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JOURNAL OF MECHANICAL, INDUSTRIAL, ELECTRICAL, AND CIVIL ENGINEERING

BIBLIOMETRIC ANALYSIS OF LAMINATED TIMBER IN BUILDING STRUCTURES: 2015-2025

Simon Petrus Hamonangan Simorangkir

Mahasiswa Program Doktoral Departemen Teknik Sipil, Universitas Andalas, Indonesia, Jl. Lingkar Universitas Andalas, Limau Manis, Kec. Pauh, Kota Padang, Sumatera Barat 25175

Email: simonpetrussimorangkir@gmail.com

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Abstrac

The increasing adoption of laminated timber products (e.g., glulam and CLT) in modern construction requires a systematic mapping of the scientific landscape to understand research trajectories, collaboration patterns, and the ongoing shift toward sustainability-related topics. This study aims to map the development of laminated timber research during 2015–2025 through bibliometric analysis, covering publication trends, dominant subject areas, leading sources, productive authors, keyword evolution, and thematic structures. Prior studies are often descriptive or limited to specific technical aspects, while large-scale, metadata-driven quantitative mapping remains relatively limited. The novelty lies in integrating quantitative analysis using RStudio with network-based science mapping using VOSviewer to provide a more comprehensive overview (trends, co-occurrence networks, thematic maps, and topic shifts). Publication data were mined from Scopus, yielding 1,875 documents (2015–2025), and then analyzed and visualized using RStudio (data cleaning, descriptive statistics, trend analysis) and VOSviewer (network, overlay, and density visualizations). The results indicate a strong growth in publications with a peak around 2023, dominance of Engineering-related contributions and structural/material-focused outlets, and a noticeable shift from mechanical-performance studies toward sustainability and environmental impact themes, highlighting opportunities for deeper cross-disciplinary integration in future research.

Abstrak

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JOURNAL OF MECHANICAL, INDUSTRIAL, ELECTRICAL, AND CIVIL ENGINEERING

Kata Kunci: Bibliometrik, Laminated timber, VOSviewer

Peningkatan adopsi produk kayu laminasi (misalnya glulam dan CLT) dalam konstruksi modern menuntut pemetaan lanskap ilmiah secara sistematis untuk memahami arah perkembangan penelitian, pola kolaborasi, serta pergeseran fokus yang sedang berlangsung menuju topik-topik terkait keberlanjutan. Penelitian ini bertujuan memetakan perkembangan riset kayu laminasi pada periode 2015–2025 melalui analisis bibliometrik, yang mencakup tren publikasi, bidang kajian dominan, sumber/jurnal terkemuka, penulis paling produktif, evolusi kata kunci, dan struktur tematik. Studi-studi sebelumnya umumnya bersifat deskriptif atau terbatas pada aspek teknis tertentu, sementara pemetaan kuantitatif berskala besar berbasis metadata masih relatif terbatas. Kebaruan penelitian ini terletak pada integrasi analisis kuantitatif menggunakan RStudio dengan pemetaan sains berbasis jaringan menggunakan VOSviewer untuk memberikan gambaran yang lebih komprehensif (tren, jaringan ko-okurensi, peta tematik, dan pergeseran topik). Data publikasi ditambang dari Scopus, menghasilkan 1.875 dokumen (2015–2025), kemudian dianalisis dan divisualisasikan menggunakan RStudio (pembersihan data, statistik deskriptif, analisis tren) serta VOSviewer (visualisasi jaringan, overlay, dan density). Hasil menunjukkan pertumbuhan publikasi yang kuat dengan puncak sekitar 2023, dominasi kontribusi bidang Engineering serta outlet yang berfokus pada struktur/material, dan adanya pergeseran yang jelas dari studi performa mekanik menuju tema keberlanjutan dan dampak lingkungan, yang menegaskan peluang integrasi lintas-disiplin yang lebih mendalam pada riset mendatang.

INTRODUCTION

Laminated timber, also known as engineered wood, is one of the engineered wood products that is becoming increasingly popular in the modern construction industry due to its ability to offer materials with high structural strength, stable dimensions, and efficient use of wood resources[1], [2], [3]. One of the main forms of laminated timber is glued laminated timber (glulam), which has been widely used as an alternative construction material besides steel and concrete, especially in building applications such as beams, columns, and roof trusses. With these advantages, laminated timber, particularly glulam, holds an important position in the development of environmentally friendly and sustainable building

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materials[4], [5]. The trend of using laminated timber globally is experiencing a significant increase, in line with the growing awareness of the importance of using materials with a low carbon footprint and that are environmentally friendly. Based on the review of Environmental Product Declarations (EPD) for 81 structural wood products, glulam shows lower greenhouse gas emissions compared to other wood materials, with a median emission of 0.24 kg CO2e per kg of product[6]. This makes it a more environmentally friendly choice, especially in regions such as Europe, North America, and Australia/New Zealand, which are the main production areas. In this context, recent studies indicate that the use of laminated timber can help reduce carbon emissions in the construction sector and support decarbonization efforts in the building sector[7]. However, despite the many advantages of using laminated timber, significant challenges remain, such as the need for harmonization of international standards, varying product quality, and uncertainties in environmental data that can affect calculations of the product's environmental impact. In addition, there are research gaps still limited to technical and regulatory aspects, especially those related to fire resistance, durability, and seismic performance in multi-story buildings using laminated timber[8], [9]. This study aims to fill these gaps by examining international experiences in the application of laminated timber in multi-story buildings, as well as evaluating the architectural design challenges and opportunities associated with it[10], [11]. The primary focus of this research is to develop more efficient, safe, and environmentally friendly construction systems that meet the needs of multi-story building development utilizing laminated timber technology. Furthermore, this study also aims to analyze social impacts, public perceptions, and market acceptance of the use of laminated timber in multi-story building construction[12], [13]. Along with advancements in research on laminated timber, there are still several gaps that need to be addressed, such as the lack of development of precise analytical methods for structural connections and protection against moisture and material degradation[14], [15]. Another gap is the lack of exploration in cross-disciplinary design collaboration and stakeholder integration from the early design stages. This research will offer innovation by integrating comprehensive architectural and structural analysis in the context of sustainability and efficient resource use, as well as proposing performance-based design solutions that can optimize the performance and safety of multi-story buildings. With the expected contributions from this research, it is anticipated that the adoption of laminated timber in the construction of multi-story buildings that are more environmentally friendly, safe, and sustainable can be accelerated in the future.

State of The Art

Laminated timber, particularly glulam and cross laminated timber (CLT), is an environmentally friendly

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construction material with high structural strength and superior design flexibility. This product is made by bonding several layers of wood (lamella) using special adhesives, thereby eliminating the natural defects of wood and resulting in an even distribution of strength, even rivaling that of steel and concrete. Laminated timber can be produced in a variety of sizes and shapes according to architectural needs, supporting construction efficiency and design freedom[16], [17].The quality of the glued joints is crucial for structural integrity, influenced by the type of wood, type of adhesive, pressing pressure, and surface conditions. Process control during manufacturing is key to maintaining product consistency. Various innovations have been implemented, including reinforcement with FRP, use of bio-based adhesives, dowel laminated timber (DLT), and densified wood, which enhance performance while also promoting sustainability[18], [19].Laminated timber has already been used in high-rise buildings, replacing steel and concrete, thanks to its modularity, lightweight, and biophilic qualities. The main challenges include fire regulations, structural design standards, and product certification, especially in developing countries. From a sustainability perspective, laminated timber has proven to reduce carbon emissions compared to traditional materials, though more comprehensive data is still needed regarding biogenic emissions and regional impacts[20], [21].Overall, laminated timber offers a sustainable and high-performance construction solution, with great potential in resource efficiency, design flexibility, and environmental impact reduction, provided that challenges in joint quality, material innovation, and regulation are addressed[22], [23].

Research Novelty

This study offers innovation through a comprehensive and integrated bibliometric analysis approach in examining the development of laminated timber during the 2015–2025 period. Unlike previous research, which is generally descriptive in nature, this study combines quantitative analysis using RStudio with network visualization based on VOSviewer to produce more in-depth scientific mapping. This includes publication trends, researcher collaboration structures, keyword evolution, and thematic distribution based on the level of relevance and topic development. Another novelty lies in the study's ability to identify a shift in the global research paradigm from focusing on the mechanical performance of materials toward sustainability issues, such as carbon emissions, energy efficiency, and environmental impact, supported by large-scale bibliometric data analysis. In addition, this research systematically reveals underexplored research gaps, particularly related to the integration between structural and environmental aspects, seismic performance and fire resistance in multi-story buildings, as well as the limitations of cross-disciplinary approaches in the design process. Furthermore, this study proposes new directions for development in the form of performance-based design integration that combines

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architectural, structural, and sustainability dimensions within a single conceptual framework. Thus, this study not only contributes to systematically mapping the scientific landscape but also provides a strategic foundation for the development and implementation of more efficient, safer, and sustainable laminated timber in the future.

RESEARCH METHODS

This study uses bibliometric analysis to evaluate scientific output and its impact. The analysis was conducted using RStudio with the R programming language for data import, cleaning, transformation, visualization, and modeling. Research data was obtained through data mining on the Scopus database, which provides access to abstracts, citations, and publication metadata from various indexed journals (Norshariza, Mohamad, et al., 2021; Zhang et al., 2021). Furthermore, the data was visualized using VOSviewer, which enables the creation of bibliometric maps, including networks of authors, journals, co-citations, and keywords based on co-occurrence, thus facilitating quantitative and visual analysis of the development of knowledge and research collaboration. This approach ensures a systematic, transparent, and replicable method in bibliometric studies.

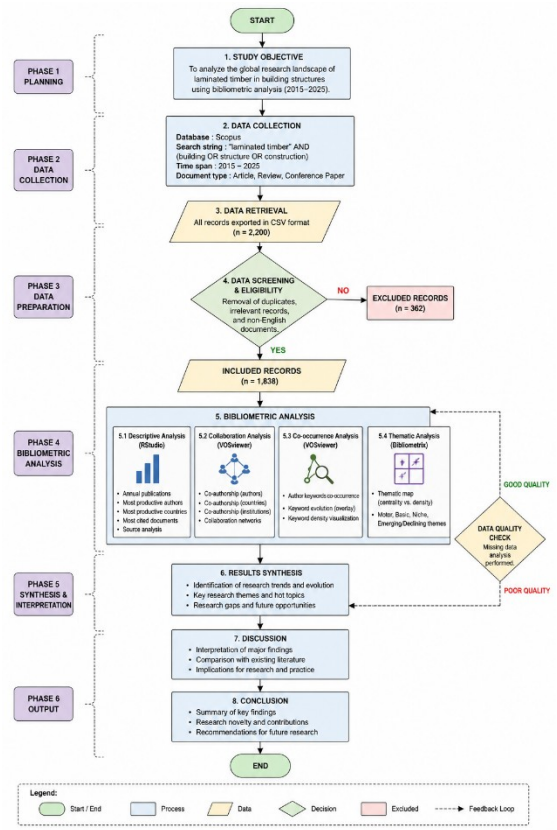

Figure 1 Research Flow Chart

The IoT-integrated automatic water filter system consists of two primary processes:

ANALYSIS AND EVALUATION

Identification of Data Mining on Laminated Timber in Scopus

A total of 1,875 articles were identified through the Scopus application from 2015 to 2025. The publication data per year can be seen in the following table.

Table 1 Number of Publication Distributions

Year	Number of Documents
2025	273

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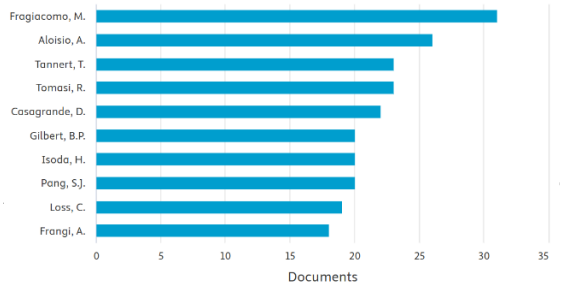
2024	252
2023	403
2022	200
2021	193
2020	142
2019	142



32 documents in 2015 to 403 documents in 2023. Although there is a decrease to 273 documents in 2025, the overall trend demonstrates significant growth, reflecting heightened attention to research and development of this material in sustainable construction. The research fields identified by Scopus can be seen in the following diagram.

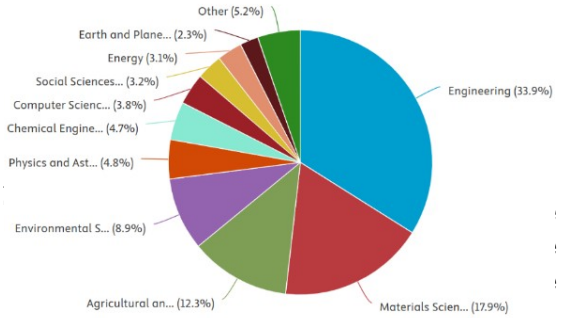


Figure 1 Research Field Diagram

comes from the DIPA POLMED fund in

The distribution of Laminated Timber publications shows a dominance in the field of Engineering (33.9%), followed by Materials Science (17.9%) and Agricultural and Biological Sciences (12.3%), indicating that research focuses more on technical and material aspects. Scopus also displays the researchers who have published in this field. The following is a chart of researchers in the field of Laminated Timber.

Figure 2 Laminated Timber Researcher Chart

This graphic shows the top 10 authors based on the number of Laminated Timber publications. Fragiacomo, M. holds the first position with 31 publications, followed by Aloisio, A. (26 publication documents), and both Tannert, T. and Tomasi, R. (23 publication documents each). The other authors have between 18–22 publication documents. This indicates significant contributions from several key authors in the development of Laminated Timber research.

RStudio Analysis

The data obtained from Scopus was then analyzed using the RStudio application as follows:

Table 2 Missing Data Table

Metadata	Description	Missing Counts	Missing %	Status
AU	Author	0	0.00	Excellent
DI	DOI	0	0.00	Excellent
DT	Document Type	0	0.00	Excellent
LA	Language	0	0.00	Excellent
PY	Publication Year	0	0.00	Excellent
TI	Title	0	0.00	Excellent
TC	Total Citation	0	0.00	Excellent
AB	Abstract	2	0.11	Good
C1	Affiliation	7	0.37	Good
SO	Journal	193	10.30	Acceptable
DE	Keywords	204	10.89	Acceptable
ID	Keywords Plus	381	20.33	Poor
RP	Corresponding Author	385	20.54	Poor
CR	Cited References	1874	100.00	Completely missing
WC	Science Categories	1874	100.00	Completely missing

This table shows the metadata completeness quality of the Laminated Timber publication dataset. Core columns such as Author, DOI, Document Type, Language, Publication Year, Title, and Total Citation have 100% completeness (Excellent), while Abstract and Affiliation are nearly complete (Good). The Journal and Keywords columns have about 10% missing data (Acceptable), whereas Keywords Plus and Corresponding Author are missing more than 20% of data (Poor). The Cited References and Science Categories columns are completely empty (Completely Missing), indicating the dataset's limitations for citation analysis and mapping scientific categories. These results highlight the need to pay attention to metadata quality when conducting bibliometric analyses to ensure the validity of the data interpretation[24], [25]

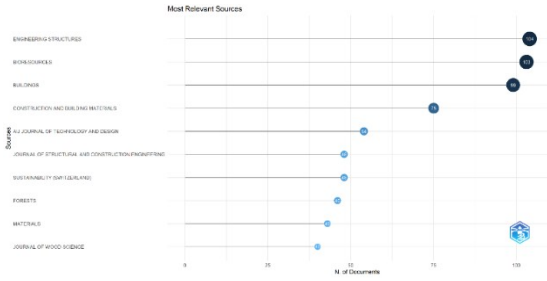


Figure 3 RStudio Analysis – Research Relevance Area

This graphic shows the most relevant publication sources related to Laminated Timber research. Engineering Structures is the leading journal with 104 documents, followed by Bioresources (103) and Buildings (99). Other sources such as Construction and Building Materials (75) and AIJ Journal of Technology and Design (54) also make significant contributions. These results indicate that Laminated Timber research is predominantly published in journals focusing on structural engineering, materials, and construction, confirming a trend in the literature toward technical and material aspects[26].

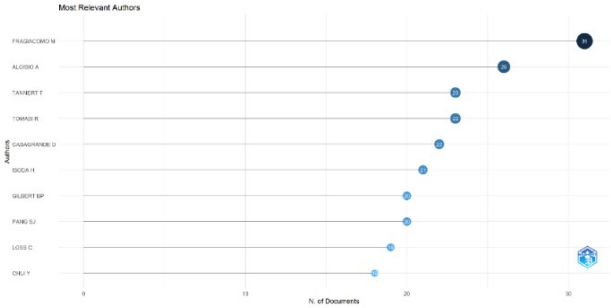


Figure 4 RStudio Analysis – Research Author

This graphic shows the top ten authors based on the number of documents they have contributed. Fragacimo M leads with 31 documents, followed by Aloisio A with 26 documents. Other authors, such as Tannert T and Tomasi R, each have 23 documents, while the remaining authors contributed between 18 and 22 documents. This reflects a fairly even distribution of contributions, with Fragacimo M as the most productive author[2].

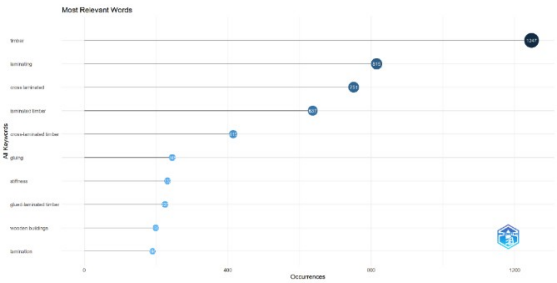


Figure 5 Research Keywords

This graphic shows the most relevant words based on their frequency of occurrence in research documents. Timber dominates with 1,247 occurrences, followed by Laminating with 515 occurrences. Other terms, such as Cross Laminated Timber, appear 353 times, while Glued Laminated Timber has 121 occurrences. Other relevant words include Stiffness, Wooden Buildings, and Limitation, each appearing with lower frequency. (Corpataux et al., 2020; Rescalvo et al., 2023)

Figure 6 Main Research Topic

This image shows the frequency distribution of relevant keywords in the research, presented in the form of a tree map. The most prominent keyword is Timber with 1,247 occurrences (14%), followed by Laminated Timber with 637 occurrences (7%). Other keywords with high frequencies include Cross-Laminated Timber with 415 occurrences (5%), and Gluing with 245 occurrences (3%). Additionally, several other keywords such as Stiffness and Wooden Buildings also appear quite frequently, with 232 occurrences (3%) and 199 occurrences (2%) respectively. This data indicates the dominance of keywords related to laminated wood and wood processing in the research literature.

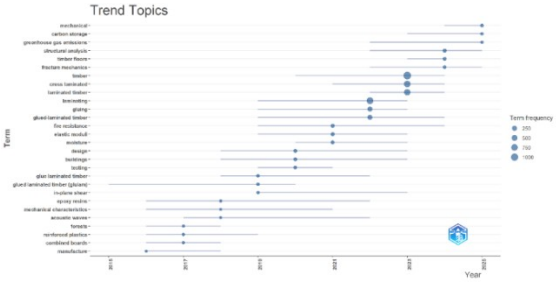


Figure 7 Research Topic Trends

This graphic illustrates the trending research topics based on the frequency of related term occurrences from 2015 to 2025. Some of the most prominent terms include Mechanical and Carbon Storage, which began to show a significant increase in frequency since 2020. Greenhouse Gas Emissions and Structural Analysis have also demonstrated a consistently rising trend in recent years. Other terms, such as Timber, Cross Laminated, and Glued Laminated Timber, show a more moderate increase, peaking in 2023–2025. The frequency of appearance for some topics, such as Acoustic Waves and Reinforced Plastics, is relatively low but has started to rise after 2023. This data provides a clear overview of topics that are becoming increasingly relevant and developing in research related to plywood and wood processing technology, as well as environmental and mechanical issues.

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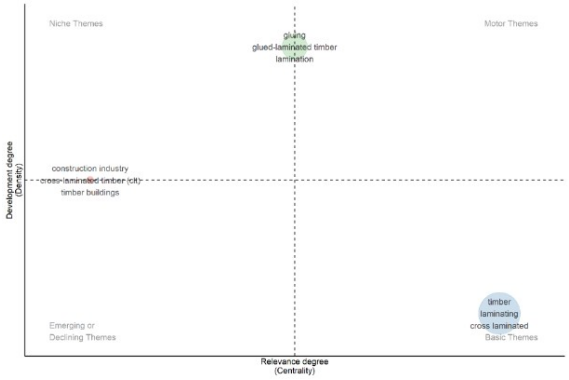

Figure 8 Thematic Map (Research Visualization Map)

This graphic illustrates a thematic map of research with two main dimensions: Degree of Relevance (Centrality) and Degree of Development (Development Degree). Several research themes are positioned in different quadrants, indicating their relevance and progress within the literature. Motor Themes: Themes with high levels of relevance and development, such as Gluling, Glued-Laminated Timber, and Lamination. These themes are located in the upper right quadrant, highlighting their importance and rapid advancement in plywood-related research. Basic Themes: Themes such as Timber, Laminating, and Cross Laminated are in the lower left quadrant, which shows that although they have high relevance, these topics are more fundamental and stable in their development. Niche Themes: Other themes, such as Construction Industry, Cross Laminated Timber (CLT), and Timber Buildings, are located in the lower left section, indicating that while they are relevant, these topics are still in a more limited stage of development. This map provides insights into the evolution of topics in plywood research and its applications in the construction industry, with a focus on more developed and relevant themes.

VOSViewer Analysis

The data obtained from Scopus was then analyzed using the VOSViewer application as follows

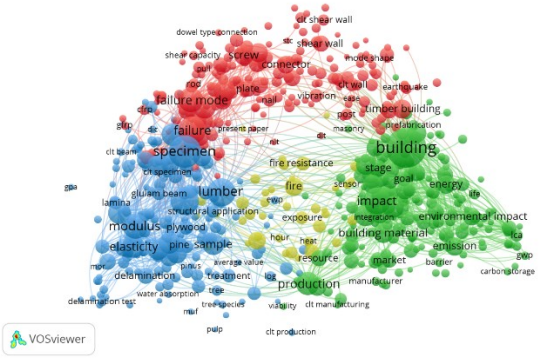

Figure 9 Analisis Network Visualization

This Network Visualization Analysis image is a bibliometric analysis visualization that shows the relationships between keywords in research on wood-based building materials, using VOSviewer. This analysis divides the research into three main clusters: Red Cluster: Focuses on testing the durability and failure of wood materials, with keywords such as "failure mode," "specimen," and "shear capacity."

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This cluster highlights the mechanical aspects of wood in construction applications. Blue Cluster: Highlights the physical properties of wood, such as "lumber," "modulus," and "elasticity," which are related to testing the mechanical characteristics of wood materials. Green Cluster: Describes the environmental impact of using wood, with keywords such as "building material," "impact," and "emission," which are related to sustainability and the reduction of carbon emissions in construction. The connecting lines between keywords illustrate the interrelation of these topics in existing publications, indicating that current research is more focused on mechanical and environmental aspects, with opportunities for further integration between the two. This visualization provides insights into the main research trends and directions that can be developed for further studies on wood materials for sustainable buildings.

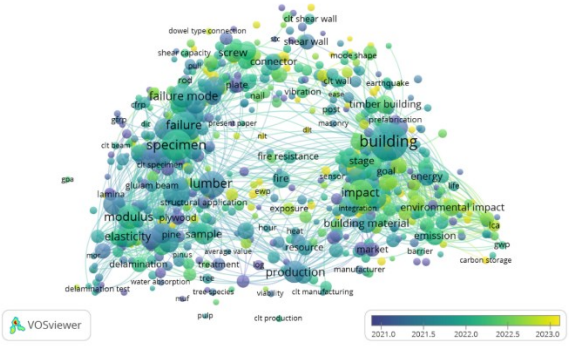

Figure 10 Analisis Overlay Visualization

The Analysis Overlay Visualization image shows the results of a bibliometric analysis using VOSviewer on the relationships between keywords in research on wood materials for building construction. This visualization covers the period from 2021 to 2023, with colors representing the year of publication.

Research Clusters:

Red and Blue Clusters: Focus on the mechanical aspects and testing of wood materials, such as "failure mode", "specimen", and "lumber". Research in these clusters is predominantly about testing the strength of wood.

Green Cluster: Highlights the environmental impact and sustainability of wood materials in construction, with keywords like "building material", "impact", "emission", and "energy".

Temporal Developments:

Colors indicate the progression of research from 2021 to 2023, with increased attention to sustainability and environmental impact in 2023, as seen in keywords such as "impact", "energy", and "emission".

The research indicates a shift in focus from testing wood strength towards issues of sustainability and environmental impact, reflecting a growing trend in the wood-based construction industry.

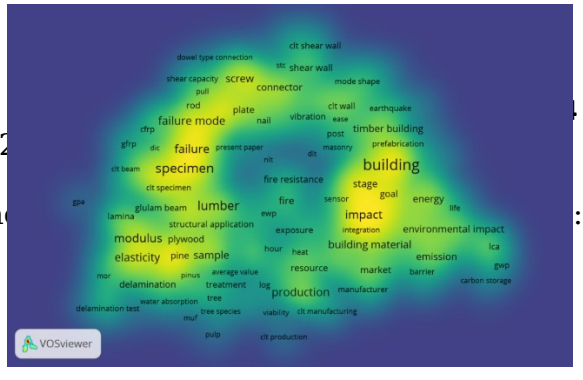

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Figure 11 Analisis Density Visualization

This Density Visualization image shows the results of a bibliometric analysis using VOSviewer, which maps the relationships between keywords in research on wood materials for building construction. This visualization uses a heatmap to illustrate the intensity of keyword associations based on their frequency of occurrence in the analyzed literature.

1. Research Cluster:
   - Wood Mechanics: Focuses on testing the strength of wood with keywords such as "failure mode," "specimen," "modulus," and "elasticity."
   - Sustainability and Environmental Impact: Highlighting topics such as "impact", "building material", "environmental impact", and "emission".
2. Patterns of Correlation:
   - Research has mostly focused on the technical aspects of wood (its strength and material properties) as well as the environmental impact of its use in building construction.
   - Research on wood materials for building construction has shown a shift in focus from material strength testing to sustainability and environmental impact, reflecting increased attention to sustainability issues in the construction industry.

CONCLUSION

This study provides a bibliometric mapping of laminated timber research from 2015 to 2025 using Scopus-indexed publications, offering quantitative evidence on publication growth, dominant subject areas, leading journals, prolific authors, and the evolution of thematic emphases. The findings reveal a substantial increase in research output over the examined period, with publication activity peaking around 2023, and with Engineering and Materials Science emerging as the most prominent subject domains, underscoring the technical and structural character of the field. Keyword-based analyses and VOSviewer cluster visualizations demonstrate clear interconnections between material/mechanical performance topics and sustainability-oriented themes, as well as an emerging shift of research attention toward environmental impact, emissions, energy, and decarbonization-related issues in more recent years. Methodologically, the combined use of RStudio and VOSviewer strengthens the analysis by linking descriptive trend results with network- and theme-level knowledge structures, enabling the identification of well-developed “motor themes,” stable foundational topics, and underexplored areas. The study contributes practical implications for researchers by

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indicating potential research gaps, particularly in integrating structural performance with environmental metrics and in strengthening cross-disciplinary design and stakeholder integration. However, the analysis is constrained by the coverage and metadata completeness of the Scopus dataset, which may limit citation-based interpretations and introduce database-related bias. Future work is recommended to triangulate findings with other databases (e.g., Web of Science), extend to deeper citation/co-citation analyses, and conduct focused mapping of critical subtopics such as fire resistance, durability, seismic performance, and life-cycle/environmental assessment to provide more prescriptive directions for research and application.

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