Global Review Research

Overview of Cross-Laminated Timber (CLT) and Timber Structure Standards Across the World

Shaghayegh Kurzinski[1], Paul Crovella, & Paul Kremer

In recent years, Cross-laminated Timber (CLT) has experienced exponential growth internationally, fostering substantial awareness and inter¬est in this renewable construction material. The increasing adoption of CLT in countries and regions of world is resulting in considerable manufacturing investment in engineered wood products more generally. Fabrication of solid timber structural systems using CLT panels requires product standards ensuring strength and stiffness characteristics of the base material in meeting rigorous performance requirements. Given that this nascent technology was only introduced within the last three decades, standards for manufacturing and design are still being developed. Indeed, multiple approaches to standards development have occurred in several regions of the world with little thought to harmonisation. This paper aims to review design standards from throughout the world for CLT and associated timber structures with recommendations towards future development of CLT standardization. For this purpose, an explanation of the general approach used by the following standards relating to CLT and timber codes is presented; Europe: EN-16351, North America: APA/PRG-320, Japan: JAS-3079, International Organization for Standardization (ISO) CLT standard: ISO 16696-1, Africa: South Africa: SANS-1783/ SANS 10163/ SABS-0163, South America: Brazil: NBR-7190, Oceania: Australia: AS-1720.1, and Asia: China: GB-50005. The current versions of each standard are briefly outlined with the related standard background. For the development of standards in those countries that are yet to adopt a CLT standard, the potential of using other existing standards has been outlined as suggestions. The present review can be a useful resource for researchers, manufacturers, companies, and investors interested in further study of a worldwide harmonized CLT standard.

Keywords: *Cross-laminated Timber, Design standard and code, Timber structures standards, Harmonized standard, Construction materials, Mass Timber.*

1.1 Fabrication

Cross-laminated Timber (CLT), a common component in Mass Timber construction, has seen a notable increase in fabrication and installation over the last two decades [1]. Regarding the ongoing global activities, CLT production volume is expected to significantly increase over the next decade [2]. CLT products allow for the use of timber in panels with dimensions larger than typical sawn lumber. CLT and Mass Timber construction are widely recognized as providing an environmentally preferable path for meeting worldwide construction demands. An additional advantage is the strength uniformity of CLT due to its defect dispersing properties, and lower variation between products from various production groups [2]. A further advantage of CLT over alternative timber products is its dimensional stability due to the crosswise structure. Each layer of timber constrains the dimensional change of the adjacent layer at right angles to it. This characteristic, known as dimensional stability, is a common issue with individual boards, due to changes in moisture content. The main steps in the production process of CLT, as shown in Figure 1, include material categorization and creative assembling to form stable composite elements using adhesive bonding.

The first step includes preparing the lumber based on the selected species and moisture content (% MC). CLT utilizes structural grade kiln-dried lumber with typical dimensions ranging from 16 to 51 mm thick and 60 to 240 mm wide (12% ± 3% MC). The planed and kiln-dried boards are graded visually or by machine according to strength or stiffness to define the design values. The outer lamellas may also be selected according to visual criteria. Also, in this step, defects with strength-reducing or unsightly growth deviations (e.g. large knots, resin pockets, bark inclusions) discovered in the lamellae during grading, are cut out depending on the strength and surface class. The process of trimming and finger jointing the lumber to obtain the desired lengths for layer construction is the next step in the actual assembly of the panel. Next, the lumber is planed on two or four sides to ensure dimensional integrity and proper adhesion. After the boards are prepared, a structural adhesive layer is added to the timber layers which are stacked in alternating directions to create the bond. Then the layers are compressed in a stack of multiple layers to create a panel. The adhesive used in CLT applications needs to meet stringent product standards. It also must comply with the manufacturer adhesive specifications. The layers are formed with adhesive surface bonding on the faces

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of the lamellae. Some panel layup configurations also include edge-gluing where adhesive is applied between the boards in a single layer. Once these steps are completed, CLT panels are ready to undergo quality control and finally customization and shipping.

timber construction (there are countries in five continents that havebuildings constructed with CLT panels). However, not all the continents have countries that have established CLT manufacturing standards. Most countries are in the process of developing a specific manufacturing standard for CLT.

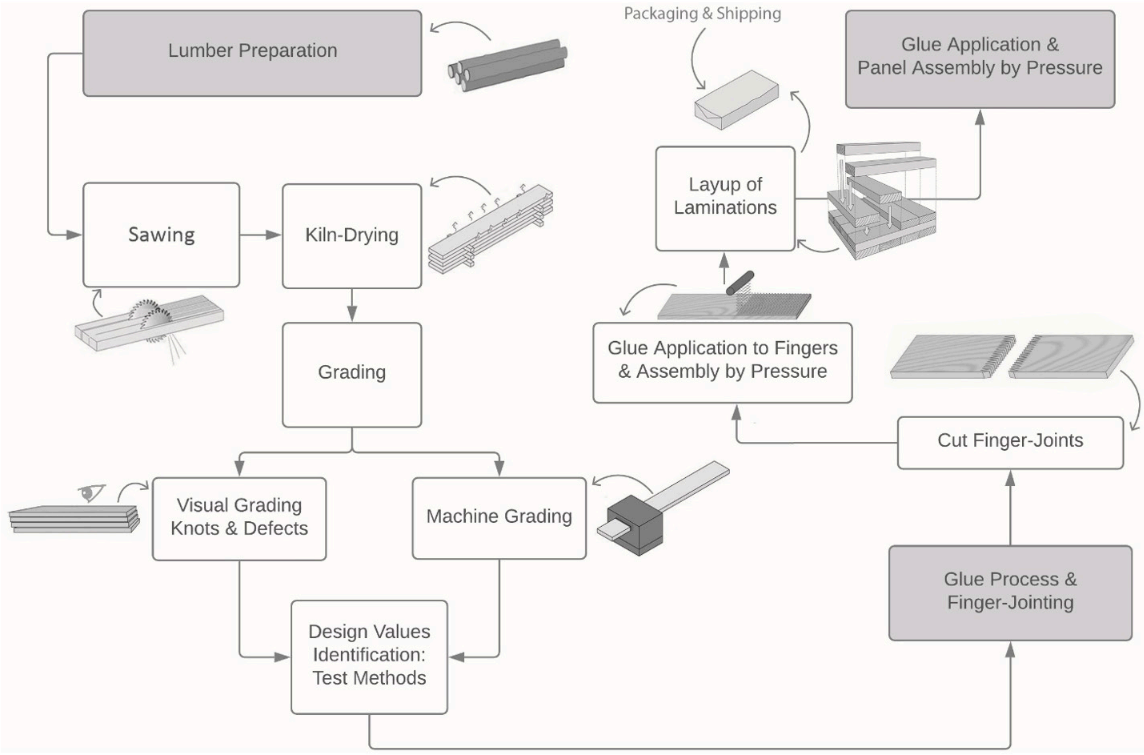

Figure 1. Basic CLT Fabrication and Manufacturing Flowchart

1.2 Standards

Several primary domain activities involved in the development and manufacturing of CLT around the world include research, development, production, fabrication, utilization, and standardization. Manufacturing and fabrication of timber structures using engineered products, including CLT, require specific standards. Manufacturing standards correspond in structure to the steps of producing CLT.

For harmonisation, a logical next step would include looking at the way these smaller scale manufacturing standards interact with larger scale standards such as construction and building codes.

Building codes and standards provide homogenous regulations and specifications for construction. Countries all over the world have adopted different codes and standards, making cross-certification of products like CLT difficult. The interest in establishing codes and standards for timber structures is performance based. This means the CLT element should meet a minimum level of performance. Standards provide uniform specifications for calculating CLT properties relating to the material properties of the timber boards (strength, stiffness etc.). These standards facilitate the use of local timber species, and appropriate CLT assembly systems [1]. Most continents around the world have shown interest in CLT products in mass Also, some countries are adopting the existing exterior manufacturing standards for this product while adjusting the requirements for their current version of timber structure codes.

Countries which have adopted CLT technology include (alphabetically) Australia and New Zealand, Brazil, Canada, China, European Union, Japan, South Africa, the United Kingdom and the United States [1]. As previously mentioned, different countries have been using regional construction standards based on the country or continent where they are located. Therefore, this paper selected manufacturing standards relating to CLT and timber codes of the regions where CLT standard development has begun. Then the paper focuses on background information and general approaches used by these standards. The paper aims to review the current versions of each standard with the related standards background. For the development of standards in those countries that are yet to adopt a CLT standard, the potential of using other existing standards has been outlined as suggestions. Figure 2 shows the status of the selected countries towards the development of a CLT standard. Figure 3 illustrates the hierarchical systems for CLT and timber structure standards between the five continents around the world and the ISO standardization system:

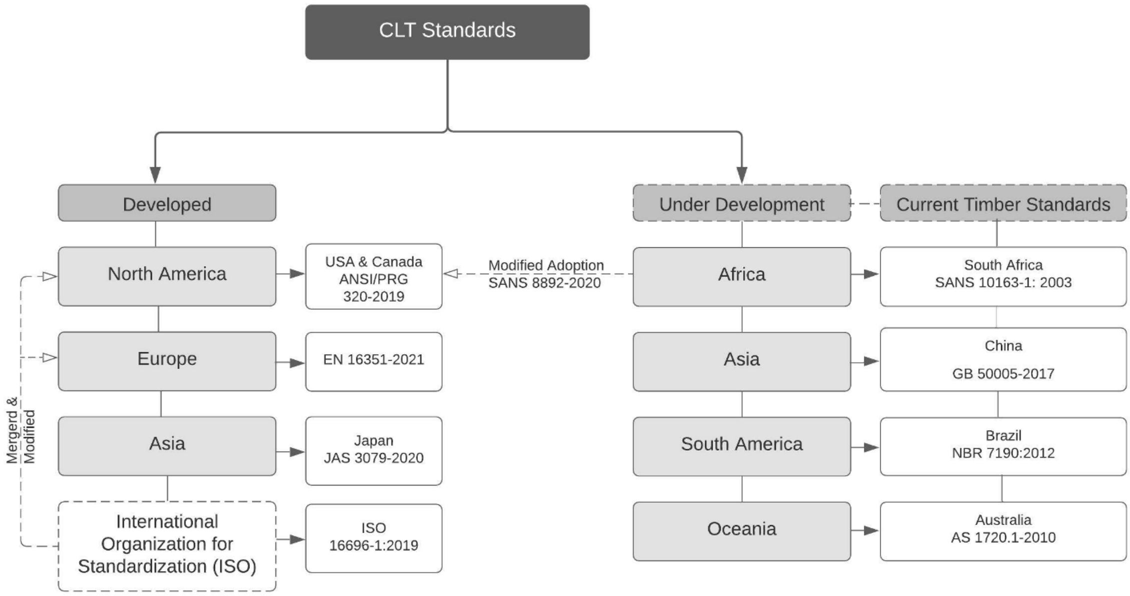

Figure 2. The Existing CLT and Timber Structure Standards in Different Continents

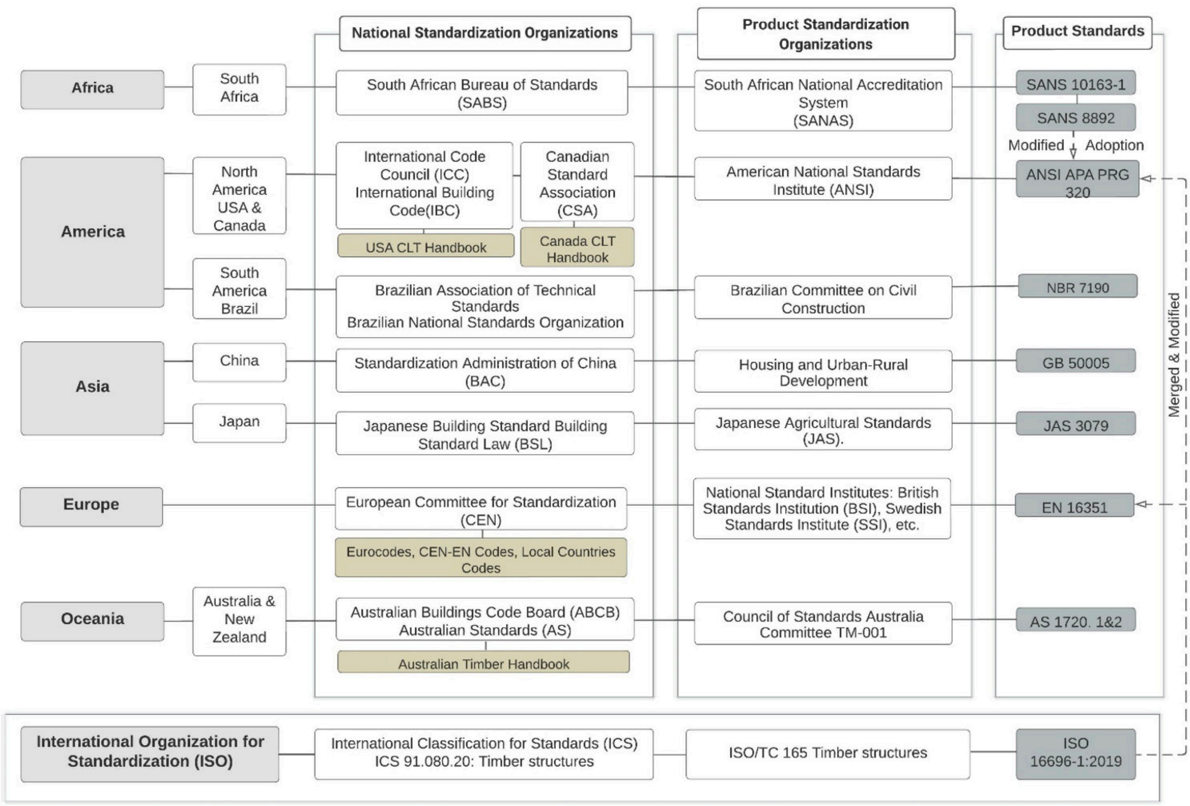

Figure 3. Hierarchical Product Standardization Systems in Selected Countries with Timber and/or CLT Standards

The present review can be a useful resource for researchers, manufacturers, companies, and investors interested in further study of a worldwide harmonized CLT standard. The information provided in the paper can help these professionals to become familiar with the code characteristics of timber and CLT product around the world. The ultimate objective of the paper is to provide guidance towards the development of harmonized codes for future CLT manufacture.

2. Current Cross-laminated Timber (CLT) Standards Around the World

CLT Standard in North America: Canada and United States:

North America is one of the regions that has specifically released specifications on CLT through Handbooks and product standards. In North America, CLT was first introduced during the early 2000s.Since then, its usage has gained momentum despite the lack of comprehensive, streamlined building code adoption. CLT is now used either as a standalone system or in combination with other structural materials in the construction of mid-rise and high-rise buildings for residential and commercial purposes.

The CLT Handbook was developed as the initial published document for North American CLT applications. It was published first by FPInnovations with a Canadian version in 2011 [3] and a US version in 2012 [4]. The CLT Handbook has been a helpful resource for CLT products design in North America and beyond. Primarily because there was no other available design information in the codes at that time [5].

The CLT manufacturing standard for North America is ANSI/APA PRG 320 that was first published in 2012 by the American National Standards Institute (ANSI). The most current version of the standard, ANSI/APA PRG 320-2019 [6], is arranged in nine different sections with two annexes and three appendixes. The standard is a bi-national standard between the U.S. and Canada. APA-The Engineered Wood Association as a standards developer accredited by the American National Standards Institute (ANSI) has developed this standard through an agreement standard development process [7]. ANSI/APA PRG 320 was first referenced in the 2015 edition of the National Design Specifications (NDS) for Wood Construction in the U.S. and the 2014 edition of the Canadian National Standard for Engineering Design in Wood (CSAO86) [5]. This standard, as its scope explains in its first chapter, provides dimensions and tolerances, performance specifications, test methods, quality assurance, and trademarking for CLT panels [6]. As this standard states, CLT can be fabricated with the layers of solid lumber, or with engineered lumber such as structural composite lumber (SCL), laminated veneer lumber (LVL), laminated strand lumber (LSL) or oriented strand lumber (OSL). These products are adhered with structural adhesives through face joint, end joints and/or edge joints. ANSI/APA PRG 320-2019 [6] does not cover nail-laminated CLT or other CLT products fabricated without adhesive face bonds [7].

With the European experience in engineering theories and manufacturing processes of CLT, ANSI/APA PRG 320-2019 [6] considers the North American timber resources, manufacturing preference, and the users' expectations. As an example, any softwood timber species recognized by the American Lumber Standards Committee (ALSC) under PS 20-20 [8] or the Canadian Lumber Standards Accreditation Board (CLSAB) under CSA O141-2019 [9] with a minimum specific gravity of 0.35, as published in the National Design Specification for Wood Construction (NDS) [10] in the U.S. or CSA O86-2017 [11] in Canada, is allowed to be used in the fabrication [7]. Figure 4shows the technical standards and codes that have been used in this standard to address the requirements for manufacturing the CLT panels:

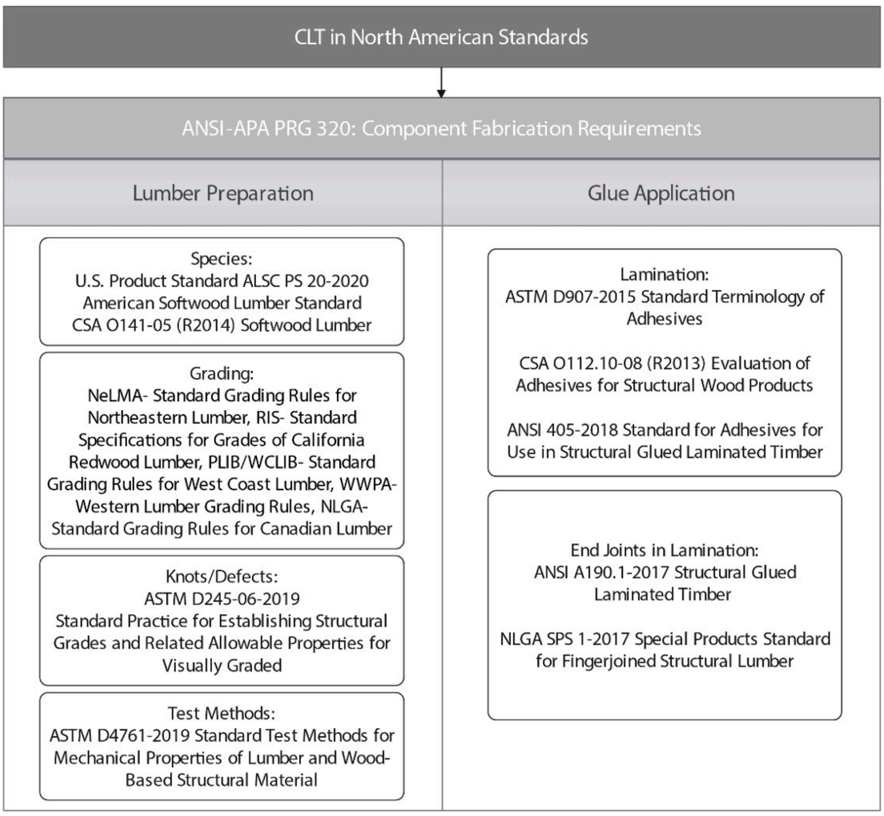

Figure 4. North American Corresponding Standards for North American CLT Standard

CLT Standard in Europe:

Regarding European standardization, different groups of experts contribute as committee members to organize the design and format of a standard. CEN members are bound to comply with the CEN (European Committee for Standardization, Comité Européen de Normalisation in French)/CENELEC (European Committee for Electrotechnical Standardization). They also should collaborate with the Internal Regulations to specify the conditions for providing a national standard status without any alteration for the European standards. It should be noted here that upon the United Kingdom (UK) leaving the European Union (EU), they will not be represented in the EU political institutions anymore. However, the British Standards Institution (BSI)'s membership in CEN and CENELEC was confirmed to be continued. This decision has been confirmed after voting in November 2021 by the CEN CENELEC General Assemblies. This confirmation is based on the fact that CEN and CENELEC are not agencies of the EU. It will further enable UK experts to continue to influence the content of standards that are tools of the market used voluntarily across Europe [12].

Comprehensive research on CLT in Europe started in 1990 at the University of Graz, Austria, and the first residential buildings built of CLT were completed by Moser in 1995. Since then, CLT as an innovative Central European product, has garnered global interest. Europe still has more than half of the worldwide CLT production per year [2]. As a pioneer in CLT production, Europe has released various manufacturing standards regarding timber grading and eventually the last one specifically for CLT structural requirements.

The most used standard for timber structural design is Eurocode 5-2004 [13] (EN 1995). This code was initially published in 2004, and describes the requirements and the principles for safety, durability, and serviceability of timber structures. There is currently an ongoing revision of the Eurocode 5 -2004 [13] by CEN TC250 SC5 WG4 with scheduled publication date of this version set for 2025. The new version of Eurocode 5 -2004 [13] is projected to include a section for rules of Cross-laminated Timber with the behaviour of adhesives. However, an individual CLT standard was published by CEN in 2015 with specific corresponding standards that makes the product requirement independent of Eurocode 5.

The most recent version of CLT products standard in Europe is EN 16351-2021 [14], which is used all around the continent with various translated versions. This European standard has been published originally in three official versions (English, French, German). Its versions in other languages have been translated under a CEN member's supervision into the native language to obtain the same status as the official versions [15]. EN 16351-2021 [14], unlike standard EN 14080-2013 [16] for glued laminated timber (GLT), does not cover the equations that are required to determine the strength and stiffness properties of CLT panels. So, the strength classes of CLT panels are not specified and are regarded as the strength classes of the base lumbers [17]. Figure 5shows the technical standards and codes that have been used in this standard to address the requirements for manufacturing the CLT panels based on European standards:

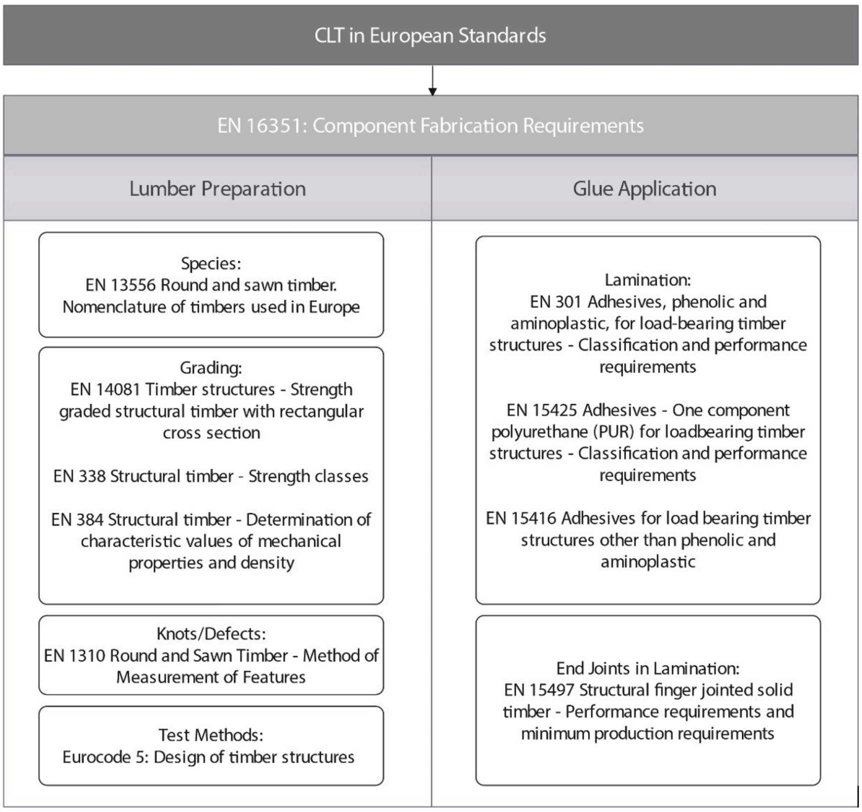

Figure 5. European Corresponding Standards for European CLT Standard

International Organization for Standardization (ISO) CLT Standard

After the first two CLT standards were released for North America and Europe, the International Organization for Standardization (ISO) initiated an International CLT standard related to the two documents: ANSI/APA PRG 320 and EN 16351. ISO brings together a worldwide association of national standards bodies called ISO member bodies. The members, if interested in a subject for which a technical committee has been established, generally become responsible for preparing the International Standards as ISO technical committees. The technical committee of the ISO standards related to timber technologies has been established as ISO/TC 165 Timber Structures, under International Classification for Standards (ICS). This committee participates in standardization processes concerning structural applications of timber, wood-based products, and panels such as CLT [18]. The most current published ISO standard for CLT is ISO 16696-1-2019 [19]. This document covers a 'manufacturing-to-market' perspective, not a 'design-to-construction' perspective. The main principle of this standard is specifying the minimum requirements for CLT production. It also identifies CLT performance assessment to a certain level of required production techniques to be acceptable for structural application of the product. The standard ISO 16696-1-2019 [19] is a merged and modified version based on the technical contents of the two CLT standards from North America; ANSI/APA PRG 320 and Europe; EN 16351 in conformance with ISO procedures and requirements. The ISO is considering a series of two-part standard for ISO 16696 consisting of: ISO 16696-1-2019 [19]. Part one provides performance and production requirements for CLT, which also includes conformance requirements, as provided in Annex D of the document. Part two, ISO 16696-2 which has not yet been published, gives guidance on how CLT is to be installed and used. ISO 16696-1-2019 [14] is applicable to CLT products manufactured from known species and species combination of solid-sawn timber or wood-based panels built up of at least three layers [20].

The diagram in Figure 6 shows the technical standards and codes used in ISO CLT regarding the requirements for manufacturing CLT panels:

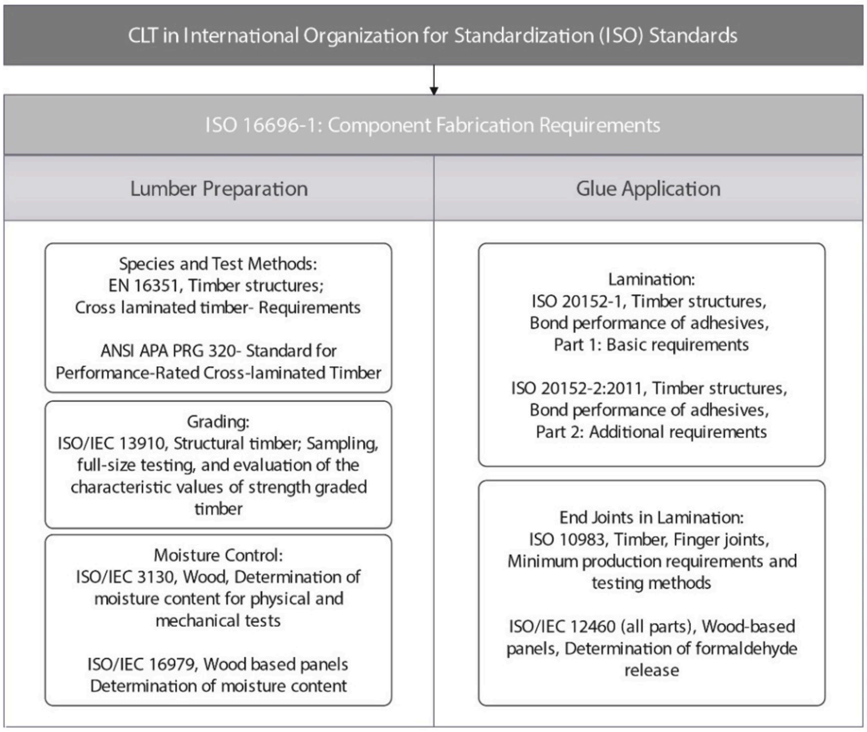

Figure 6. ISO Corresponding Standards for ISO CLT Standard

CLT Standard in Asia: Japan

In Japan, forest products are categorized by Japan's Ministry of Agriculture, Forestry, and Fisheries (MAFF). These organizations incorporate the standards under Japanese Agricultural Standards (JAS). There are eleven forest product standards published by JAS as shown in Table 1 below [21].

Each of these wood product standards provide specific requirements and classifications different from the other one. The Japanese government has been working on introducing legislation for CLT that would provide clear and concise standards under the Building Standards Act. Most of the wood products before CLT were associated with several imported species. Therefore, CLT in Japan has been developed to bring more opportunities for using local species such as Japanese Red-Cedar, Cryptomeria japonica (Sugi), as an engineered wood product. According to the 2014 CLT Roadmap by the Japan Ministry of Land, Infrastructure and Transport (MLIT) and the Japan Forestry Agency, CLT annual production capacity in the country is targeted to reach 500,000 cubic meters by 2024 [22]. It is worth noting that in addition to the JAS that authorizes wood-related products standards in Japan, there are some associations that contribute to the effective utilization of forest resources, such as the Japan CLT Association [23]. This association was established in 2012 with the goal of increasing the use of CLT as a structural material and enabling mid- and large-scale CLT buildings in the future. Beginning in 2016, the Japan CLT Association with the Japan Housing and Wood Technology Centre collaboration (HOWTEC) started publishing design manuals for CLT construction with the goal of providing the industry with more CLT structural design details.

The JAS No. 3079-2019 [24] is the recently released CLT standard for Japan that was initially established in December 2013. The standard was modified in August 2019 by the Food and Agricultural Materials Inspection Centre (FAMIC). This standard provides specifications for tree species classifications, rather than the categories of softwoods and hardwoods. JAS 3079-2019 [24] includes comprehensive detail of the adhesive particles and the bonding procedure by referring to a number of standards, and the adhesive usage has been classified considering three different conditions: A (outside the building), B (inside the building, higher fire integrity), and C (inside the building, normal fire integrity). Also, it provides the required strength classes detail and the test processes, specifically for the CLT panels. The standard JAS 3079 does not refer to any lumber or sawn board code such as JAS 1083-2019 [24]: Sawn Lumber Requirements, and individually provides specific requirements for timber-based lamina of the CLT panels. Figure 7 illustrates the corresponding standards for JAS 3079-2019 [24].

Table 1. Forest Products Categorized by Japan's Ministry of Agriculture, Forestry, and Fisheries (MAFF)

No.	Standard's Code Name	Standard's Descriptive Name
1	JAS 1083	Sawn Lumber
2	JAS 0600	Lumber, for framed wall construction
3	-	Laminated wood
4	JAS 3079	Cross-laminated Timber (CLT)
5	JAS 0701	Laminated Veneer Lumber (LVL)
6	JAS 0360	Structural panel (i.e., Oriented Strand Board (OSB))
7	-	Plywood
8	JAS 1073	Flooring
9	-	Logs
10	JAS 0006 & JAS 0007	Glued Built-Up Timber
11	JAS 0015	Width-wise Glued Timber

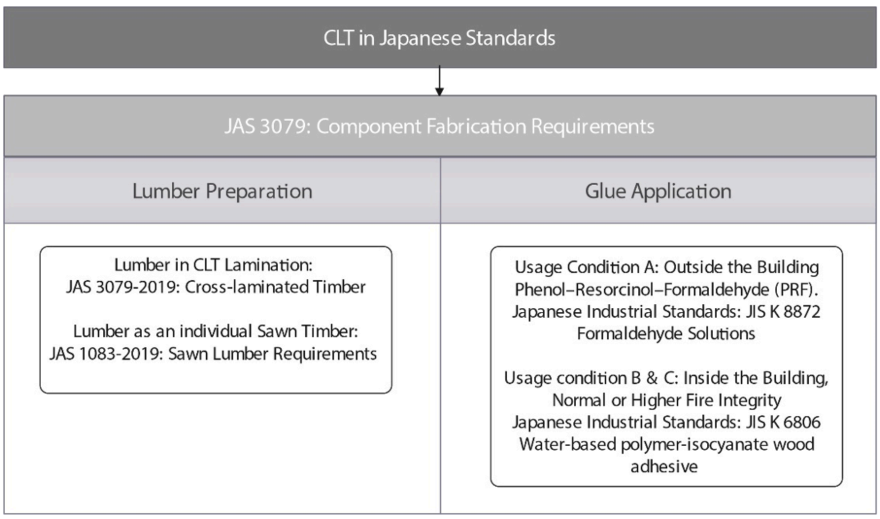

Figure 7. Japanese Corresponding Standards for Japanese CLT Standard

3. Timber Structure Standards with Potential of Including CLT Development

Timber standards in Africa: South Africa:

The use of timber in South African construction has a different and more vital aspect compared to other parts of the world. There are rural communities around this region that extensively use this natural resource to supply them with environmental goods and services. Studies on several regions of South Africa have shown that using wood was a fundamental if not crucial element for the rural areas to survive. The most used lumber species in the South African industry is South African pine for softwoods with about 70 percent of it classified as structural or building timber [25]. Also, hardwood species Eucalyptus or Gum are used in industrial and laminated structural components. In South Africa, stress-graded timber is mainly being used for building structures [26]. Stress-grading in South Africa started in the late 1950s. It was initially practiced only by visual grading. In the 1960s, mechanical stress-grading was introduced to the South African stress-grading system.

All the South African National Standards (SANS) are developed and promoted under the supervision of the South African Bureau of Standards (SABS). In April 2020, SABS published a CLT performance standard: SANS 8892-2020 [27]. This standard is a modified adoption of ANSI/APA PRG 320-2017 [28] (not the 2019 edition), helping the South African CLT construction industries and production manufacturers. While the body and content of the standard has not changed for this adoption, the modifications are stated in the national annex of the document providing references to other SANS standards for timber grading (SANS 10163-2003 [29], SANS 1783-2 [30] and 1783-5 [31]), adhesive (SANS 10183-2 [32]) and finger jointing (SANS 10096 [33]) requirements. This standard provides future perspective of developing a specific South African CLT classification system in next steps.

Both SANS 1783-2005 [30] and SANS 10163-2003 [29] reference other standards regarding timber grading. They provide the grading and timber structural requirements for South African Pine (SAP) for the market and the supply chains in the area. SANS 10163-2003 [29] includes two parts; the first part is limited to the fabrication and construction aspect of timber. The second part focuses on the details and strength properties of the timber. Both parts of SANS 10163-2003 [29] are the most used codes and general design requirements for timber works in South Africa. Figure 8 illustrates the consideration of future development. These considerations can be used towards the revisions for the next editions of the adopted version of ANSI/APA PRG 320-2017 [28], SANS 8892 [27] or any future individual South African CLT standard developments.

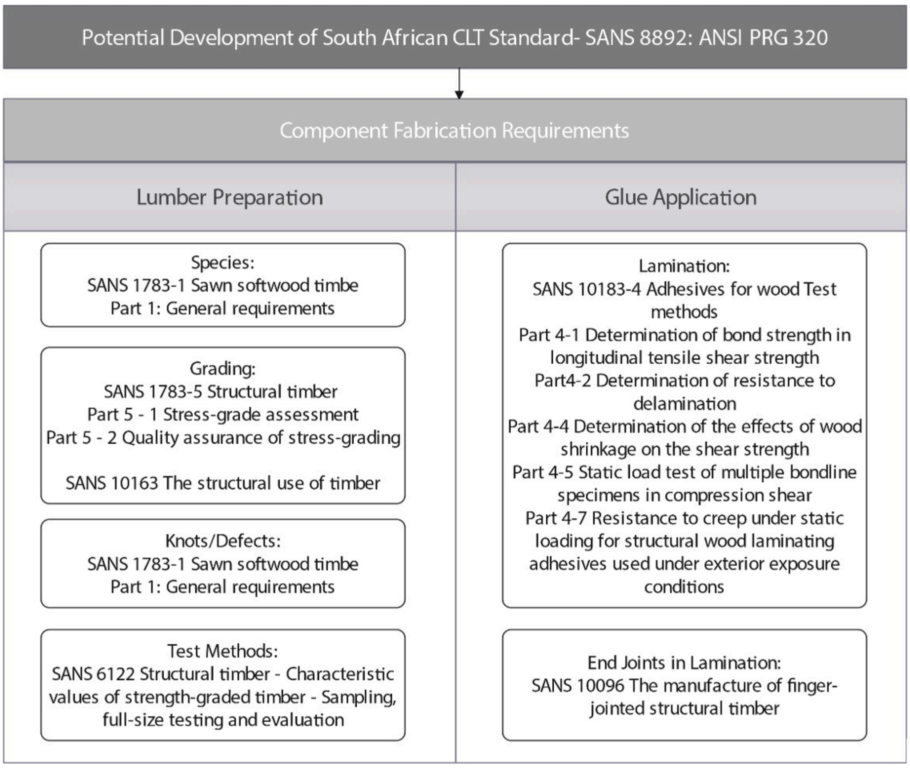

Figure 8. South African Corresponding Standards for a Potential CLT Development

Timber Standards in South America: Brazil:

Almost all countries in South America are currently using the European or North American standards for timber constructions. Since South America has a large amount of hardwood species, the European codes must be adjusted for hardwood utilization. Regarding the South American timber standards, Brazil is a pioneer for the region and has already released a timber standard with revisions afterwards. The first timber structure standard for the region (NBR 7199:1997) was published in Brazil in 1997 and has since been revised to the recent version in November 2011 [34]. The Brazilian timber design code has been published regarding the Limit States Design (LSD) concept. It has used the partial factor method, from the code published as Allowable Stress Design (ASD) in 1982 and the code of Probabilistic Limit States Design (PLSD) in 1997. The standard also has used a calibration coefficient to convert tabulated medium-strength properties to the characteristic 5% values of load effects with consideration of resistances [35].

In 2008, Calil [35] investigated the new revision for Brazilian Code for Timber Structures Design, NBR 7199 [34], regarding the improvements for grading South American local softwoods and hardwoods. The suggestions included drawings with details, connections, fire recommendations design, and constructive timber systems that countries in South America can use to initiate a harmonized code for timber structures design for the continent. NBR 7199 [34] is only a code for timber structures and not any composite or engineered timber products. Therefore, in addition to this standard, this paper proposes other current codes in the region shown in the Figure 9 for any future CLT standard consideration:

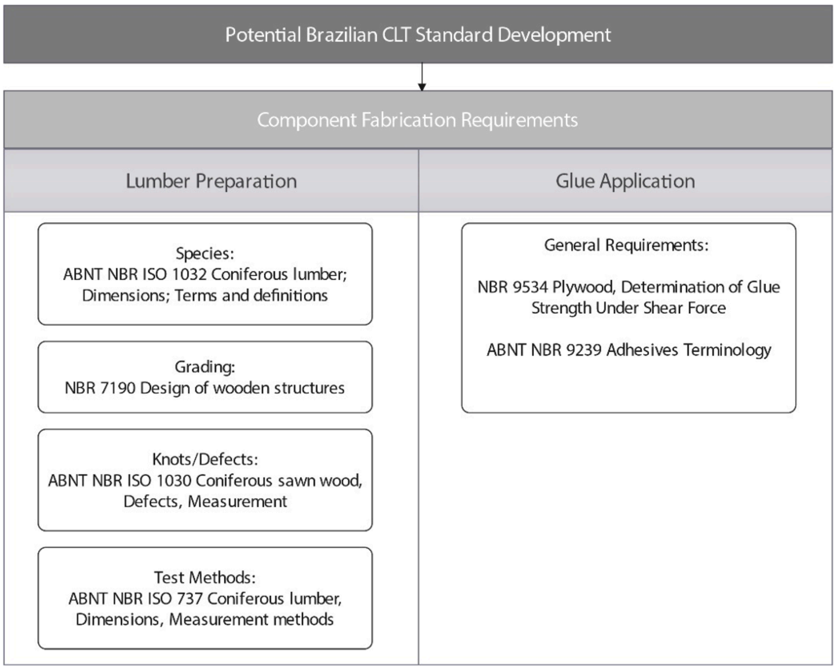

Figure 9. Brazilian Corresponding Standards for a Potential CLT Development

Timber Standards in Asia: China:

There are several countries in Asia that are pioneers in the wood construction industry and have a long history in timber buildings. China is among the countries that have been developing their own timber product standards. China has several codes regarding timber structure design methods and use in construction. There are other Asian countries, such as Singapore and The Republic of Korea that have adopted European or North American standards for the use of timber and other timber-based products for construction.

China has already established codes for the design of timber structures, code for construction quality acceptance of timber structures, the standard for testing methods of timber structures, and the technical code for partitions with timber framework [36]. GB 50005-2017 [37]: The Code for Design of Timber Structures is the most important national wood construction code in China. This standard provides details for the design and fabrication of load-bearing wooden structures. The first edition of GB50005 was published in 2003 by the China Southwest Architectural Design & Research Institute and Sichuan Institute of Architectural Science. The 2003 version of GB 50005 is an alternative to the GBJ5-88 standard which is suspended for use since 2003. The new version of GB 50005-2017 [37] employs requirements mainly for residential construction, one-story industrial buildings, and large or medium-sized multifunctional public constructions [36].

The GB 50005-2017 [37] standard refers to timber as a structural material that may be used as logs, square timbers, planks, dimension lumber (which is mostly imported from Europe or North America), glue-laminated timber, structural composite lumber, and wood-based structural panels. The standard also states that the main load-bearing members should be softwood timbers due to the trees faster growth rate, availability, and workability. Also, any imported dimensional lumber that is a new tree species to China should include the origin country's marking and should be used according to this standard after determining their physical and mechanical properties through testing [37]. Due to a lack of specifications and codes for CLT products and the public's awareness of the potential of wood construction in high-rise buildings, CLT has been used predominantly in low-rise buildings in China, constructed primarily for the purpose of exposition. Although the new versions of the GB 50005-2017 [37]: standard for design of timber structures and the GB/T 51226-2017 [38] standard for multi-story and high-rise timber buildings, have briefly provided some requirements and guidelines for the CLT elements, nonetheless product design and design of the connections, etc., and the specification for acceptance and fabrication, still need to be completed.

Figure 10 illustrates the standards that are already used in GB 50005-2017 [37] and/or could be used for a potential CLT standard:

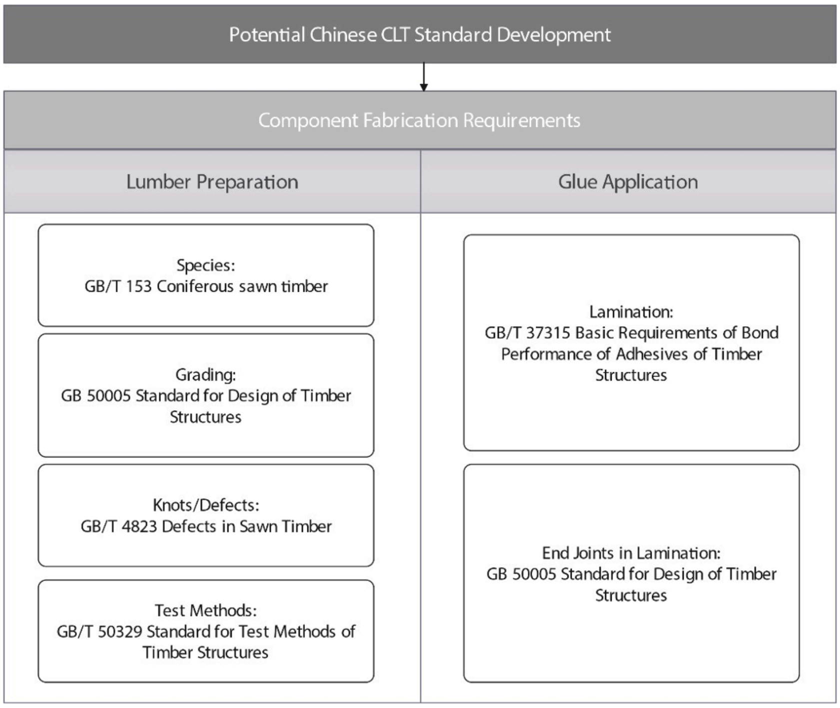

Figure 10. Chinese Corresponding Standards for a Potential CLT Standard

Timber standards in Oceania: Australia and New Zealand:

CLT production is gaining an increasing interest within the construction industry in Australia. In Australian industries, CLT panels are generally fabricated with softwood, and it is proposed to fabricate the panels using grown pine from local resources. Locally grown Australian pine (Pinus radiata) has been shown by the University of Technology Sydney (UTS) to meet the required properties for successful manufacture of CLT panels. Further evidence of this is that this species, as the prevailing species in the region, is being used by all onshore producers [39].

Regarding the process of standards development within the continent, there is a formal process by which a project proposal is submitted to Standards Australia and Standards New Zealand for consideration. The relevant Standards Australia / Standards New Zealand "Timber Committee" would then be asked for their review. Then, if it is endorsed, it would formally go through the project prioritization and selection process. It is the role of the Timber Committees to be constantly working through their catalogue of timber standards to improve the existing ones and add the missing and required sections.

There is a Glued Laminated Timber (GLT) standard for the region, AS/NZS 1328- parts 1 [40] and 2 [41]: Australian and New Zealand Standard for Glued Laminated Structural Timber. However, at present, there are no specific CLT structures code and construction standard. Also, CLT is not covered under the 'deemed-to-satisfy' provision of the Building Code of Australia (BCA).

The most recent and commonly used timber standard in the continent is AS 1720.1: Timber structure [42]. The standard was developed by the Joint Standard Australia/Standards New Zealand Committee, Timber Structures, in 1997. It is intended to provide designers, engineers, and architects in the area with a design standard for timber structures and elements. For this purpose, the standard addresses the design methods and appropriate data for utilizing structural elements, materials, and requirements for installation and maintenance of timber structures [39]. The current timber structure standard, AS 1720.1-2010 [42], provides comprehensive information on various design elements, the strength properties for stress-graded timber, bending, tension, compression, and shear strengths to be considered for stresses acting parallel and perpendicular to the grain of the wood. It also addresses specifications regarding test methods, and timber products, including Laminated Veneer Lumber, plywood, and Glued-laminated Timber. Since this standard does not include any particular section explaining Cross-laminated Timber, a CLT manufacturing standard is needed to accelerate the adoption of the product. Figure 11proposes how a prospective CLT standard might be organized regarding the existing component standards in Australia and New Zealand:

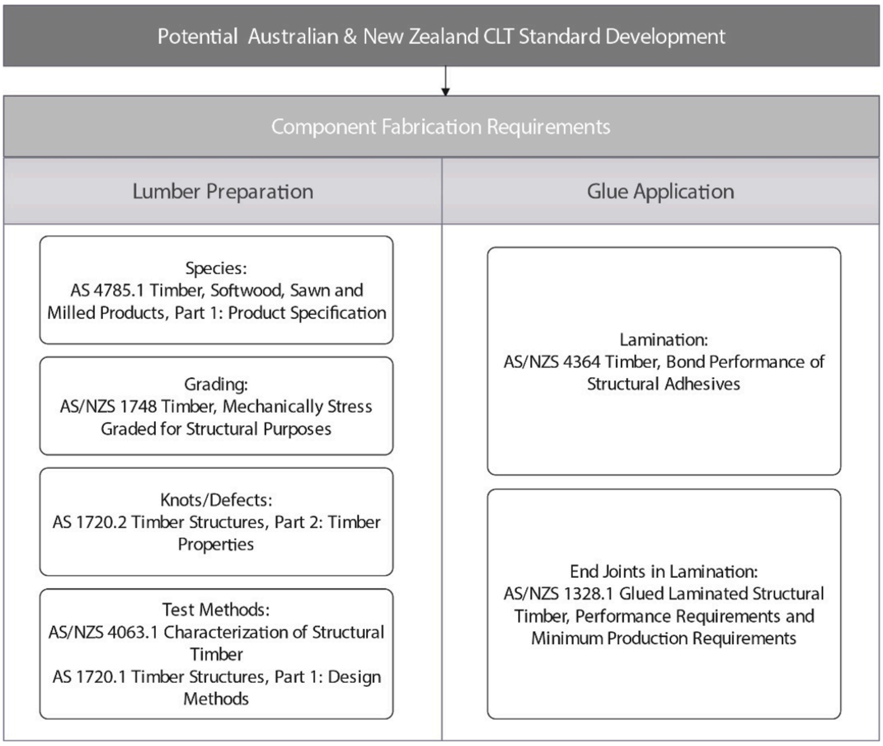

Figure 11. Australian Corresponding Standards for a Potential CLT Development

4.Conclusion and outlook:

CLT is a recently introduced engineered wood product with high structural performance and durability in addition to its sustainability and environmental benefits. Although CLT has been fabricated and utilized in Europe for over three decades, the design and production of this engineered wood product have started all around the world with some industries currently being in the production or product qualification phase. The competitiveness of CLT versus other building materials is of great interest in the marketplace and deserves the focus of future research. Information of current CLT and timber structure standards can play a vital role in understanding how to adopt these standards to develop a future harmonized standard for CLT product. The present paper studied existing standards and explained the current status of the regional markets of the countries which have initiated CLT standards. The paper's goal is to provide basic required information for developing a universal CLT standard. The development and adoption of this product in the international marketplace will depend on developing a common approach to the design, production, and qualification of manufacturing facilities worldwide. There must be more efforts supporting CLT standardization in the near future to help define this sustainable product and reveal all its structural potential.

5. Recommendations:

As an output of the paper, the following recommendations are proposed by the authors to provide a road map for the future development of CLT standards.

1. A review could be undertaken to look at specific similarities and difference in each of the 'standardized' processes identified in the present paper. Thereby, a common lexicon can be developed and beside adjustments for imperial and metric conversion, the same language is adopted globally.
2. Develop a global harmonised standard to ensure that the sale of CLT across the world will be accepted and provide product certainty for Architectural, Engineering and Construction stakeholders when using the technology in building design and delivery.
3. An international board could be employed to help guiding ISO as a global technical committee in creating a common technical language to align with current CLT and timber standards in any part of the world instead of adopting and modifying the few existing CLT standards.
4. A global commitment to contribute to these standards could support the development of common and interchangeable manufacturing equipment that could be used to support the manufacturing of CLT in countries that are less developed/ industrialized however have a strong forestry community.

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