, 2023)

Integrating CE strategies such as recycling timber waste into CLT-inspired panels can significantly reduce environmental impacts, with studies showing that recycled CLT can lower life cycle impacts by 50–80% compared to virgin materials (Vasuks et al., 2025). According to Vamza et al. (2021), the feasibility of the repurposing of construction timber waste in the form of CLT panels depends on technical, environmental and economic factors, including costs of production, energy consumption and mechanical characteristics of recycled materials. Furthermore, design innovations, such as modular construction and interlocking connections, further enhance material circularity by enabling rapid assembly, disassembly, and reuse, supporting closed-loop systems and future autonomous construction (Z. Li et al., 2024). Ultimately, CE principles adopted in timber construction in developing countries offer a practical pathway to sustainability and resource efficiency while overcoming barriers to CLT adoption requires targeted innovation, capacity building, and supportive policy frameworks (Ahn et al., 2022; Ghobadi & Sepasgozar, 2023).

This study examines the potential to improve the viability of CLT-inspired technology implementation in developing nations through CE ideas, particularly the possibility of repurposing construction timber waste to create CLT-inspired sustainable panels. Despite the rapid pace of research on engineered timber and CLT worldwide, a significant gap remains in how developing nations can implement these systems using locally available waste timber instead of imported materials

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at high costs. The identified gap makes the key research question as follows: To what extent can the timber waste of constructions be recycled to CLT-inspired panels to facilitate CE meeting sustainable construction in developing countries? The review responds to this by reviewing the available literature on the extent of timber wastage during the construction process, the possibility of reclaiming the discarded wood-based materials, and technical, environmental, and economic factors affecting the feasibility. By synthesizing these findings, the study establishes a clear pathway for advancing waste-derived timber innovation within CE frameworks and delivers actionable, context-specific guidance to enable developing countries to adopt and scale CLT-inspired waste-repurposing strategies in their construction sectors.

2. Research Methodology

The main question of this research is the following: To what extent can the timber waste of constructions be recycled to CLT-inspired panels to facilitate CE meeting sustainable construction in developing countries? It was conducted as a narrative literature review since it allows combining various findings of construction, materials engineering, and sustainability disciplines, which is suitable for a new topic where not much research is standardized. It is the academic journals, conference papers, books, industry reports, and reliable electronic databases that were used as sources of secondary data because of their relevance to CLT systems, their use across the world, and the practices of timber waste generation and reuse. Synthesis of technical, environmental, and economic findings was done in order to determine feasibility, which offered a systematic base to determine opportunities and constraints that could be used in developing countries.

3. Literature Review

3.1 CONSTRUCTION TIMBER WASTE

Timber waste in construction occurs in various stages of operations spanning from cutting and sizing, which result in the creation of offcuts and irregular pieces (Zyryanov & Medvedev, 2024), to demolition and renovation works that generate contaminated or weathered wood (Graham, 2022). Moreover, engineered wood cuttings and logging residues among other polluted timber are difficult to recycle since they enshrine timber as an important waste stream in the construction sector (Kuzmenkov et al., 2023). However, extensive construction activities in developing countries generate large volumes of timber waste with poor management practices leading to environmental and economic concerns, mirroring global trends in construction waste generation and disposal (Daniel, 2023; Jonathan & Onyoni, 2025; Wu et al., 2025). Table 1 presents the main sources of timber waste in the construction industry as identified in previous literature,

Table 1: Sources of Timber Waste

Source of Timber Waste	Description	Citations
Processing Offcuts & Short Elements	Waste generated from cutting timber to size, including non-standard, short, or irregular pieces that cannot be reused directly.	(Kuzmenkov et al., 2023)
Demolition and Deconstruction Waste	Timber recovered from building demolition, often in varied conditions (e.g., weathered, broken, contaminated, or infested).	(Graham, 2022; Rose & Stegemann, 2019)
Formwork and Scaffolding	Temporary timber structures (e.g., shuttering boards, scaffolding poles) discarded after use, often deformed or damaged.	(Kuzmenkov et al., 2023)
Sawmill By-products	Sawdust, bark, slats, and slabs produced during primary wood processing, often burned or landfilled if not reused.	(Kuzmenkov et al., 2023; Zyryanov & Medvedev, 2024)
Packaging and Transport Materials	Pallets, crates, and containers used for transporting construction materials, typically discarded after single use.	(Kuzmenkov et al., 2023)
Engineered Timber Waste	Waste from engineered products such as particleboard, MDF, and plywood, which are difficult to recycle due to adhesives and treatments.	(Graham, 2022; Kuzmenkov et al., 2023)
Contamination and Quality Issues	Timber is often contaminated with nails, paints, plastics, or affected by insects and fungi, reducing reuse potential.	(Graham, 2022; Kuzmenkov et al., 2023)

The nature of this waste and its form, origin, and level of contamination ultimately influences both its recovery potential and environmental impact where poor management can harm ecosystems and intensify climate change whereas proper valorisation can reduce these effects (Graham, 2022; Kuzmenkov et al., 2023; Zyryanov & Medvedev, 2024). However, the most common forms of timber waste are frequently managed through practices such as open dumping and burning which

contribute significantly to air and water pollution as well as greenhouse gas emissions (Arquiñigo et al., 2021). Table 2 presents the common disposal methods of timber waste and their associated environmental impacts highlighting the consequences of such practices.

Table 2: Disposal methods and their Impacts

Main Source	Common Disposal Method	Environmental Impact	References
Sawmills	Dumping, burning	Air/water pollution, GHG emissions	(Erni et al., 2020; Nnaji & Udokpoh, 2022)
Construction, processing	Dumping, limited reuse	Resource loss, landfill pressure	(Graham, 2022a; Nnaji & Udokpoh, 2022)
Building demolition	Landfill, incineration	Toxin release, soil/water pollution	(Graham, 2022; Koyano et al., 2019)
Demolition, old structures	Landfill, incineration	POPs/metals leaching, health risks	(Koyano et al., 2019)

However, adopting CE approaches such as reuse, recycling, and cascading utilization can minimize waste, extend material life cycles, and promote sustainable construction practices (Jahan et al., 2022; Kiesnere et al., 2024; Tanthanawiwat et al., 2024).

3.2 CIRCULAR ECONOMY AND SUSTAINABLE CONSTRUCTION PERSPECTIVES FOR CONSTRUCTION TIMBER WASTE

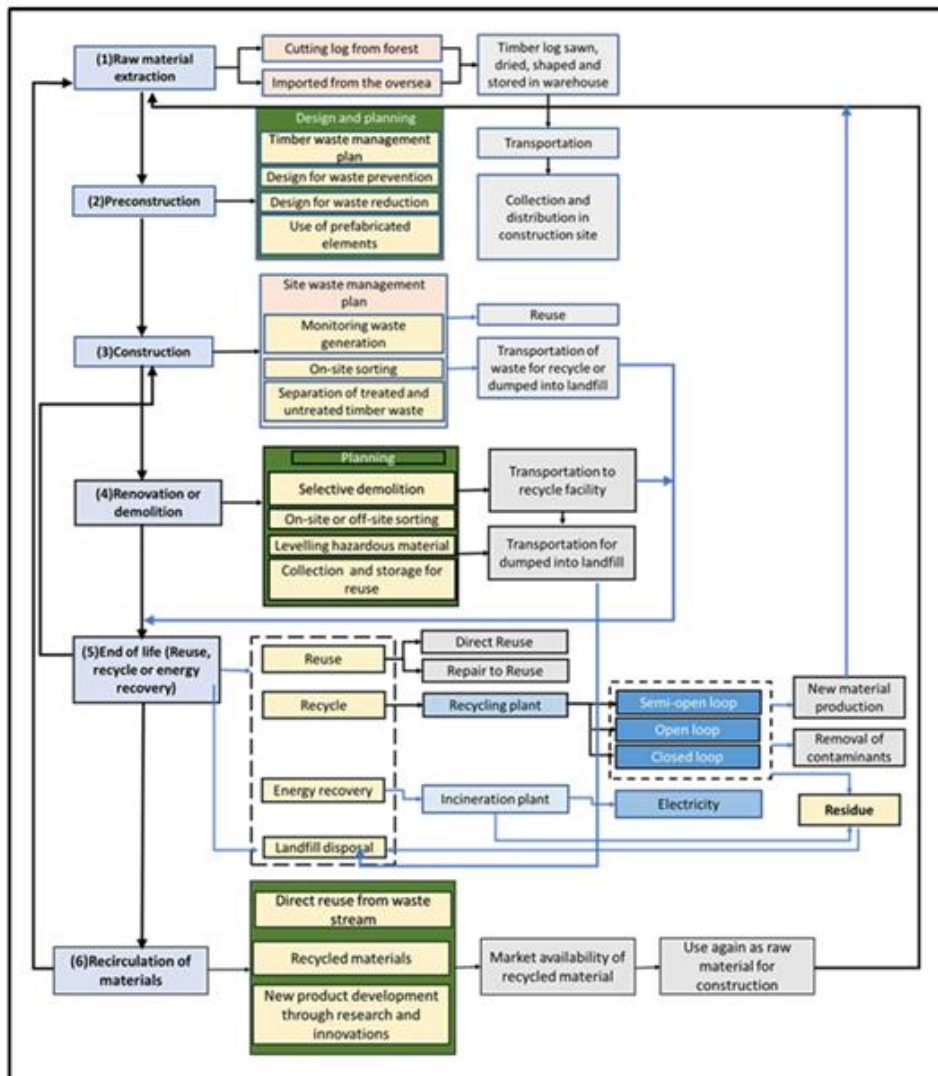


Figure 1: Framework for Life Cycle Stages of Cdw Toward a Circular Economy (Source:Jahan Et Al., 2022))

The construction sector generates substantial volumes of timber waste and integrating CE principles such as recycling, reuse, and eco-design can significantly reduce environmental impacts and stimulate innovation and economic growth (Jahan et al., 2022; Ogunmakinde et al., 2022). However, applying CE principles to construction and demolition wood waste enables resource recovery and high value product creation but further research is needed to integrate economic and social aspects across all life cycle stages (Jahan et al., 2022). Moreover, according to Ghobadi & Sepasgozar (2023), modern timber construction benefits from CE strategies such as prefabrication, modular design, and design for deconstruction, which facilitate the reuse and recycling of timber elements and enhance the circularity of building materials throughout their life cycle. Nevertheless, despite these advantages, there are several barriers to their widespread adoption such as the inclusion of insufficient regulatory frameworks, the lack of established supply chains for reclaimed timber, technical challenges in terms of the separation of the material, and a lack of stakeholder awareness, all of which hinder the widespread adoption of CE in timber construction (Ahn et al., 2022). Additionally, comprehensive literature reviews reveal that the construction industry has been slow to fully embrace CE principles, with most research focusing on waste valorization and promotion of CE, while areas such as design, manufacturing, and end of life management remain understudied, highlighting the need for more holistic and lifecycle-based approaches (Chen et al., 2022; Çimen, 2021). As a result, policy support, stakeholder collaboration, and investment in advanced recycling processes and digital tools are essential for scaling up CE practices and achieving sustainable construction outcomes (Chen et al., 2022).

According to Figure 1, the management of construction and demolition wood waste (CDWW) covers the entire life cycle of buildings, combining waste prevention, on-site sorting, selective demolition, reuse, recycling and energy recovery. It advocates a closed loop approach in accordance with CE principles to reduce landfill disposal and maximise the recirculation of materials for new product development. Nevertheless, using these CE approaches to reuse timber waste for producing CLT panels is a sustainable practice that can be effectively applied in developing countries offering reduced environmental impacts and resource efficiency (Balasbaneh et al., 2025; C. M. Rose et al., 2018; Vasuks et al., 2025).

3.3 CROSS-LAMINATED TIMBER (CLT) SYSTEMS

Cross-laminated timber (CLT) has emerged as one of the most prominent engineered wood products in modern construction due to its strength, versatility, and sustainability (Harte, 2017; Jahedi et al., 2024). Moreover, structural performance of CLT is attributed to its orthogonal laminar structure where sequential layers of timber boards are placed at 90 degrees to one another which enhances dimension stability and ensures effective load distribution in both in and out of plane directions (Jahedi et al., 2024; Lum et al., 2021). However, the CLT manufacturing process starts with lumber grading which may be achieved through visual inspection, density-based grading or ultrasonic methods to ensure the quality and uniformity of boards (Li H., et al., 2021). Liao et al. (2017) and Baño et al. (2018) noted that adhesive selection is a crucial step in the production and polyurethane and emulsion polymer isocyanate adhesives are widely used due to high bond strength and long-term durability. Figure 2 from Lum et al. (2021) illustrates the schematic diagram for typical CLT manufacturing processes.

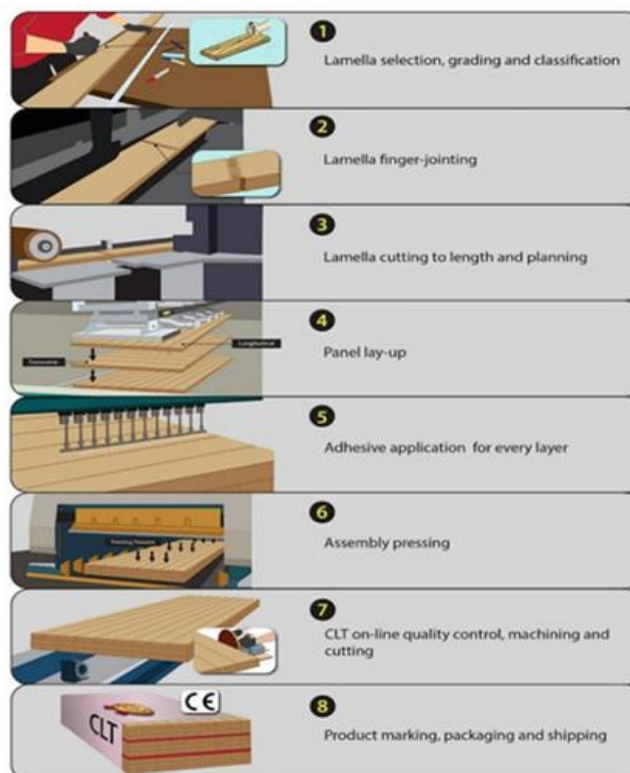


Figure 2: Schematic diagram for typical CLT manufacturing processes (Source: Lum et al. (2021))

Beyond conventional production methods, sustainability considerations have become increasingly central with recycled and secondary timber, along with production offcuts, are progressively incorporated into CLT manufacturing, aligning with CE principles and reducing the volume of timber waste entering disposal streams (Llana et al., 2022; Tuksam & Pihlak, 2024).

3.3.1 Advantages of Cross-Laminated Timber (CLT)

The environmental gain through CLT systems is significant enough to be familiar among the circles of sustainability enthusiasts, where reducing greenhouse gas emissions by a figure that can reach to 40 percent over conventional concrete and steel is observed in multi-story buildings (Jayalath et al., 2020; Lan et al., 2020; Younis & Dadoo, 2022). Moreover, the decrease is possible since CLT panels captivate and store carbon dioxide during their lifecycle and effectively transforming buildings into long term carbon sinks and helping to mitigate climate change (Lan et al., 2020). In addition, Gilbert et al. (2020) stated that that CLT can be used in urban infill construction projects where cities can incorporate more sustainable construction models because the low embodying energy and the renewable character of CLT make it supportive to eco-friendly urban development. Moreover, CLT panels have a high strength to weight ratio, which makes them applicable in mid and high-rise construction that offers both vertical and lateral load resistance and limits the necessity to use heavy foundations (Bhandari et al., 2023; Deus et al., 2024; Jayalath et al., 2020). Furthermore, the orthogonal and laminar structure of CLT makes it possible to act as full size wall and floor products and carry in and out of plane loads and have high mechanical properties than conventional timber products (Brandner et al., 2016; Deus et al., 2024; Jahedi et al., 2024; Lum et al., 2021). Nevertheless, the prefabricated quality of CLT panels make them possible to manufacture quickly offsite and to assemble quickly onsite which may save the construction time by up to half of the one of conventional reinforced concrete systems (Bhandari et al., 2023; Tažiková et al., 2024). However, economic analyses reveal that CLT buildings often have lower life cycle costs than reinforced concrete with savings realized in both construction and foundation expenses due to the lighter weight of CLT panels (Gilbert et al., 2020; Jayalath et al., 2020; Tažiková et al., 2024). Nevertheless, the potential for reuse or recycling at the end of a building life cycle further enhances the economic sustainability of CLT systems (Jayalath et al., 2020; Lan et al., 2020). Furthermore, CLT offers exceptional design versatility allowing architects to create innovative forms and exposed timber aesthetics that appeal to both developers and occupants (Bhandari et al., 2023; Espinoza & Buehlmann, 2018). Furthermore, the standardization and flexibility of CLT panels can be applied to a broad spectrum of applications including residential and institutional structures and can also be combined with other materials to make hybrid systems (Bhandari et al., 2023). Although market acceptance varies by region, increasing awareness and industry collaboration are driving broader adoption of CLT especially as sustainability becomes a priority in construction (Gilbert et al., 2020; Ilgin et al., 2023).

3.3.2 Limitations and cost challenges of CLT in developing countries

CLT is an emerging sustainable building material that is gaining popularity but facing multiple significant limitations and cost barriers to implementation in the developing markets (Benedetti et al., 2022). Furthermore, there is a lack of expertise and training among the construction professionals which limits the effective implementation of CLT in these regions (Ilgin et al., 2023). However, according to Benedetti et al. (2022) and Ilgin & Karjalainen (2023) stated that one of the foremost barriers is the high initial investment required for specialized manufacturing equipment which can be prohibitive for small and emerging markets where demand is still nascent. Moreover, the cost competitiveness of CLT is also a problem because the cost of production is generally too high and sensitive compared to the conventional materials such as concrete (Andersen et al., 2023). Nevertheless, this variability is pre-determined by such aspects as the unstable lumber prices and low production volumes that are a problem with small capacity plants (Andersen et al., 2023; Benedetti et al., 2022). However, another challenge is the absence of harmonized standards and testing protocols which complicates the use of local timber species and impedes the development of efficient connection systems for CLT assemblies (Brandner et al., 2016). However, the concentration of CLT production in a few regions such as in the northern hemisphere also limits access to affordable supply chains for developing markets resulting in higher transportation costs and reduced competitiveness (De Araujo & Christoforo, 2023). As per the literature, even though CLT has significant environmental and structural advantages, its usage in developing markets is limited by expensive entry barriers, expertise, no standards, and supply chain issues (Benedetti et al., 2022; Ilgin et al., 2023; Ilgin & Karjalainen, 2023).

Table 3: Challenges to develop CLT in developing countries

Challenge	Description	References
High initial investment	Costly specialized equipment needed for production	(Benedetti et al., 2022)
Limited expertise	Lack of knowledge and training among professionals	(Ilgin et al., 2023; Ilgin & Karjalainen, 2023)
Cost-competitiveness	Higher and more variable production costs than conventional materials	(Andersen et al., 2023)
Lack of standards	Absence of harmonized guidelines and testing protocols	(Brandner et al., 2016)

Supply chain concentration	Production and supply concentrated in a few regions, raising costs	(De Araujo & Christoforo, 2023)
Fluctuating lumber prices	Lumber cost and production volume strongly affect economic viability	(Andersen et al., 2023; Benedetti et al., 2022)

To overcome the limitations and cost challenges of CLT in developing countries, applying CE principles demonstrates the feasibility of repurposing construction timber waste into CLT-inspired panels, offering both environmental and economic benefits (Balasbaneh et al., 2025; Llana et al., 2022; Vamza, Diaz, et al., 2021).

3.4 FEASIBILITY OF REPURPOSING CONSTRUCTION TIMBER WASTE INTO CLT-INSPIRED PANELS IN DEVELOPING COUNTRIES

Repurposing construction timber waste into CLT inspired panels is increasingly viewed as a sustainable solution due to environmental and economic benefits, including a decrease in landfill waste and the implementation of cyclicity in the construction industry (Balasbaneh et al., 2025; Llana et al., 2023; C. M. Rose et al., 2018). Moreover, it was proven that it is also possible to produce CLT panels using recovered timber as a source of new timber in the studies, which showed that the static modulus of elasticity of the panel with recovered timber can be comparable to that of a new timber but the strength of bending can be slightly lower, although adequate to apply to the structure (Chúláin et al., 2023; Llana et al., 2022, 2023). Moreover, hybrid CLT panels that combine new and recovered timber have been experimented and can be proven to work just as well in terms of bending strength and stiffness further supporting the idea of incorporating waste timber into mass CLT production (Chúláin et al., 2023; C. M. Rose et al., 2018). Additionally, the reprocessing of CLT production offcuts and residues into new CLT panels has been shown to significantly reduce environmental impacts compared to traditional waste disposal with life cycle assessments indicating substantial reductions in global warming potential and embodied energy (Balasbaneh et al., 2025; Vamza, Diaz, et al., 2021). Notably, there are innovative design systems such as elementarily utilize CLT offcuts to create modular construction elements for walls, floors, and facades through maximizing material efficiency and design flexibility while aligning with CE principles (Resnais et al., 2021; Tuksam & Pihlak, 2024; Vamza, et al., 2021). Furthermore, research has explored the use of alternative waste wood sources such as coffee wood and oil palm trunk waste to manufacture CLT inspired panels while demonstrating that these panels can meet or exceed standard requirements for mechanical, acoustic, and thermal performance, thus broadening the scope of sustainable panel production beyond conventional timber sources (Srivaro et al., 2019; Vamza et al., 2021).

Moreover, the development of composite panels such as cross-laminated bamboo and timber (CLBT) further exemplifies the potential for innovative hybrid solutions that leverage both timber and alternative bio-based materials to enhance sustainability and performance in construction applications (Shan et al., 2023; Srivaro et al., 2019). Nevertheless, Dong et al. (2024) and C. M. Rose et al. (2018) stated that the concept of cross-laminated secondary timber (CLST) has been introduced to upcycle a wide range of secondary timber sources into CLT-inspired products for mainstream construction with studies confirming its technical feasibility and structural performance. However, ongoing challenges such as quality control and large-scale implementation remain, highlighting the need for further research to advance CLST towards commercial application (C. M. Rose et al., 2018; C. Rose & Stegemann, 2019). Nevertheless, smaller timber elements or offcuts can also be joined with the help of finger joints, which allows creating large CLT-inspired panels out of construction waste without threats to mechanical performance (Llana et al., 2023; Muthumala et al., 2021; Resnais et al., 2021). Furthermore, finger jointed boards have been demonstrated to provide similar bending capabilities as an unjointed CLT material and in much of the weak-weak joint groups, the characteristic strength and stiffness requirements are met (Balasbaneh et al., 2025; Resnais et al., 2021).

Table 4: Timber waste into CLT-inspired panels

Panel Type	Waste Source/Material	Key Benefit	Finger Joints	References
CLT from recovered demolition timber	Demolition timber (oak, spruce)	Lower modulus of elasticity but sufficient bending strength	Yes	(Chúláin et al., 2023; Komatsu et al., 2021; Llana et al., 2022, 2023; Olsson & Abdeljaber, 2024; Perstorper et al., 2023)
Hybrid CLT panels	Mix of new and recovered timber	Equivalent bending strength and stiffness	Yes	(Chúláin et al., 2023; Komatsu et al., 2021; Olsson & Abdeljaber, 2024; Perstorper et al., 2023; C. M. Rose et al., 2018)
Reprocessed CLT from offcuts	CLT production residues	70% offcut reuse; significant environmental impact reduction	Yes	(Perstorper et al., 2023; Resnais et al., 2021; Tuksam & Pihlak, 2024; Vamza, Diaz, et al., 2021; Vessby et al., 2023)

Panel Type	Waste Source/Material	Key Benefit	Finger Joints	References
CLT from alternative waste (coffee, oil palm)	Coffee wood, oil palm trunk	Meets mechanical, acoustic, thermal standards	No	(Gutierrez et al., 2023; Srivaro et al., 2019; Vamza, Diaz, et al., 2021)
CLBT composite panels	Timber and bamboo	Enhanced insulation, carbon sequestration	No	(Gutierrez et al., 2023; Herrera Builes et al., 2025; Shan et al., 2023; Srivaro et al., 2019)
Finger-jointed CLT panels	Offcuts, small timber elements	Comparable bending strength and stiffness	Yes	(Gutierrez et al., 2023; Komatsu et al., 2021; Perstorper et al., 2023)

Table 4 and these findings collectively demonstrate that CLT-inspired panels produced from demolition timber, offcuts, and other waste wood streams offer a technically viable and low-cost alternative, particularly suited to developing countries. The integration of finger-jointing, modular fabrication, and CE principles enables efficient material recovery, reduced production expenses, and improved structural performance, making waste-derived engineered timber panels a practical and sustainable solution for resource-constrained construction environments.

From these results, developing countries could have the feasibility of adopting CLT-inspired panels manufactured from construction timber waste is shaped by several interlinked factors and the abundance of timber waste, often unmanaged or underutilized, presents a significant opportunity for value-added recovery within a circular economic framework (Jonathan & Onyoni, 2025). Reprocessing this waste into CLT-inspired panels offers potential environmental benefits such as reduced waste disposal, lower carbon emissions, and decreased reliance on virgin timber. Economically, local repurpose can reduce material import costs and stimulate new manufacturing sectors (Balasbaneh et al., 2025). However, feasibility is moderated by challenges, including limited technical expertise, lack of standardized processing facilities, restricted access to advanced adhesives and machinery, and regulatory gaps surrounding engineered wood products (Rose et al., 2018). Despite these constraints, the demonstrated structural performance of panels made from recovered timber, combined with the adaptability of finger-jointing and modular production techniques, indicates strong potential for successful implementation (Llana et al., 2023). With appropriate capacity building, investment in small-scale production technologies, and supportive policy frameworks, developing countries can effectively establish CLT-inspired systems using construction timber waste, contributing to both sustainable construction practices and broader circular economic objectives (Jonathan & Onyoni, 2025).

Figure 3 provides a conceptual framework showing the interaction of the CLT systems, timber-waste issues, and CE strategies to facilitate this transition. It demonstrates that the combination of the impact of technical performance, resource recovery, material innovation, and policy support contributes to its feasibility. The connection of these aspects makes it obvious that the scheme provides a clear picture of how the developing nations can turn the timber waste that is not managed into CLT-driven sustainable panels.

4. Conclusion

Timber waste in construction is an increasing environmental issue, although it is evident in the literature that timber waste is reused as part of the circular material flows. Recycling this waste into CLT-inspired panels is consistent with the principles of CE and converts wasted wood into products with structural value that can be used and does not rely on virgin timber. Despite its acclaimed performance in structural performance and sustainability in the world, the high costs of production, high demand of raw materials and high infrastructure requirements are some of the limitations of CLT adoption especially in developing nations. Results show that these limitations may be overcome by using recovered timber, hybrid lamination and joining such as finger-jointing, where waste wood may be used to achieve acceptable stiffness and bending characteristics. The principal novelty of the paper is that it develops a framework that is useful in advocating the application of waste-based CLT-inspired technologies in developing nations. The framework provides a facilitated timber waste recovery, mixed species preprocessing, laminating recovered materials, making a modular panel and basic quality checks. It is optimized to operate under resource-constrained environments and allows harnessing the locally accessible waste wood, which makes the CLT implementation more affordable compared to one that relies on expensive virgin materials. The framework and results allow supporting low-carbon construction by promoting the reduction of wood waste, reducing material costs, and enhancing low-waste production, as well as triggering local value chains and improving environmental performance in developing countries. However, challenges remain regarding the variability of recovered wood, adhesive behavior, long-term durability, and the absence of formal standards for waste-derived timber products. Future research should focus on pilot production in developing countries, species-independent grading systems, cost-benefit assessments, and long-term structural testing. Overall, the framework and literature together demonstrate that repurposing construction

timber waste into CLT-inspired panels presents a feasible and impactful strategy for advancing sustainable and circular construction in developing regions.

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