Eco-innovation in the Built Environment: A Bibliometric and Systematic Literature Review

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Abstract

Eco-innovation is quickly gaining traction to achieve the goal of long-term sustainability in the built environment. This is due to its capacity to reduce the environmental impacts of our production modes, improve nature's resistance to environmental challenges, and achieve more efficient and responsible use of natural resources while building infrastructure. This study used bibliometric analysis and systematic literature review to assess current state research on eco-innovation in the built environment to identify established and emerging research subjects for future study. The systematic research review we used in our study has not been grasped or assessed by other researchers on this topic. Firstly, based on our methodology, the systematic review identified 84 publications raised from scientific journals, including literature from 2012. Twenty-six publications were used after inclusion criteria were followed. According to our findings, 2021 produced the most articles and citations. China is the leader in publications and citations, and eco-innovation research in the built environment can be classified into five clusters. The research identified various limits that may allow new academics and practitioners to investigate Eco-innovation in new ways. Because most practitioners and policymakers are unfamiliar with this form of research, many remain theatrical and conceptual. Instead of focusing solely on opinion, future studies should focus on practical applications.

Keywords
Bibliometric Analysis, Built Environment, Eco-innovation, Systematic Literature Review

1. Introduction

The built environment consumes large amounts of raw materials and has high energy consumption (Zabalza Bribián et al., 2011). This is because the generation of goods and services is highly dependent on natural resources. It is estimated that half of the total nonrenewable resources consumed is spent on engineering and the built environment. The construction sector consumes 60% of all extracted raw materials globally. Despite accounting for a small portion of the total building cost, building materials such as glass, steel, and concrete consume a significant amount of energy during manufacturing, transportation, and installation processes (Hazarika and Zhang, 2019). It is common knowledge that existing production and consumption systems have unsustainable socioeconomic and environmental consequences. In short to long term, achieving advanced environmental, social, and economic sustainability has become a significant societal demand and a big challenge for the industrial sector (Freire, 2018). Increased environmental pressure and support for modernisation have made innovation one of the most important tools for businesses to achieve long-term success. Combining environmental sustainability and innovative concepts would promote innovative actions that prioritise environmental concerns while promoting innovations and improvements in construction and building projects. Eco-innovation (EI) refers to the outcomes of such innovation (Isa and Abidin, 2021).

Eco-innovation is defined as the development or implementation of new (or significantly improved) products (goods and services), processes, marketing methods, organisational structures, and institutional arrangements that, with or without intent, improve the environment in comparison to relevant alternatives(Isa et al., 2019). Improved processes, products, and organisational practices that mitigate or eliminate negative environmental impacts are examples of eco-innovations (Klewitz et al., 2012). Eco-innovation can boost productivity, but it necessitates a set of conditions for the processes to provide the desired outcomes (Geng et al., 2021). Eco-innovation research has been conducted to examine its theoretical foundations, alternative definitions, and how business models assist eco-innovation (Vallet et al., 2016). This study aims to discuss trends and ideas in eco-innovation research. The following is a breakdown of the paper's structure. Section 2 explains the methodology; Section 3 presents the analysis results. Section4 presents the discussion. Finally, in Section 5, the conclusion, limitations and future research.

2. Research Methodology

A literature review tries to assess and analyse the body of literature in a certain knowledge domain to identify potential research gaps and advise researchers and practitioners (Huang et al., 2020). This study was based on a thorough and bibliometric review of the scholarly literature on Eco-Innovation research. A bibliometrics review is a quantitative analysis of scholarly output on a certain topic using scientific indexes that translate the articles' most essential qualities (Liu et al., 2021). When these two approaches are combined, they can indicate the evolution of scientific studies statistically via bibliometrics and qualitatively via a systematic review of in-depth studies on issues and contents (Boloy et al., 2021). The literature methodology is depicted in Figure 1.

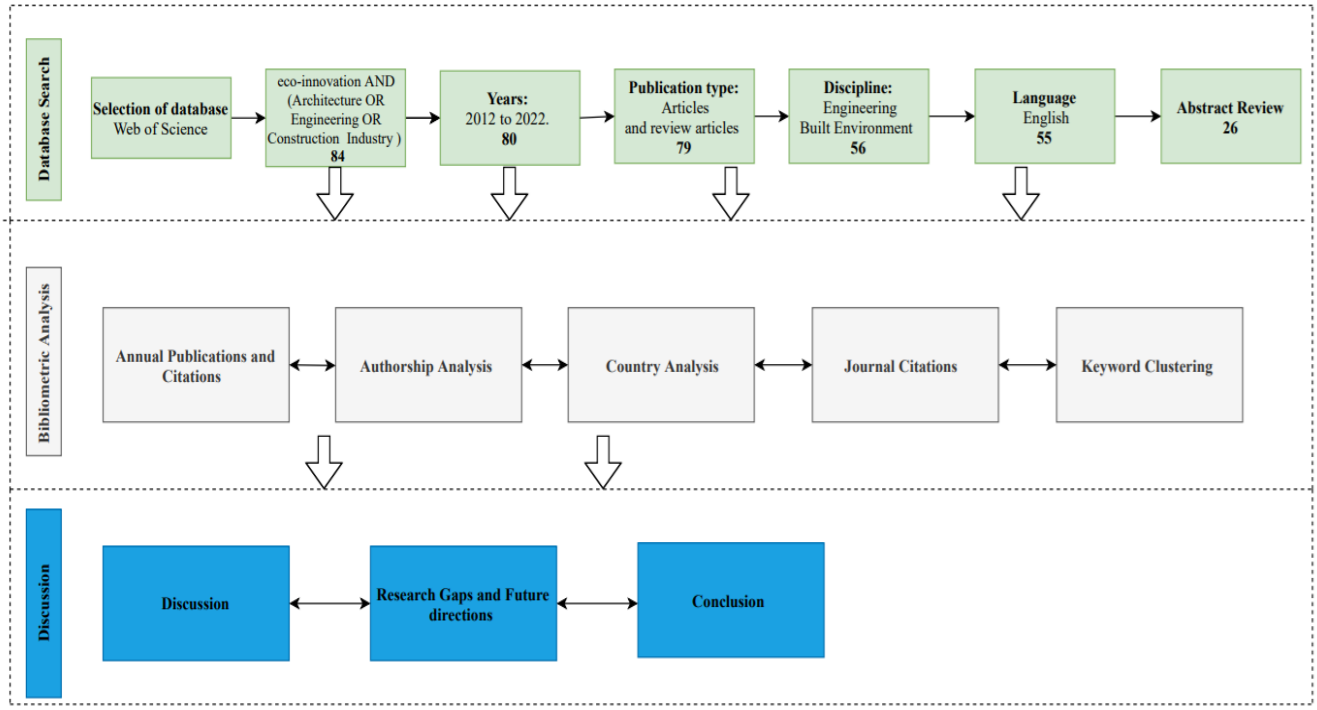

Figure 1. Literature review Methodology

2.1 Systematic Literature Review

A systematic literature review approach was used to facilitate identifying, assessing, and interpreting studies in a specific field by examining and systemising concepts, practices, and theories (Rodrigues and Mendes, 2018). Under the heading of Eco-Innovations, this method entails identifying current trends, practical implications, and future potential. The essential advantage of SLR in discovering, systematically choosing, and critically evaluating current research for answering the defined questions underpins its use in this study.

Web of Science was used to gather publications related to Eco-Innovations in the Built Environment. The database is multidisciplinary and reliable in encompassing an extensive range of articles in domains, such as built environment, engineering management, technology, information systems science, psychology and consumer behaviour, among others (Tandon et al., 2021)

Determining keywords that identify all publications related to the study objectives is a fundamental challenge when doing database queries. Studying the most frequently used terms in the peer-reviewed literature for the topic under consideration is one technique to handle this issue (Bartolini et al., 2019). A database search in January 2022 with the following keywords *eco-innovation AND (Architecture OR Engineering OR Construction Industry).* For the search string, Boolean operators were used, with the [OR] Boolean to increase coverage (between keywords) and the [AND] Boolean to add specificity (between the levels). This is to identify relevant articles published between 2012 and 2022.

The following inclusion criteria were followed

- Article title or abstract has to do with Eco-Innovations in the engineering or the built environment
- Peer-reviewed journal articles
- Published between 2012 and 2022
- Published in the English language

In total, 84 on Web of Science. After refining the articles according to the years, 80 articles met the criteria. Following the refining of the articles according to publications to journals, only 79 articles were left. The journal articles outside the scope of engineering and the built environment were excluded leaving only 56 articles. Following the removal of articles not written in English, 55 articles were left. The title and abstract of 55 articles were assessed, which resulted in 29 articles being excluded for not meeting the eligibility criteria. This resulted in 26 full-text articles eligible for assessment. Atlas.ti 9 was used to undertake a thematic analysis of the SLR of the articles. These evaluations are particularly beneficial for doing in-depth analyses of cutting-edge research and incorporating the results into a specific topic (Abu et al., 2021).

2.2 Bibliometric Analysis

The scientific indexes of the bibliometric study include a historical analysis of the theme, the number of publications, authors, countries of periodical publishing, and keyword frequency, among other things. These indexes help better understand the subject at hand by offering an overview of, for example, the primary authors, publications, and keywords used in the studies and contributing to the most up-to-date research on the subject (Visentin et al., 2020). A bibliometric analysis based on the documents identified throughout the systematic review. VOSviewer software to present results, designed specifically for constructing and visualising bibliometric maps (Souza and Bueno, 2021). VOSviewer is a free computer software that allows you to create and study bibliometric maps using a thorough approach in an easy-to-understand format. The tool gives keyword co-occurrence links, publication citation relationships, and researcher co-authorship networks (Safura Zabidin et al., 2020; Turatto et al., 2021).

3. Results

3.1 Annual Publication and Citations

The number of papers published in Eco-Innovation in the Built Environment from 2012 to 2022. Figure No. 2 Because the data was collected in January 2022, the number of published papers for 2022 was incomplete. However, the number of research papers has increased steadily, from one in 2012 to eight in 2022. From 2012 to 2017, the number of publications fluctuated between 0 and 1. There were three publications in the years 2016, 2018, and 2019. In 2020, the number of publications began to increase, with 4. Eight publications were made in the year 2021. The graph gives a trend that there is an interest in the academic on eco-innovation. This year, there were 183 citations, which is the most in the last decade.

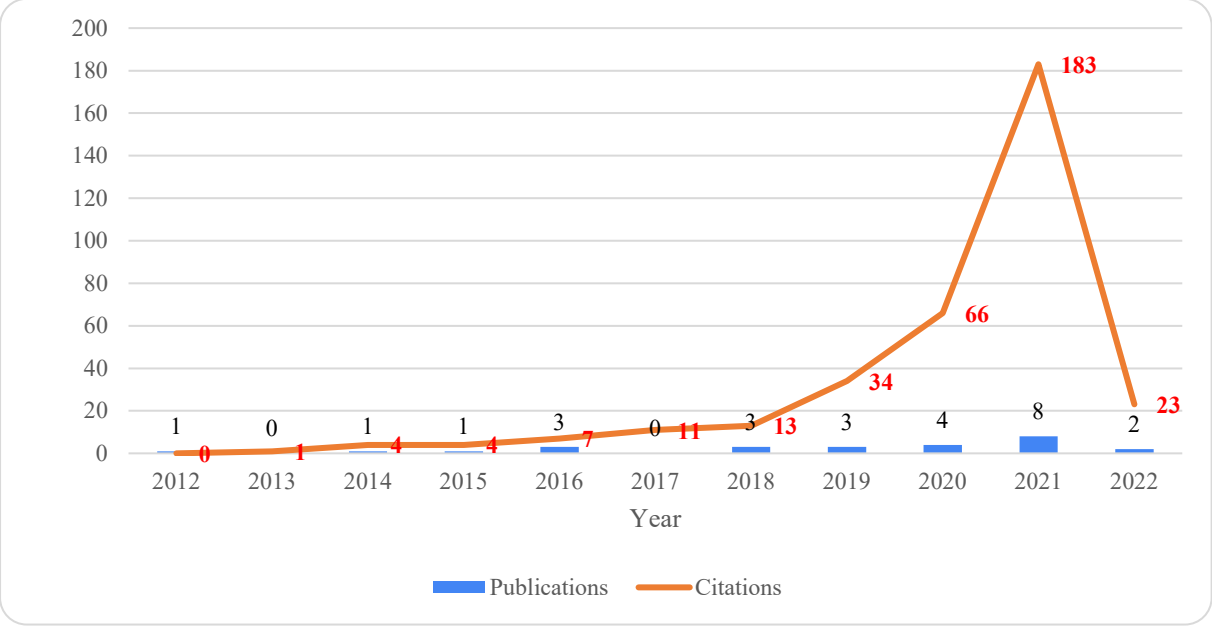

Figure 2. Annual publications and citations

3.2 Publications per country

Certain countries have contributed more to current research than others, and they continue to do so. In terms of the number of publications and citations related to the current study topic, Figure 3 illustrates which countries are the most active. With 10 and 5, respectively, China and France contributed the most publications. These countries, along with Italy, garnered the most citations for their publications, with China accounting for the largest with 207, Italy with 74, and France with 56. Pakistan, Mexico, Japan, Greece and Belgium had one publication each related to the topic. This figure shows that Europe and Asia are the continents driving for eco-innovation in the built environment.

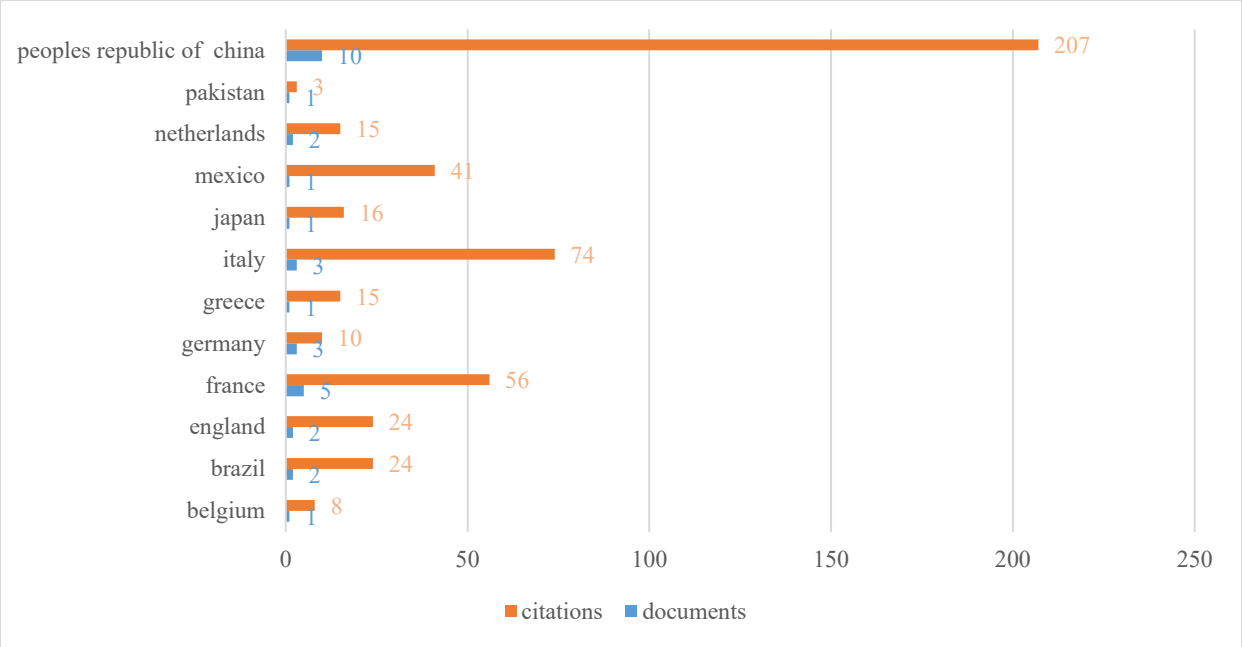

Figure 3. Publications per country

3.4 Authors

The number of citations a researcher receives measures their influence in a field (Figure 4). According to data gathered from the Web of Science database, Figure 4 presents the top writers in Eco-innovation in the Built Environment who have the most citations. The authors with the most citations were Patrizia Ghisellini, Xi Ji, Gengyuan Liu, and Sergio Ulgiati (6). Manzoor Ahmad and Shoukat Iqbal Khattak came in second and third, respectively, with 56 citations. With 41 citations, J. P. Belaud had the least.

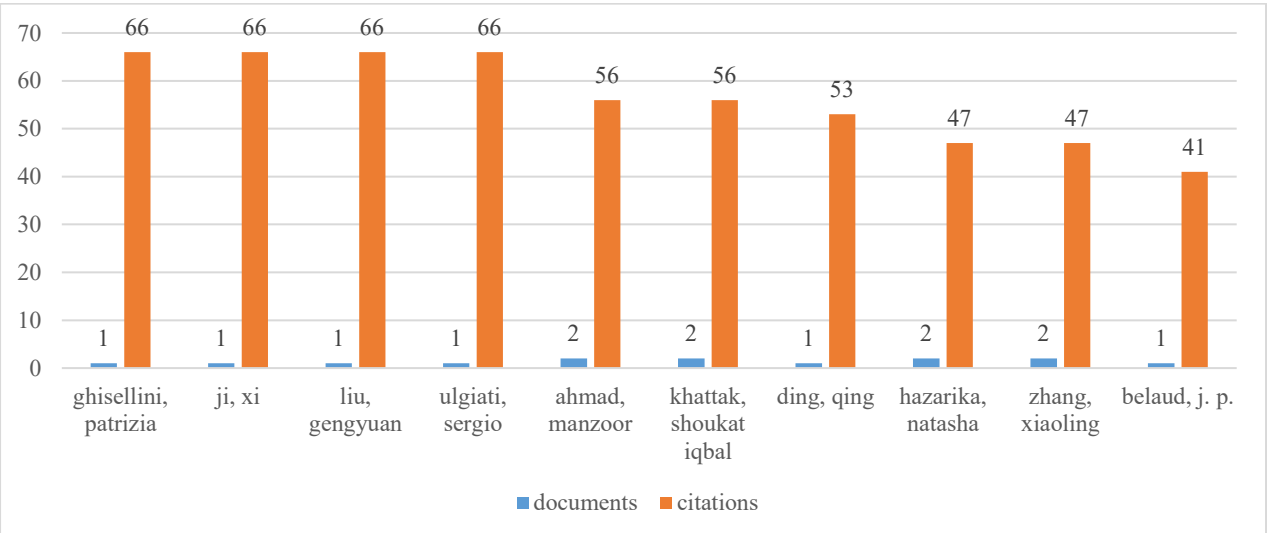

Figure 4. Publication per author

3.5 Journal source

Numerous studies have demonstrated and clarified the importance of reviewing academic publications in any branch of knowledge. In terms of citations and publications, the Journal of Cleaner Production contributed the most to articles on Eco-Innovation in the built environment, followed by Sustainable Production and Consumption. This means that practitioners, researchers, and students interested in doing further study on Eco-Innovation in the Built Environment should prioritise the Journal of Cleaner Production because of its considerable contribution to the field (Figure 5).

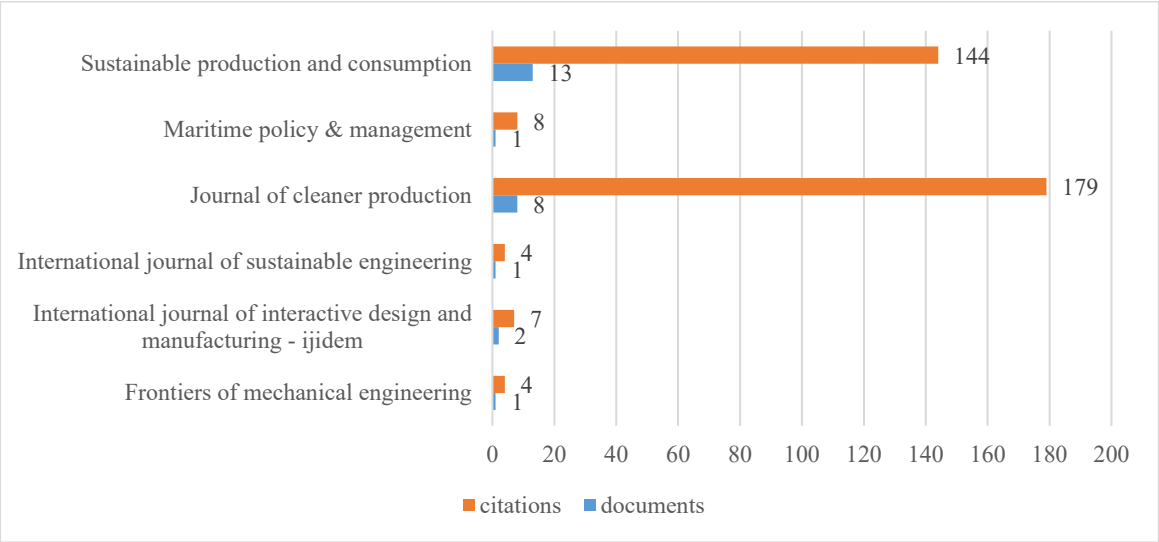

Figure 5. Journal contributions

Clusters of keywords are frequently associated with them, indicating close interdependencies and relatedness (Khan et al., 2010). A cluster is a collection of tightly related nodes, with each node belonging to a specific group (Khudhair et al., 2021). As illustrated in Figure 6 and Table 1, the clusters helped split down the literature into distinct groups that focus on different aspects. The greatest number of keywords per cluster was ten, while the minimum was two, as shown in Table 1. The terms in the same category appear to have a lot in common.

Table 1. Keyword cluster

1 (Red)	2 (Green)	3 (Blue)	4(Yellow)	5(Purple)
Circular Economy Cleaner productions Emissions Empirical- analysis Environmental performance Firm performance Supply chain management Sustainable consumption and production	Drivers Environmental innovation Green innovation Impact Orientation Performance Policy Technology	Competitive advantage Design Innovation Life-cycle assessment Management Sustainability Systems	CO2 emissions Empirical-evidence Financial development G7 Renewable energy consumption Research-and-Development	Eco-innovation Triz

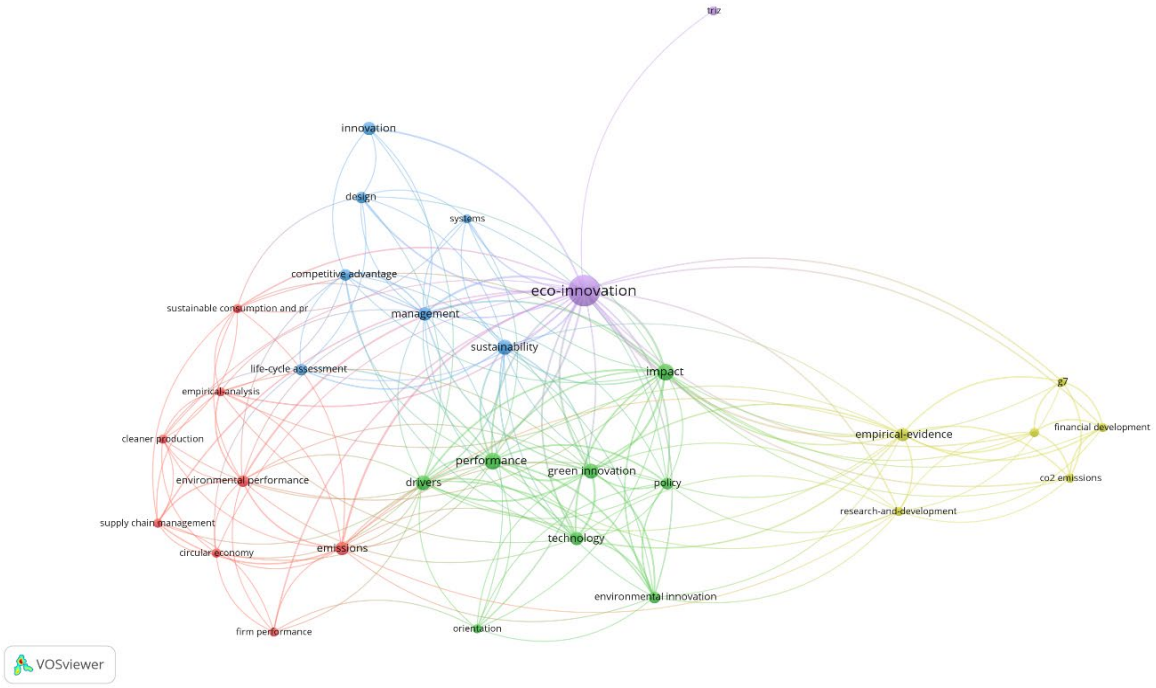

Figure 6. keyword cluster network

4. Discussion- Cluster Analysis

4.1 Cluster 1

In this cluster, the keywords identified were Circular Economy, Cleaner productions, Emissions, Empirical-analysis, Environmental performance, Firm performance, Supply chain management and sustainable consumption and production. In the construction industry, every process or action requires processing and transforming available materials (water, raw materials, energy, and other additional resources) into other materials while generating emissions into the environment (air, land, water). The interdependencies and economic interactions of all the entities participating in the supply chain are also considered in the system's economic analysis (Arampatzis et al., 2016). Waste management goes from an environmental to an economic perspective, with waste being a resource to be maximised rather than a constraint to be minimised, culminating in a circular economy (Negny et al., 2012). Economic performance is improved through environmentally friendly supply chain management, which contributes to sustainable consumption and production. According to Hazarika and Zhang (2019a), theories for empirical investigation of the eco-innovation process and theories as guides for improving the built environment's eco-innovation processes are required. Environmental and company performance can be improved by implementing eco-innovative methods such as life cycle analysis, end-of-pipe solutions, and integrated cleaner technology (Hazarika and Zhang, 2019b). Because firms with better environmentally friendly supply chain management improve economic performance by contributing to sustainable consumption and production, firms with better environmentally friendly supply chain management improve economic performance by contributing to sustainable consumption and production.

4.2 Cluster 2

The main keywords found in this cluster were Drivers, Environmental innovation, Green innovation, Impact, Orientation, Performance, Policy and Technology. According to Hazarika and Zhang (2019b), it is unknown if the factors that drive enterprises to adopt eco-innovation in the past will motivate firms. Green innovation, ecological, environmental, and eco-innovation are all interchangeable terms, according to Motta et al. (2018) and Yang and Lin (2020). Eco-innovation uses resources in a sustainable way to lessen the environmental effect of products and processes throughout their entire life cycle (Negny et al., 2012; De Giorgi et al., 2015). Innovation willingness refers to people's attitudes and organisations' learning and performance goals (Wilde and Hermans, 2021). Companies must make eco-innovation an explicit goal of their strategies to improve performance, which can be accomplished through environmentally friendly technologies (Motta et al., 2018). Eco-efficiency and eco-innovation are terms used to describe a notion that combines resource efficiency (the use of fewer resources to produce a unit of output) and resource productivity. The effectiveness of economic

operations in generating added value from resources encompasses an important part of environmental policymaking (Arampatzis et al., 2016).

4.3 Cluster 3

The main keywords found in this cluster were a competitive advantage, design, innovation, life-cycle assessment, management, sustainability and systems. According to Hazarika and Zhang (2019b), Eco-innovations are likely to create a competitive advantage through market share image building. New methodologies must be established and adapted to incorporate the restrictions of eco-innovation in the early design to accelerate and improve the design of eco-innovation solutions (Negny et al., 2012). Innovation is seen as critical in the built environment for creating profits, lowering manufacturing costs, and enhancing the quality and performance of products and services. The Life Cycle Assessment (LCA) is an important technique for ensuring environmental sustainability. It aims to revise the complicated relationship between environmental factors and the product life cycle, taking the complete product supply chain (Motta et al., 2018). Environmental considerations can be facilitated by applying management approaches such as eco-management and audit systems cost-benefit analysis in the built environment. This comprises the best accessible procedures that are not prohibitively expensive, environmental impact assessments, and the most environmentally feasible alternative (Hazarika and Zhang, 2019a). New or updated methods, practices, systems, and products that enhance the environment and contribute to environmental sustainability are considered innovations (Motta et al., 2018).

4.4 Cluster 4

The main keywords found in this cluster are CO2 emissions, Empirical-evidence, Financial development, G7, Renewable energy consumption and Research-and-Development. As it stands, the environment is at a higher risk of deterioration due to CO2 emissions arising from the excessive use of fossil fuels (Ding et al., 2021). Thus, renewable energy consumption is predicted to reduce CCO2 emissions, given that it emits no or low greenhouse gases. Moreover, financial development, economic growth, and energy use significantly affect CO2 emissions. Firms recognise the importance of product and market demand competitiveness and seek empirical evidence on managing effective product competitiveness (Fernando et al., 2021). Global commerce, technological innovation, and per capita income have all improved significantly in the G7 (most industrialised) countries. If developing countries' built environments are disadvantaged in terms of environmental innovation realities, it is primarily because they cannot afford to invest in and thus benefit from a Research and Development unit; additionally, no permanent educational tool has yet been provided to support both the managerial level and the innovators involved in the enterprises (Khattak et al., 2022).

4.5 Cluster 5

The two main keywords found in this cluster are Eco-innovation and Triz. Eco-innovation can be identified in a product or a process and can be incremental when a component occurs within a large system. At the same time, the system itself stays intact, or radical, when the overall system design changes and hence the way that the parts interact with each other. Theory of Inventive Problem Solving (TRIZ) incorporates the eco-innovative design approach. The TRIZ method without requiring contradiction analysis have been identified in order to solve eco-innovative design tasks (Negny et al., 2012; Chakroun et al., 2014)

5. Conclusion

Eco-innovation is a process to address sustainability in the built environment. This article presents the outcomes based on the Web of Science core collection database from 2012 to 2022. This paper uses VOSviewer and Atlas.ti to analyse the development situation and research hotspots of 26 publications. Clear evidence was found that demonstrates that the Eco-innovation literature in the built environment is highly fragmented. The years 2013 and 2017, no publication was released. While 2018 saw the highest number of publications (8). Thus, this paper contributes to extending the current dominant theoretical perspectives. In total, 12 countries/territories were recorded as publication geographic distributions, and the most productive ones were the Peoples Republic of China, Italy and France. European countries make up 53% of the publications, while Asia makes up 38%, South America makes up 6%, and North America makes up 3%. Africa and Oceania have no representation. Future studies should look at eco-innovation in African and Oceania countries. The study also found sustainable production and consumption and journal of cleaner production to the leading journals in terms of impact and publications. Our network analysis conclusion shows that eco-innovation in the built environment can be divided into five clusters, with the popular cluster being cluster 1.

The main limitation comes from our initial search. We focused only on articles and reviews covered by the Web of Science Core Collection, but that database does not cover all journals from their foundation as the search was

up to January 2022. Furthermore, future research should develop a framework for eco-innovation in the built environment.

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