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Integrating Digital Technologies and Lean Construction for Waste Management in Developing Countries: A Bibliometric Review

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Abstract

Construction waste continues to pose a significant challenge to the global construction industry, contributing to environmental degradation, resource depletion, and reduced project efficiency. This study presents a bibliometric review of research on integrating Digital Technologies into construction waste management (CWM), analyzing 30 peer-reviewed publications indexed in Scopus between 2020 and 2025. Bibliographic data were retrieved exclusively from Scopus database and VOSviewer was employed for science mapping, thematic clustering, and keyword co-occurrence network visualization. The findings indicate that Chile and Spain ranked highest, with four publications each, followed by Australia and Egypt with three publications each. Among the BRICS countries, only China (three publications) and Brazil (two publications) met the inclusion criteria, Russia, India and South Africa (three of the five founding BRICS members) produced no papers that qualified. Given that South Africa has an advanced construction sector within the African context, its total absence is especially notable. Egypt was the only African country represented in the dataset. The journal Buildings occurred as the most prominent journal publication in this research domain. Scientometric analysis identified three dominant thematic clusters: (1) information and process integration, highlighting BIM's role in lifecycle data management and material quantification; (2) systems and lean production, linking BIM to waste reduction through process optimization; and (3) industry and practical implementation, focusing on applied waste management strategies within construction projects. Based on the findings, the study recommends that policymakers and practitioners adopt integrated digital-based waste management frameworks that align digital modeling processes with lean construction principles and lifecycle. It is recommended that future studies expand regional participation, develop standardized digital-based waste data frameworks, and strengthen integration with lean and circular economy principles to enhance sustainable construction practices.

Keywords
Digital Technologies, Construction Industry, Waste Management, Bibliometric Literature

1. Introduction

Construction activities generate large volumes of waste each year, making the sector one of the leading contributors to global solid waste (Alotaibi et al., 2024). Moreso, Javed et al. (2025) in his study also stressed that this remains a major concern across both developed and developing economies. The increasing emphasis on sustainable development has led the construction industry to recognise its significant environmental impacts, including resource depletion and environmental degradation (Muhamad et al., 2025). Construction processes contribute to land deterioration, excessive material consumption, and different forms of pollution, which negatively affect both the environment and human well-being (Nadeem et al., 2026). For instance, Islam et al. (2024) highlighted that buildings are responsible for substantial environmental emissions and resource use, thereby emphasising the need for improved practices during the construction phase. Similarly, Boakye and Adanu (2022) pointed out that construction-related activities such as dust generation, noise, and vibration have serious impacts on environmental quality and worker health. Nevertheless, construction waste remains a complex and difficult concept to measure and manage effectively. According to Spišáková et al. (2021) construction waste is often treated as a high-level and abstract concept, making systematic measurement and control challenging. Also Wen et al. (2025) added that traditional waste management approaches have largely failed to adequately capture and reduce the impacts of construction waste. Oliinyk et al. (2024) highlighted that these limitations highlight the need for more advanced and data-driven approaches to improve waste management practices in the construction industry. In recent years, digital technologies have emerged as potential solutions to address inefficiencies in construction processes. Ellis et al. (2025) and Shojaei and Burgess (2022) explain that lean construction principles focus on reducing waste and improving efficiency through effective planning and process optimisation. They further argue that there is an increasing need to integrate digital technologies into lean construction, as these tools enhance accurate material quantification, support efficient lifecycle data management, and enable seamless integration of project processes. However, most previous studies have examined digital technologies and lean construction practices as separate approaches, with limited research exploring their integration into a unified framework (Yang et al., 2025). Integrating digital technologies with lean tools can significantly enhance waste reduction efforts. This is because lean construction tools require accurate data and improved collaboration, which can be facilitated by digital technologies such as BIM and artificial intelligence (Gang et al., 2024). However, despite the growing interest in digital transformation within the construction industry, research remains fragmented and geographically concentrated, particularly in developing countries (Adewale et al., 2024). There is limited evidence on how digital technologies can be effectively integrated with lean construction practices to improve construction waste management in developing countries (Bui et al., 2024). Therefore, there is a need for understanding literature gaps in relation to digital technologies with focus in waste management in developing countries.

1.1 Objectives

This study aims to bridge the gap in existing literature in developing countries by systematically identifying key research themes related to the integration of digital technologies and lean construction management. Furthermore, it seeks to examine the most influential countries and academic journals contributing to this field, while also identifying critical research gaps and proposing future research directions, particularly within developing country contexts.

2. Literature Review

The construction industry in developing countries continues to face significant challenges, including low productivity, project delays, cost overruns, and inefficient resource utilisation (Nishaant et al., 2025) and (Ntuli et al., 2025). These challenges are often attributed to fragmented project delivery systems, limited technological adoption, and inadequate management practices (Mohd et al., 2025). In response, lean construction and digital technologies have emerged as promising approaches to improve efficiency and performance (Ellis et al., 2025). While both concepts have been widely studied in developed countries, their integration within developing countries remains relatively underexplored (Liu et al., 2024). Lean construction is derived from lean manufacturing principles and focuses on maximising value while minimising waste throughout the project lifecycle (Ximenes & Pramesti, 2025). It emphasises continuous improvement, efficient workflow, and collaboration among project stakeholders (Kamble, 2025). Moreover, Mohd Ikram et al. (2025) argues that in developing countries, the adoption of lean construction practices remains at an early stage. Studies indicate that many construction firms still rely on traditional management approaches, which limit their ability to achieve optimal project outcomes (Aslam et al., 2024). Factors such as lack of awareness, insufficient training, and resistance to organisational change continue to hinder the widespread implementation of lean principles (Nangesh, 2026).

At the same time, digital technologies are transforming the global construction industry by enhancing productivity, communication, and decision-making (Bidhendi et al., 2025). Technologies such as Artificial Intelligence (AI), Information Modelling (BIM), the Internet of Things (IoT), cloud computing, and Geographic Information Systems (GIS) enable real-time data sharing, improved visualisation, and better coordination among stakeholders (Adejola & Nwobodo-Anyadiegwu, 2025). Despite these benefits, Qadir et al. (2025) notes that the adoption of advanced digital technologies in developing countries remains limited. He further claims that any firms operate with basic digital tools, and the transition to more sophisticated systems is constrained by high implementation costs, lack of technical expertise, and weak institutional support.

The integration of digital technologies with lean construction management has been identified as a critical pathway for improving construction performance (Alnajjar et al., 2025). Digital tools serve as enablers of lean principles by facilitating transparency, collaboration, and process optimisation (Shukla et al., 2026). For instance, BIM enhances coordination and reduces design errors, thereby minimising rework and waste. Similarly, IoT technologies enable real-time monitoring of construction activities, improving resource efficiency and supporting just-in-time delivery systems (Bamigboye & Kirgiz, 2025). As a result, the combined application of digital technologies and lean practices has the potential to significantly enhance project delivery outcomes in developing countries, however, the integration of these approaches is still in its infancy. The majority of existing studies focus on either lean construction or digital technologies in isolation, with limited attention given to their combined application (Mohan et al., 2026). Furthermore, most empirical research is concentrated in developed regions, resulting in a lack of context-specific insights for developing countries (Ibrahim et al., 2025). This gap is particularly evident in Africa, where the construction industry is characterised by informal practices, limited technological infrastructure, and capacity constraints (Mararo et al., 2025). This deficiency underscores the imperative for comprehensive research examining the synergistic integration of digital technologies and lean methodologies within the unique socio-economic and infrastructural landscapes of developing nations, particularly concerning waste management (Sarhan & Pretlove, 2021);(Windapo & Umeokafor, 2023).

For example, design errors are a significant source of waste in construction, which can be mitigated through Building Information Modelling (Mitera-Kiełbasa & Zima, 2025). Specifically, Lean Design, a subset of lean construction, leverages digital tools like BIM to optimize the design phase, thus preventing waste at its source rather than managing it downstream (Aziz et al., 2024). However, the implementation of BIM in developing countries, particularly in regions like sub-Saharan Africa, faces significant barriers, including high software and training costs, insufficient cross-field expertise, limited software interoperability, and a general shortage of BIM skills (Saliu et al., 2024). Furthermore, the capabilities of IoT, particularly when integrated with BIM for sustainability, remain largely unexplored within the existing literature, highlighting a critical research void (Sepasgozar et al., 2020). Further investigation into the pragmatic applications of IoT in conjunction with BIM for lean construction practices in developing nations is warranted to elucidate pathways for enhanced waste reduction and improved project delivery (Landim et al., 2022).

In the African context, the adoption of lean construction has been slow but gradually increasing (Omer et al., 2025). Some studies highlight the potential benefits of lean practices in reducing waste and improving project performance, yet their practical implementation remains inconsistent (Elmalky et al., 2024). Similarly, digital transformation in construction across Africa is uneven, with countries such as South Africa demonstrating relatively higher levels of adoption compared to others (Maru et al., 2024). Nevertheless, the overall level of integration between digital technologies and lean construction remains limited across the continent (Precious, 2024).

South Africa presents a unique case within the developing world, as it exhibits a relatively advanced construction sector with growing interest in both lean practices and digital innovation (Adetoro et al., 2025). Research indicates that the adoption of BIM and other digital tools is gaining momentum, particularly in large-scale projects. Additionally, there is increasing recognition of the importance of lean construction in improving efficiency and sustainability (Yang et al., 2025). However, several barriers continue to impede full integration, including high costs of technology, shortage of skilled professionals, resistance to change, and fragmentation within the industry (Chen et al., 2024). These challenges highlight the need for strategies that are tailored to the local context. The existing literature also reveals several critical gaps. Firstly, there is a lack of comprehensive frameworks that guide the integration of digital technologies and lean construction in developing countries (Pittri et al., 2025). Secondly, empirical studies examining real-world applications of this integration are limited, particularly within African contexts (Sepasgozar et al., 2020). Thirdly, there is insufficient focus on small and medium-sized enterprises, which constitute a significant

portion of the construction industry in developing countries (Saka et al., 2020). Lastly, the role of policy and institutional support in facilitating adoption has not been adequately explored (Saliu et al., 2024).

Given these gaps, future research should focus on developing context-specific models that address the unique challenges faced by developing countries (Becerra-Encinales et al., 2024). There is also a need for empirical studies that examine the practical implementation of digital-lean integration in real construction projects. Furthermore, research should explore cost-effective and scalable solutions that can be adopted by smaller firms. Strengthening policy frameworks and promoting capacity building will also be essential in supporting the transition towards more efficient and sustainable construction practices.

The integration of digital technologies and lean construction management offers significant potential to improve the performance of the construction industry in developing countries (Oke et al., 2023). However, the current level of adoption remains limited due to various economic, institutional, and technical challenges (Rinchen et al., 2024). While countries such as South Africa show promising progress, there is still a need for more research, practical frameworks, and targeted interventions to fully realise the benefits of this integration (Favour et al., 2024). Addressing these issues will be critical in enhancing productivity, reducing waste, and achieving sustainable development in the construction sector.

3. Methods

A Bibliometric literature review refers to the study of academic publishing that uses quantitative methods or statistics to analyze and describe publications, citations and their patterns to assess research impact and trends and to highlight relationships between published works (Laolang et al., 2022). It helps map scientific landscapes, identify influential works, and spot emerging topics(Yan & Zhiping, 2023). In this type of study, the author(s) introduces bibliometrics and define its key terminology and concepts, including relational and evaluative bibliometrics.

The Scopus database was used in this study due to its wide-ranging coverage of multidisciplinary publication (Baas et al., 2020). Additional databases were deliberately excluded in this study in order to minimize the time required for the identification, sorting, and elimination of duplicate or overlapping records (Singh et al., 2021). Guided by selected keywords aligned with the research objectives, an initial search of the database was conducted in March 2026, resulting in the retrieval of 71 documents. The author further refined the search limited to subject areas including Engineering, Environmental and Social and the documents produced reduced to 63. A further refinement was applied limiting the search to Journal Articles (31) written in the English language and the final result was a total of 30 documents as seen in the Table 1 below. A time limit of range between 2020-2025 was applied to this search as the authors interests lies in determining the historical trends of the past 5 years. The 30 documents were then downloaded into the "Comma-separated values (CSV) file format due to its compatibility with the VOSviewer software widely used for Scientometric analysis.

Table 1: Data search protocols and document synthesis

Database and search string	*Scopus: "((TITLE-ABS-KEY (Waste AND Management AND Construction AND Lean AND BIM) AND PUBYEAR > 2019 AND PUBYEAR < 2026 AND (LIMIT-TO (SUBJAREA, "ENGI") OR LIMIT-TO (SUBJAREA, "ENVI") OR LIMIT-TO (SUBJAREA, "SOCI")) AND (LIMIT-TO (DOCTYPE, "ar")) AND (LIMIT-TO (LANGUAGE, "English"))*	71
Refinement 1: Subject area	"Engineering", "Environmental" and "Social"	63
Refinement 2: Document Type	Articles	31
Refinement 3: Language	English	30

4. Data Collection

The refined dataset of 30 documents was meticulously extracted from the Scopus database, ensuring adherence to the predefined search parameters and exclusion criteria. This comprehensive data collection process laid the groundwork for a robust bibliometric analysis, which employed VOSviewer to systematically map the thematic landscape and identify prevalent research trends within the dataset. This approach enabled the identification of salient features within the studies, facilitating the exploration of current and future research hotspots and institutional collaborations. This

analytical process involved generating co-occurrence networks of keywords, authors, and countries, thereby illuminating the intellectual structure and geographical distribution of research contributions in the field.

5. Results and Discussion

5.1 Numerical Results

Table 2 below presents a list of influential authors regarding integrated digital technologies with lean construction. It shows the number of articles and Scopus citations per author., revealing that each author had a minimum of 2 articles that are indexed in Scopus with a minimum of 8 citations. The total link strength of the authors is depicted in the fourth column showing zero link strengths for all. The table shows that the top authors are Babaeian Jelodar Mostafa, with 2 documents and 31 citations, Drogemuller, Robin M with 2 documents and 19 citations, Herrera, Rodrigo, F with 2 documents, 47 citations and Karaz, Mahmoud with 2 documents and 8 citations and Likita Ayuba Jerry with 2 documents and 31 citations all which have zero link strength. This demonstrates a gap in literature within the subject area.

Table 1: Publication per Author

Author	documents	citations	Total link strength
Babaeian Jelodar Mostafa	2	31	0
Drogemuller, Robin M	2	19	0
Herrera, Rodrigo F	2	47	0
Karaz, Mahmoud	2	8	0
Likita Ayuba Jerry	2	31	0
Omrani, Sara	2	19	0
Rashidian, Sara	2	19	0
Rotimi, James Olabode Bamidele	2	31	0
Teixeira, Jose Cardoso	2	8	0
Vishnupriya, Vishnupriya	2	31	0
			0

Leading journals for Integrating Digital Technologies for Lean Construction Management in Developing Countries
Table 3 below presents the top journals for Integrating digital technologies for lean construction management in developing countries. The table depicts the journals ranking from highest to lowest total link strength. These results were extracted from VOSviewer, a Java-based application that is used to generate maps based on network data, as well as visualize and examine these maps (Umar et al., 2023). The Journal with the highest total link strength is therefore the most important for the study. It can therefore be derived from the table that the top five (5) journals concerning integrating digital technologies into lean construction management in developing countries are Buildings, Smart and Sustainable Built Environment, Sustainability (Switzerland), Ain Shams Engineering Journal and Engineering, Construction and Architectural Management.

Table 2: Leading journals for Integrating Digital Technologies for Lean Construction Management in Developing Countries

Source	Documents	Citations	Total link strength
Buildings	5	79	6
Smart and Sustainable Built Environment	3	58	4
Sustainability (Switzerland)	3	60	3
Ain Shams Engineering Journal	1	79	2
Engineering, Construction and Architectural Management	3	88	2
Journal of Building Engineering	1	25	2
Journal of and Construction Engineering and Management	1	43	2
Production Planning and Control	1	56	2
Journal of Engineering and Applied Science	1	26	2

Iranian Journal of Science and Technology-transactions of civil Engineering	1	14	1

The most productive countries in respect to digital technologies and lean were determined by a citations analysis. The minimum number of documents from a country was set at 2 and set at 7 for citations of a country and of the 24 countries, only 10 met the threshold. Chile (f=4; citations=53), Spain (f=4; citations=49), Germany(f=2;citations=71), Brazil (f=2;citations=8), Portugal (f=2;citations=8), China (f=3;citations=50), Turkey (f=3;citations 46), (Australia f=3;citations75), New Zealand (f=2;citations=31) and Egypt (f=3;citations=130). From this it can be can be derived that Chile, Spain, Germany, Brazil and Portugal were the most productive countries. A further investigation revealed that Egypt was the only African country that met the threshold. Crucially, no qualifying papers were produced in this dataset by South Africa founding member of BRICS with a relatively developed construction sector and significant interest in both BIM adoption and lean approaches. This finding reflects a gap in the broader BRICS research landscape and exposes a deficit in African scholarly output on the subject. It also denotes a missed opportunity and an urgent call to action for South African academics, industry practitioners, and research funding bodies.

Table 3: Publication Per Country

Country	Documents	Citations	Total link strength
Chile	4	53	35
Spain	4	49	26
Germany	2	71	23
Brazil	2	8	21
Portugal	2	8	21
China	3	50	16
Turkey	3	46	16
Australia	3	75	7
New Zealand	2	31	7
Egypt	3	130	4

The bibliometric data provided offers significant insights into the current state of research regarding the integration of digital technologies with lean construction management. Based on the analysis of authors, journals, and geographical distribution, several critical implications and research gaps can be identified. The analysis of influential authors in Table 2 reveals a striking phenomenon: despite the high number of citations for individuals such as Herrera, Rodrigo F. (47 citations) and Likita Ayuba Jerry (31 citations), every top-ranked author exhibited a "total link strength" of zero. This suggests that research in this niche is currently conducted in silos, with a marked absence of co-authorship networks or formal collaborations between the leading scholars.

In the broader context of construction digitalisation, fostering multidisciplinary collaborative networks is considered crucial for ensuring that research transcends isolated discussions and drives meaningful progress. The fragmentation observed here limits the industry's ability to harness synergies between lean process optimisation and digital modelling. Without a unified and collaborative approach, the field risks continuing with "siloed solutions" that may fail to deliver the transformative improvements in productivity and sustainability required by modern megaprojects.

The leading journals for this subject, as shown in Table 3, are dominated by titles such as *Buildings*, *Smart and Sustainable Built Environment*, and *Sustainability*. This indicates that the integration of digital technologies and lean construction is primarily being framed through the lenses of environmental efficiency and smart infrastructure.

While these publications highlight the measurable efficiency gains of synchronized lean-digital implementation—such as reducing excavation durations and improving communication through real-time dashboards—there remains a need for broader industrial engineering and managerial perspectives. The presence of *Engineering, Construction and Architectural Management* suggests an emerging interest in the managerial antecedents of technology adoption, yet research often remains predominantly conceptual with limited empirical validation in certain contexts.

The most significant finding from the citation analysis in Table 4 and the associated text is the stark geographical imbalance. While countries like Chile, Spain, and Germany show high productivity, Egypt is identified as the only African nation meeting the research threshold. The total absence of South African publications in this specific dataset highlights a profound gap in the literature.

This void is particularly noteworthy given that recent studies have identified significant potential for the digitalisation of the South African construction industry to enhance efficiency and transparency. However, there is a documented scarcity of studies focused on understanding the dynamics of on-site process needs and their relation to technology infusion within the South African context. The "call to action" for African academics is therefore underpinned by a need to move beyond international trends and develop region-specific frameworks that address local barriers to adoption, such as those identified in Sub-Saharan African BIM studies.

5.2 Graphical Results

A keywords co-occurrence network analysis was done using all “authors keywords”. 3 clusters were formed from the results are illustrated in Figure 1 below. The three clusters identified provide more than a simple classification of research themes; they reveal a partial theoretical alignment between research on BIM, lean construction, and waste management, which has important implications for the development of the field. Cluster 1 (red), which includes terms such as building information model, information management, information theory, and life cycle, reflects a data-driven perspective. In this cluster, BIM is mainly understood as an information management tool. The prominence of information-related keywords suggests that researchers in this area focus on improving construction through better data integration, interoperability, and lifecycle management, drawing on concepts from information systems and knowledge management. Cluster 2 (green), characterised by keywords such as building information modelling, construction industry, architectural design, and waste management, represents a process-integration viewpoint. Here, BIM is seen as a tool that enhances design efficiency and helps prevent waste. However, waste management appears only in this cluster and does not extend into the lean production cluster. This indicates a key issue: waste is largely treated as a design problem rather than a production problem. This differs from the core principles of lean construction, which are based on the Toyota Production System and emphasise waste reduction during construction processes and workflow management. Cluster 3 (blue), which includes lean production, last planner system, system dynamics, and agile manufacturing systems, is the most theoretically consistent. It is grounded in operations management and systems theory. However, its separation from waste management—found in Cluster 2—is an important observation. It suggests that researchers in lean construction tend to focus more on process efficiency, scheduling, and workflow, rather than directly addressing construction waste.

Generally, the network shows that BIM as an information system, BIM as a design tool, and lean construction as a production system are being studied as largely separate areas. Although they share some common terms, such as building information modelling, they have not yet been fully integrated into a single theoretical framework. This fragmentation is particularly important for developing countries, where practical, integrated solutions are needed. As a result, practitioners must rely on insights from different, loosely connected research areas. At the same time, this gap presents an opportunity for future research to develop more integrated frameworks that combine BIM, lean construction, and waste management.

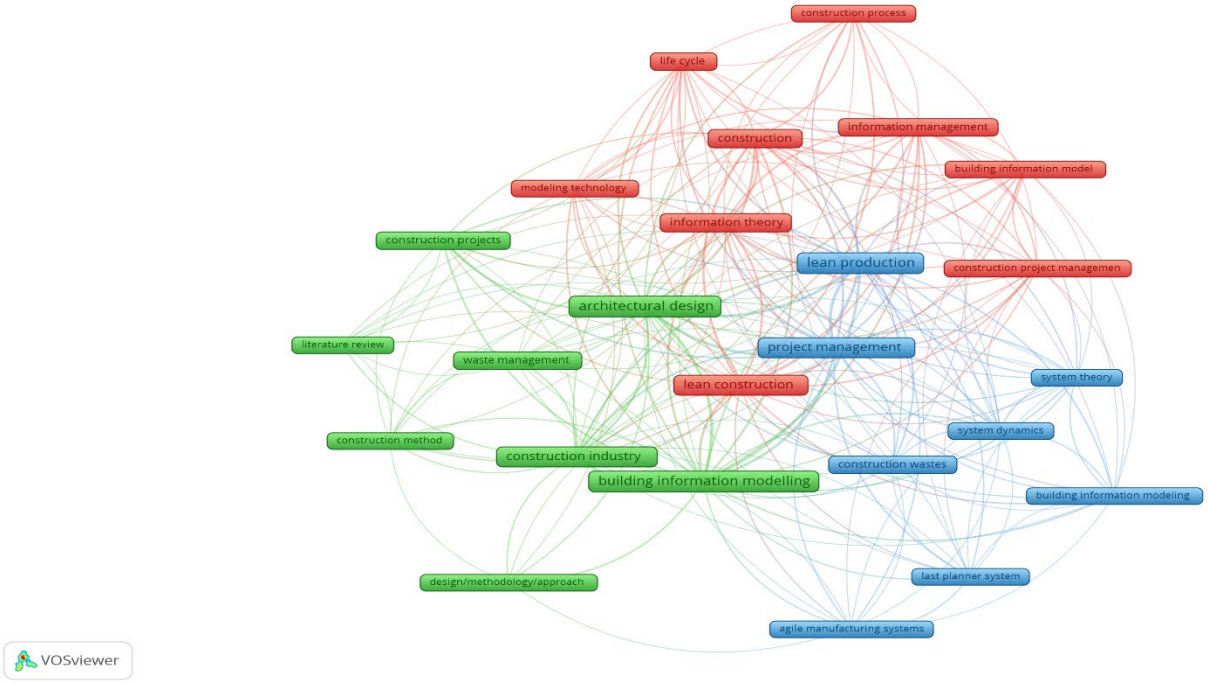

Figure 1. Key word co-occurrence network visualization

5.3 Proposed Improvements

The strength of the present study could be enhanced through several methodological refinements. Firstly, expanding the database coverage to include both Web of Science and Scopus concurrently would likely increase the corpus beyond the 30 papers retrieved, thereby capturing relevant studies that may be indexed exclusively in one database. Secondly, modifying the search strategy to allow Building Information Modelling (BIM) and other digital technologies to appear as optional rather than mandatory keywords would ensure the inclusion of research addressing technologies such as the Internet of Things (IoT), artificial intelligence (AI), geographic information systems (GIS), and cloud computing within the context of lean construction. Thirdly, the transparency and replicability of the document selection process could be improved by adopting a PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) screening framework. Finally, integrating co-citation analysis with keyword co-occurrence mapping would facilitate the identification of seminal works underpinning the three thematic clusters, thereby providing a more comprehensive understanding of the intellectual structure of the field. Collectively, the implementation of these methodological enhancements in future research would yield a more rigorous and comprehensive bibliometric mapping of the domain.

5.4 Validation

The validity of the bibliometric findings presented in this study was evaluated through two internal verification procedures. Firstly, the keyword co-occurrence clusters generated using VOSviewer were systematically cross-referenced with the thematic content of the 30 source publications to ensure that cluster classifications reflected meaningful semantic relationships rather than mere artefacts of keyword frequency. The three identified clusters—Information and Process Integration, Systems and Lean Production, and Industry and Practical Implementation—demonstrated consistent alignment with the subject matter of the respective publications, thereby supporting the analytical reliability of the VOSviewer outputs. Secondly, the geographic distribution results (as presented in Table 4) were verified against the Scopus author affiliation metadata for each of the 30 documents. This process confirmed that country classifications were based on institutional affiliations rather than author nationality, and further established that the absence of South African publications was not attributable to misclassification or metadata inaccuracies. These validation procedures provide strong assurance that the patterns identified in the bibliometric analysis accurately reflect the underlying structure of the literature, rather than being the result of methodological bias or data inconsistencies.

6. Conclusion

This study has successfully achieved its research objectives through a comprehensive bibliometric analysis of the integration of digital technologies with lean construction management in developing countries. The analysis of 24 countries and 10 influential authors have revealed critical insights into the current state of research, identifying both the strengths and significant gaps within the existing body of knowledge. The unique contribution of this research lies in its identification of the pronounced geographical disparity in scholarly output. A particularly outstanding finding is the complete absence of South African publications from the dataset — remarkable given the country's status as the only African founding member of BRICS and its relatively mature construction sector. This gap is compounded by the broader underrepresentation of BRICS nations beyond China and Brazil, and points to a structural imbalance in global construction research. This demonstration of the fragmented nature of academic collaboration through the zero-link strength is observed amongst leading authors. The findings have established that whilst countries such as Chile, Spain, and Germany demonstrate high research productivity, the African continent remains significantly underrepresented, with Egypt being the only African nation meeting the established threshold criteria. This geographical gap represents a critical research void that must be addressed to ensure the equitable development of construction management practices globally. Furthermore, the identification of leading journals, including *Buildings*, *Smart and Sustainable Built Environment*, and *Sustainability*, has provided valuable guidance for future researchers seeking to disseminate their findings within the most relevant academic forums.

The proposed improvements, including the establishment of international research consortiums and the development of regional research hubs in Africa, offer a clear pathway towards addressing the identified fragmentation and geographical disparities. The validation framework proposed, incorporating both bibliometric and empirical methodologies, provides a healthy mechanism for assessing the efficacy of these interventions over time. It is anticipated that the implementation of these recommendations will lead to increased collaborative networks, enhanced research output from developing countries, and ultimately, more effective integration of digital technologies with lean construction practices globally. This study therefore serves as both a diagnostic assessment of the current research landscape and a strategic roadmap for future scholarly endeavours in this increasingly important field.

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