AN OVERVIEW AND SCIENTOMETRIC STUDY OF GLOBAL PREFABRICATED BUILDINGS

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Abstract

In the architecture, engineering, and construction (AEC) sector, prefabricated building has emerged as one of the most important research areas and drawn a lot of academics and professionals in recent years. On the other hand, not many studies have carried out a thorough analysis of the global advancements in prefabricated building research. In this study, co-authors, co-words, and co-citation analyses are performed using the scientometric approach to examine the literature on prefabricated buildings published in the last 10 years. According to the analysis's findings, Bruno Dal Lago received the most co-citations of any researcher studying prefabricated buildings, making him the most influential researcher in his country or region. Additionally, it was discovered that the top three subject areas to which prefabricated building research belonged were engineering, civil engineering, and construction and building technology. "Cladding panel," "precast concrete," and "project" earned the most citation bursts out of all the keywords included in the gathered articles. Additionally, 11 co-citation clusters containing the themes of precast facades, carbon reduction, waste management, progressive collapse, delay, precast structures, laser scanning, and prefabricated residential buildings were found in the articles. Researchers and industry professionals in this sector should gain a thorough understanding of the current state of worldwide prefabricated building research from this paper.

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1. Introduction

Global temperatures are rising as a result of human activity-induced carbon emissions, which poses major environmental challenges and calls for an immediate social response. Carbon emissions are rising as a result of all facets of human activity. Of these, 25% of the total CO2 emissions are attributable to energy use in building activities. Using prefabricated buildings can help cut down on carbon emissions produced over the course of a building's whole life. Prefabrication takes place off-site, followed by installation on-site, in the construction of prefabricated buildings [1].While off-site prefabrication is the manufacturing process that combines various materials at a specialist facility to generate prefabricated components, on-site installation is the procedure that installs each individual component [2-4]. During a project, prefabricated structures offer a number of advantages over traditional construction methods, including reduced labour requirements, quicker construction times and prices, less pollution caused by construction, simplicity of maintenance and repair, and simpler disassembly and reconstruction [5-7]. Prefabricated buildings are becoming more and more commonplace due to the advantages outlined above. Several nations and areas are encouraging the construction of prefabricated buildings to differing degrees based on their

present levels of resource, energy, and economic development [8-10].

Urban regions need large housing developments, just as he predicted. monetary, long-term, and resource limitations in these projects have made prefabrication—one of the speedy building methods that effectively lowers construction costs—possible [11-13]. Prefabrication, or prefab, is the process of making components in factories or temporary structures and then moving them to the installation site. Terms like panelized, modular, manufactured, readymade, production houses, off-site buildings, industrialised building system, and others are used to describe prefabrication. After this technology was initially launched in the mid-1880s, the necessity for it increased during World War II [14-17]. Conventional construction techniques have been superseded by prefab technologies in countries with larger manufacturing sectors and smaller labour forces.

This technique has also been used by colder countries due to a reduction in outdoor working hours. In Sweden, prefabricated construction makes up 84% of the building sector, according to government figures.

Conventional urban housing techniques must be used in highly crowded locations with limited funding and resources. One such strategy that can improve the way that building is done now is prefabrication. Prefabrication is a proven technique that is used in many nations worldwide and is widely recognised. Prefabrication projects need a lot of work and span multiple project phases. Acquiring raw materials, manufacturing, shipping, and installing prefabricated pieces on a site are some of the most distinctive and significant aspects. Following completion of the project, an analysis of the finished products' performance on-site verifies that the anticipated design goals were met, fosters process development, and points out areas of unmet research needing further investigation. Technology has a way of growing as it improves itself through increases in the fields of research and development. The prefab sector is seeing a constant increase in demand for the adoption of new technology.

Even with the aforementioned literature reviews on prefabrications, each review to date has focused on a single component of prefabrications, such as energy performance, supply chain management, or structural design and performance. There are few reviews that offer a high-level assessment of global research trends on prefabricated buildings. The bulk of the publications discussed in these papers were published prior to 2017, with the exception of a few recent reviews. Nevertheless, the field is growing rapidly—more than 200 articles are released each year (Fig 1 and table 1). An analysis and current review of the pertinent literature are needed to show the latest research trends. Consequently, this study set out to perform a scientometric literature review on prefabricated houses manufactured within the last ten years. Scientometrics is a type of quantitative research that helps academics understand how related a certain subject is to other subjects. The scientometric technique includes thorough assessments of the topics, keywords, publications, authors, institutions, and citations in the literature. This essay will use the scientometric research approach to visually examine and discuss recent prefabricated building literature in order to highlight the state and direction of prefabricated building research.

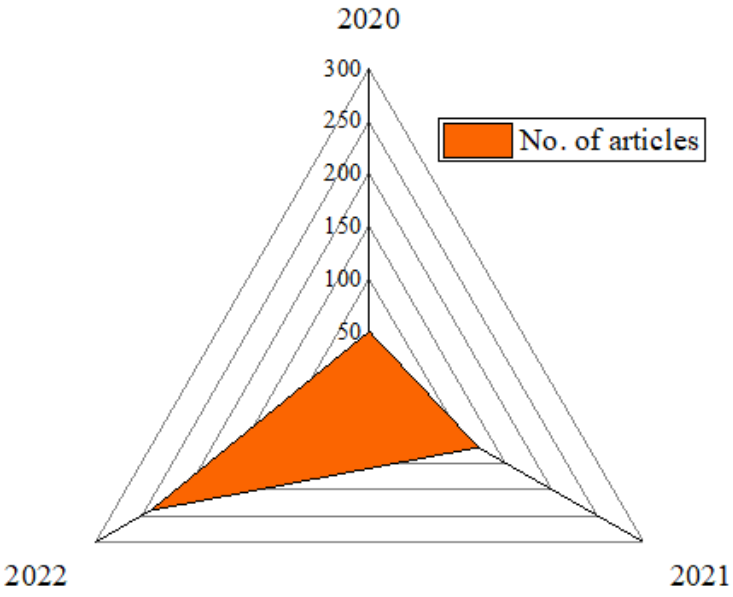

FIGURE1:Thenumberofarticlesonprefabricatedbuildingsfrom1990to2019.

TABLE1:Top11subjectcategorieswiththestrongestcitationbursts.

Subjectcategory	year	Strength
Appliedphysics	2021	2.7005
Architecture	2021	2.8017
Environmentalscience	2022	5.8137
Environmentalscienceandecology	2020	2.7965
Environmentalstudies	2022	2.9273
Greenandsustainablescienceandtechnology	2020	2.8502
Manufacturingengineering	2020	2.5941
Materialsscience,characterization,andtesting	2021	3.7124
Mechanicalengineering	2022	2.7214
Transportation	2021	3.3969
Transportationsciencesandtechnology	2022	4.0585

2. Prefabricated System

Lately, in an effort to enhance the structural performance and to shorten the overall building duration, Muhammad suggested a new reinforcing technology called the Prefabricated Cage technology (PCS). The longitudinal and lateral reinforcements in PCS are formed of a single, solid steel plate or tube and are joined monolithically. For instance, the PCS can be made by welding the edges of a steel plate after uniformly sized rectangular openings are cut out of it. When PCS reinforcement is used in beams, the longitudinal strips serve as the primary reinforcement and the vertical continuous strips serve as stirrups.

Compared to a rebar reinforced section with the same amount of steel, PCS reinforcement helps to give a larger flexural capacity since the longitudinal reinforcements and stirrups are positioned in the same plane from the member

centre. Additionally, this leads to a more effective application of the longitudinal reinforcement. Larger torsional capabilities are provided by PCS's closed-form reinforcement, which is positioned closer to the section's perimeter.

Comparing the production of PCS to the conventional rebar reinforced system, there is higher quality control. Compared to rebar construction, PCS reinforcement is built with more precision, removing the possibility of building errors. With its exact longitudinal and transverse steel spacing, this integral reinforcement technique eliminates some of the possible weaknesses and detailing issues found in conventional reinforced concrete construction with rebar.

2.1 structural performance of prefabricated building systems

The structural performance of prefabricated building systems is under-researched globally, but data on their performance is limited due to a lack of detailed engineering research and case studies. The design approach should ensure stability under natural and manmade loads, transferring loads to the foundation through structural elements, non-structural elements, and inter-component connections. However, complex structural systems like timber-framed houses, non-conventional structures, and prefabricated buildings may lead to non-optimal designs due to a lack of knowledge in load sharing and load transfer. Key factors for designing modular buildings include installation eccentricities, manufacturing tolerances, second-order effects due to sway stability, force transfer mechanism, robustness to accidental actions, and minimum horizontal force in any tie between modules. A performance-based design approach was imposed in countries like Australia, New Zealand, and the USA, involving laboratory tests and structural analyses using finite element software.

2.2 Fire resistance and acoustic performance

Fire safety is a major concern in Australia, with buildings facing the risk of bushfires. Prefabricated modular buildings use double-layer walls and floor-ceilings with fire barriers to prevent smoke or fire spread. However, manufacturing and construction vary between countries and regions, resulting in variations in fire and acoustic performance. Composite materials, lightweight Structural Insulated Panels (SIPs), Cross Laminated Timber (CLT), and Concrete-filled steel hollow sections have played a significant role in the prefabricated construction industry. Full-scale fire testing and computational fluid dynamics have shown that prefabricated, lightweight aerated concrete (PLAC) panels achieve 30 minutes of fire resistance and low thermal conductivity. Further thermo-mechanical cross-section analyses are needed to determine the structural implications of real fire exposure.

2.3 Performance of the Structure under Earth Quake and Wind Load

Prefabricated structures' performance under earthquake and wind loads is crucial. They are transported to the site and erected using horizontal and vertical connections, with lateral bracings or core walls for stability. Annan's study on Modular Steel Building braced frames found their reserve strength was greater than traditional braced systems, suggesting unique detailing requirements should be considered during the design phase to improve seismic response. Gunawardena et al.'s study on corner-supported, multistorey modular structures found that the 10-storey structure performed beyond its linear deformation zone against all six earthquake time histories (Fig 2 and 3).

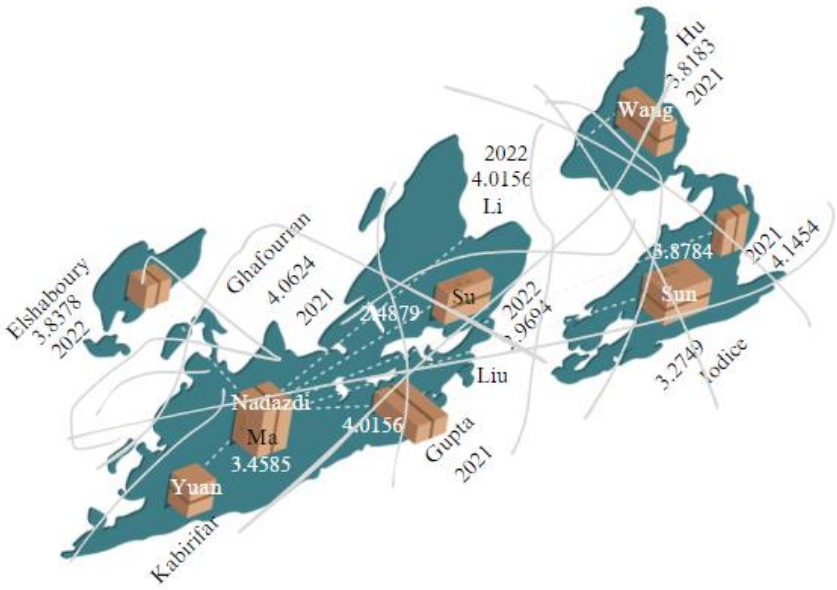

Fig 2 : earthquake and wind load data of the year 2021

Fig 3: map shows the areas with high wind direction in the year 2021

3. Discussion

Although prefabricated structures have become more popular in recent years, the last 10 years have seen a significant increase in interest in this technology. Based on the aforementioned studies of nations and regions, research institutions, and scholarly contributions, there has been a significant growth in study on prefabricated buildings in developing nations during the last five years. Also noticed a change in the emphasis of research in developing nations. For instance, there is still a high demand for building in China. Nonetheless, China is currently dealing with environmental contamination brought on by building activities. As a result, policy-oriented prefabricated buildings are being promoted in a number of Chinese cities. Early on, a lot of emphasis was paid to research on the technology involved in the construction of prefabricated buildings.

However, as sustainability has emerged as one of China's top priorities for national development, research on prefabricated structures has advanced quickly in the last three to five years in the areas of ecology, green building, and environmental sustainability. Building productization has progressively emerged as a key area of study. Construction has just recently begun to industrialise, particularly in underdeveloped nations. The cost of production and construction for prefabricated houses is now rather expensive. To increase the financial advantages of prefabricated buildings, additional research is therefore required on streamlining the industrial chain, reducing labour and material costs, and quickening the pace at which design and construction are coupled.

This study analysed the chosen papers with the subjects, keywords, journals, authors, institutes, and citations using Citespace, a data analysis programme. While the information shown is adequate, this software needs to be updated to further enhance the expression and classification. Software for correlation analysis should be utilised to contrast the variations in outcomes generated by several programmes.

The research timeline can be used to immediately see how the study has changed over time, identify its research norms, and understand the most recent research trends. To help researchers better focus their future work on prefabricated buildings, it is important to keep examining and highlighting the research hotspots from the past few years.

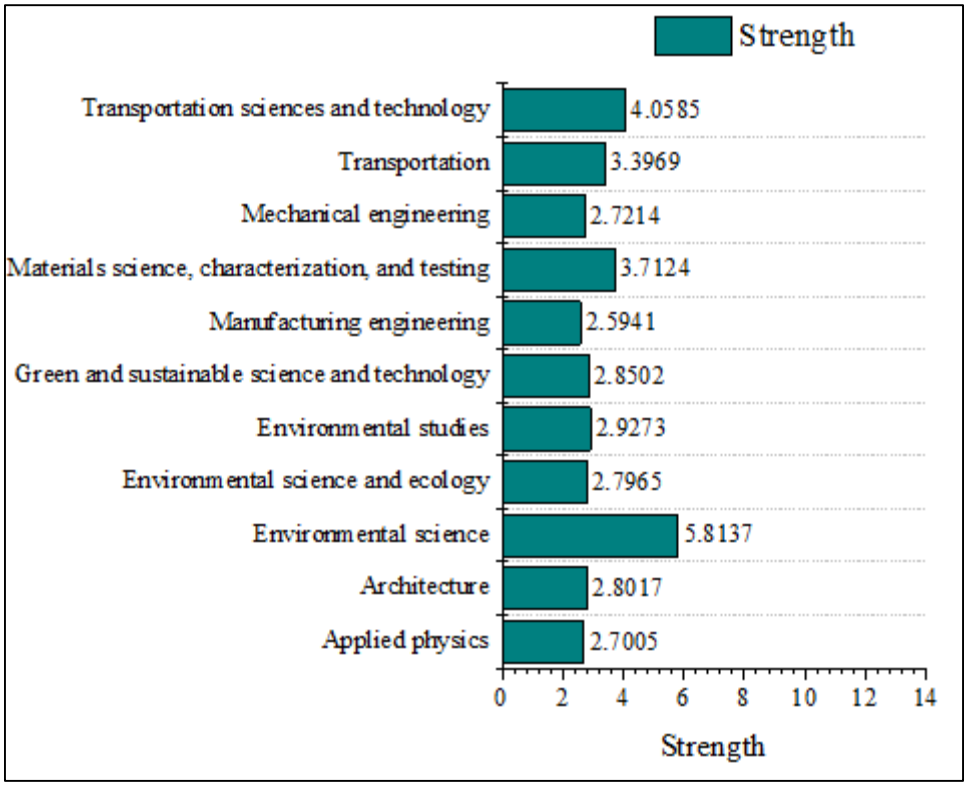

Fig 4. Results shows the wind strength in different sector

4. Conclusion

This paper examines the performance of prefabricated construction systems in the Australian construction sector, highlighting their potential to improve efficiency and sustainability. To ensure these systems offer significant economic benefits, more research is needed. Transportation planning should consider restrictions on movement, laws, and unique traffic control in the construction zone. Further case studies are needed to assess cost, scheduling, and planning for small- and large-scale projects.Design specifications and recommendations for prefabricated structures should be developed in accordance with Australian design standards. Previous research has shown that numerical models and individual component testing are commonly used to evaluate structural performance, but there may be inherent redundancy in the behavior. Full-scale tests, hybrid simulations, and numerical modeling are needed to assess structural performance under fire, wind, and seismic loads.

A key obstacle to marketing prefabricated building construction in Australia is the lack of knowledge about the performance, advantages, and affordability of prefabricated systems. Social and economic research could help improve this. Activities such as surveys, workshops, conferences, and media interviews should focus on this study. Sustainability of prefabricated construction is demonstrated through prior studies, but public education on this information needs improvement. Real case studies on public infrastructure initiatives should be conducted to demonstrate the public's benefits from prefabricated structures.

Competing interests

The authors declare that they have no competing interests.

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Authors' contribution

Author A supports to find materials and results part in this manuscript. Author B helps to develop literature part.

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