

A Decade Trend Analysis of the Literature on Lean Construction (2012 -2022): A Systematic Bibliometric Approach

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Abstract

There has been a growing emphasis on Lean construction within construction research in recent years. Presently, the utilization of bibliometric analysis has gained prominence as an effective method for synthesizing findings from prior research endeavours. This approach facilitates the progression of current knowledge and the cultivation of a comprehensive and outcome-driven comprehension of the subject matter. While numerous scholarly investigations have delved into lean construction, there is a dearth of comprehensive research exploring the patterns of publications within the context of sustainability in this domain. Consequently, this study aims to address this research gap by employing bibliometric analysis to examine the publication trends associated with lean construction. The analysis focuses on publications from 2012 to 2022, retrievable from the Web of Science database, specifically those with a "lean construction" heading. The statistical examination of published research articles was executed using Microsoft Excel 2016, VOSviewer, R Bibliometrix, and Biblioshiny packages. A comprehensive total of 872 documents published within ten years (2012 – 2022) was ascertained within the Web of Science database for the specified study duration. The findings from the analyses revealed that the annual growth rate in scientific output stood at 0.68%, with the pinnacle being observed in 2022, characterized by a total of 162 articles. Regarding authorship, Wang X and Wang Y emerged as the most prolific contributors to lean construction literature, having authored 14 and 13 published articles, respectively. Their collaboration formed a robust network within the field. Leading the publications were the journals "Construction Engineering and Management" and "Engineering Construction and Architectural Management," with 55 and 36 articles, respectively, focusing on studies related to lean construction. The outcomes of this research endeavour are anticipated to furnish researchers in the construction domain with an extensive and enriched comprehension of lean construction principles.

Keywords: Bibliometric analysis, lean construction, sustainable environment, publication trend

I. Introduction

In construction industry every activity comes with its attendance cost implications and the usage of time. Construction activities involve a lot of processes and steps. It is however, worthy of note that a lot of wastages in term of labour loss, equipment, materials, time and other resources were recognized (Dixit, 2019). The enormous wastages according to Xu et al. (2017) contribute greatly to inefficiency and eventually to low productivity rates in construction industry. These wastes hinder performance and efficiency in construction industry and this is one of the weaknesses of construction industry in recent time most especially in timely delivery of projects.

Construction operations can be categorised into two main types: conversion activities, which yield concrete outputs, and flow activities, which interconnect these conversion tasks throughout the delivery phase. Notably, a significant portion of inefficiencies has been identified to exist within the flow aspect of construction procedures. In the study conducted by Arashpour et al. (2017), it was affirmed that by eliminating wasteful operations, the processes could attain a state of leanness, thereby achieving enhanced productivity through optimising resource utilisation.

The construction sector frequently incurs substantial production costs due to wasteful practices (Aziz & Hafez, 2013). However, it is essential to recognize that the nature of waste generation differs across industries due to variations in their functions and scope of operations. Manufacturing industries waste lesser time because of the organize nature. According to Aziz and Hafez (2013), manufacturing sectors exhibit a lower waste production rate in terms of time, accounting for 12%, whereas the construction industry experiences a

significantly higher rate of 57%. In some instances, some of these physical wastes were sold out to interested buyers to compensate for the loss, but the cost cannot be compared with the gain after that. This brought about the concept of lean construction (LC) principles.

Lean construction principles (LC) assert that value is exclusively contributed by conversion activities, necessitating their enhancement. In contrast, non-value-adding flow activities should be curtailed or eradicated (Senna et al., 2016). Saieg et al. (2018) similarly elucidated lean construction as an ongoing endeavour to eliminate inefficiencies, fulfil or surpass all customer requisites, concentrate on the complete value chain, and strive for flawlessness in project execution. At its core, lean construction endeavours to optimize value while minimizing the squandering of financial resources, time, and materials (Maruyama et al., 2016).

Furthermore, extensive global scholarly efforts have been devoted to exploring lean construction from its inception, and publications encompassing lean construction have been disseminated within the scholarly literature, as documented in reputable databases such as Scopus and Web of Science. Investigations arising from these scholarly endeavours serve the purpose of contributing insights into the depth of knowledge within this research domain and identifying areas where gaps in understanding exist. Likewise, researchers are required to allocate a substantial amount of time to systematically review and identify pertinent contributions across interconnected fields, considering the diverse spectrum of studies, the sporadic excellence demonstrated by scientific research articles, the substantial volume of available data, and the dynamic interactions between lean construction and other associated and evolving concepts within the construction industry. Hence, it becomes crucial to methodically categorize significant, dynamic, and impactful sets of evidence extracted from extensive databases, offering invaluable support to rigorous scholarly investigation. This endeavour is pivotal for researchers seeking to forge innovative trajectories of inquiry and, in turn, to provide policymakers with the means to assess and propose strategies to address the existing gaps in research.

A statistical analysis methodology known as bibliometrics is commonly utilized to assess a specific area of study's fundamental evolving trends and characteristics, drawing insights from published research articles (Li et al., 2020). The utilization of bibliometrics alongside visualization techniques has been recognized as a crucial means of identifying emerging patterns of concepts within the construction industry. Furthermore, it represents an indispensable approach to the evaluation of scientific research. This assertion aligns with the contemporary landscape where copious volumes of information are exchanged amongst stakeholders within the construction sector (Unkel et al., 2012). Likewise, bibliometrics is a prevalent technique for quantitatively and qualitatively assessing scholarly research endeavours across diverse fields (Deng et al., 2020). Similarly, for the explicit purpose of systematically unveiling connections within the construction industry, the application of bibliometrics and visualization methodologies proves instrumental in analyzing publications and citations associated with lean construction and evaluating the influence of authors and countries involved.

Bibliometric analysis, a statistical technique, assesses the fundamental evolving trends and characteristics within a specific field of study by analyzing published literature (Li et al., 2020). Bibliometrics finds application across diverse disciplines to quantitatively and qualitatively evaluate the landscape of scientific research (Deng et al., 2020). Presently, the employment of bibliometric analysis holds an increasingly pivotal role in amalgamating the outcomes of prior studies, thereby facilitating the progression of current knowledge and the development of a coherent path for study and a comprehensive understanding focused on results. Hence, an imperative arises to scrutinize the published trends concerning lean construction. The outcomes of this investigation will shed light on focal areas within lean construction studies, thereby fostering the formulation of research strategies at both national and institutional levels. Furthermore, the visualized data and evidential outcomes can serve as valuable tools for exploring the historical trajectory of scholarly outputs in a specific field and identifying prospective pathways for future research and possibilities for collaborative endeavours (Roth et al., 2017). It will also give insights into number of authors, authors' collaborations, authors' impacts, countries of authors, journals, number of publications and much other information relating to lean construction.

II. Data Search and Research Methodology

2.1. Data Search

The data for this research were obtained from the Web of Science (WoS) database. The Web of Science (WoS) selection was informed by its current status as the world's most extensive and comprehensive repository of informational resources. This repository encompasses over 11,000 authoritative academic journals that significantly contribute to various disciplines, including environmental sciences, engineering, applied and natural sciences, and medical and biomedical sciences. For the present study, we focused on exploring the Web of Science™ core collection, an integral component of the WoS database. The data source comprised articles, with a title search as the search method. The language parameter encompassed all languages. The keyword "Lean Construction" was employed as the thematic term to identify documents containing this phrase within the title or keyword sections.

Five essential stages that facilitate both quantitative and qualitative analysis pertinent to bibliometric research were employed to ensure the rigorous analysis of the extracted data and the acquisition of requisite outcomes. These stages encompass data importation and transformation, descriptive bibliometric analysis, matrix creation, normalization, and mapping.

2.2. Research Methodology

Using bibliometrics analyses enables us to extract an extensive spectrum of insights from a moderately comprehensive investigation. The bibliometrics tool encapsulated within the R package is tailored explicitly for quantitative scientometrics and informetrics applications (Aria & Cuccurullo, 2017). This tool furnishes a diverse range of metrics to facilitate the importation of bibliographic data from multiple databases, including but not limited to MedLine, Social Science Citation Index (SSCI), PubMed, Scopus, Clarivate Analytics Web of Science, Lens, Digital Science Dimensions, Science Citation Index Expanded (SCI-EXPANDED), and Cochrane Library.

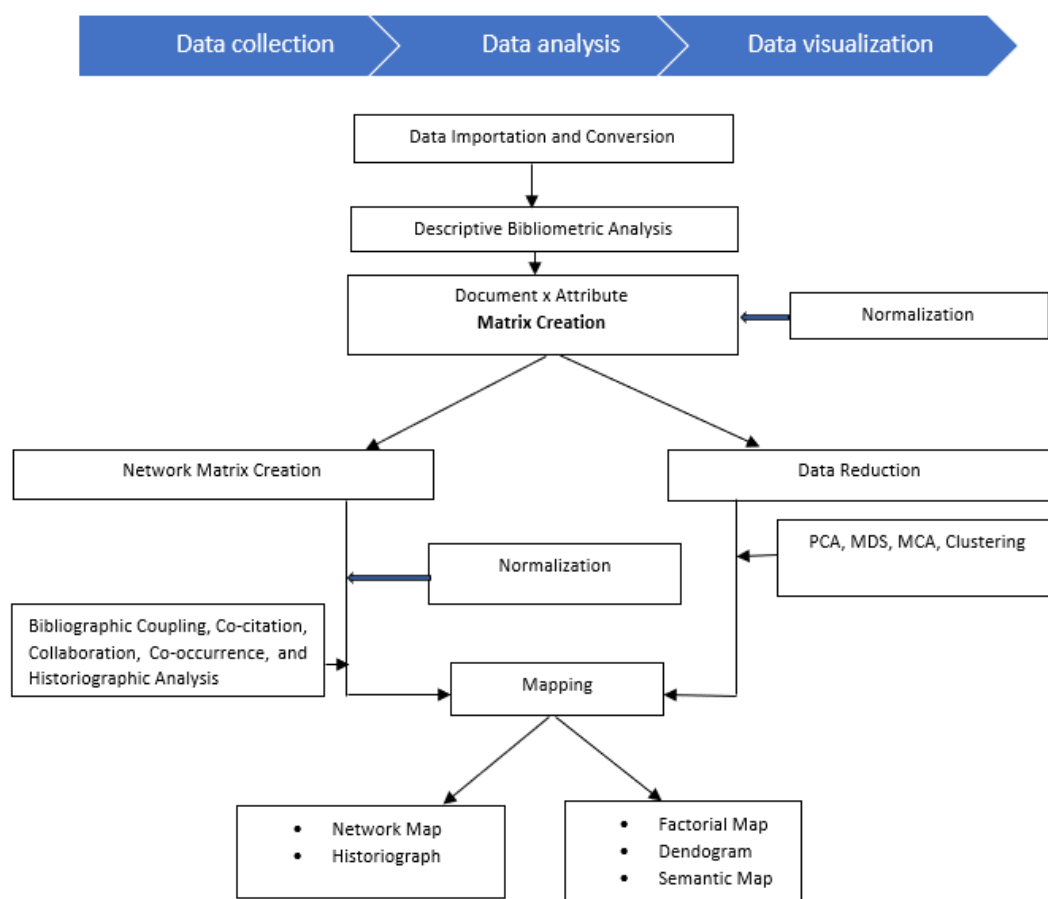


Figure 1. Bibliometrics processing of information and science mapping. Adapted from Ogunsakin et al., 2022

Furthermore, the bibliometric software packages facilitate the classification and analysis of substantial historical research data amassed over a specified timeframe, thereby extracting metadata from the designated database. After importing the documents, a sequence of steps encompassing data preprocessing and bibliometric analysis was executed, entailing examinations of source materials, authorship, citations, scientific collaborations, and studies of keywords. The graphical representations thus generated were subsequently subjected to visualization.

To illustrate the collaborative network among prolific countries and authors within Building Information Modeling (BIM) research, the VOSviewer package of the R language was employed (Van Eck and Waltman, 2013). The command `vos.path = ", type = "VOSviewer", size = T, delete; multiple = T` was employed to invoke the VOSviewer software application, thus generating cooperative maps for both countries and authors. These visualization maps were crafted using VOSviewer 1.6.17, a software application developed by the Centre for Science and Technology Studies at Leiden University. The overarching goal was to meticulously analyze

and visually represent the interconnections among authors, countries, and the terminologies employed within the research papers (Van Eck and Waltman, 2013).

III. Results and Discussion

Over the span from 2012 to 2022, 872 research articles were brought to light, with 2237 authors contributing to their creation, and these works were disseminated across 293 distinct journals. Comprehensive details outlining how the exported data were organized for subsequent analysis are meticulously summarised in Table 1. Regarding the examination of authorship and articles, the computations yielded metrics of 0.39, 2.57, and 3.40 for articles per author, authors per article, and co-authors per article, respectively. Notably, a mere 40 (0.02%) authors operated as sole contributors, while an overwhelming majority of 2197 (98.2%) authors participated in collaborative authorship, resulting in a collective index of 2.65.

Table 1. Presentation of information on lean construction research extracted from 2012 to 2022.

Description	Frequency/Rates
No. of articles	872
No. of authors	2237
Authors of single-authored articles	40
Authors of multi-authored articles	2197
Article per author	0.39
Author per article	2.57
Co-authors per article	3.4
Authors Appearances	2964
Keywords (ID)	1552
Author Keywords	3067
Collaboration index	2.65
Average citations per article	16.59
References	35628
Language	
English	2,178
German	19
Portugese	12
French	10
Spanish	5
Turkish	4
Hungarian	3
Dutch	2
Russian	2
Polish	1
Italian	1

3.1. Growth in Scholarly Publications

Figure 2 illustrates the yearly dissemination of scholarly articles on lean construction within the investigation timeframe (2012–2022). A consistent augmentation in publication frequency is evident, with an average of 88.65 ± 51.63 articles. Over the study duration, an annual expansion rate of 2.8% was observed. Notably, the zenith of scholarly productivity within lean construction was documented in 2022, encompassing 162 articles, equivalent to 7.2%. In contrast, the nadir occurred in 2013, yielding 25 articles, accounting for 1.1% of the total. Despite the relative novelty of lean construction compared to other domains within the construction industry, several determinants have been linked to the sustained escalation in scholarly output within this sphere. These factors encompass amplified recognition of the advantages conferred by lean construction, heightened awareness of the catastrophic repercussions of building collapses and subpar management, and increased construction materials squandering (Ogunbiyi et al., 2014).

Table 2. Annual publications of articles on lean construction (2012 – 2022)

Year	No. of Articles
2012	26
2013	25
2014	36
2015	43
2016	43
2017	72
2018	89
2019	88
2020	122
2021	138
2022	162

Annual Scientific Production

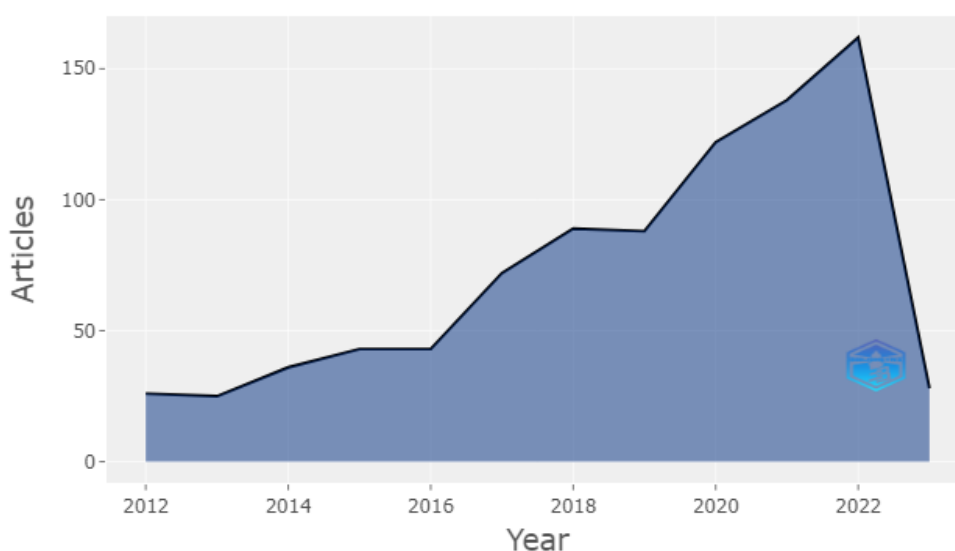


Figure 2. Annual publications of articles on lean construction (2012 – 2022)

A gradual rise in the overall citation count was evident, displaying an average of 4 citations per annum for each article. Nevertheless, the highest count of citations materialized in 2019, registering six citations, as depicted in Figure 3. Conversely, the zenith of publication frequency was noted in 2022. These findings resemble outcomes delineated in an independent investigation by Singh and Kumar in 2019.

Average Article Citations per Year

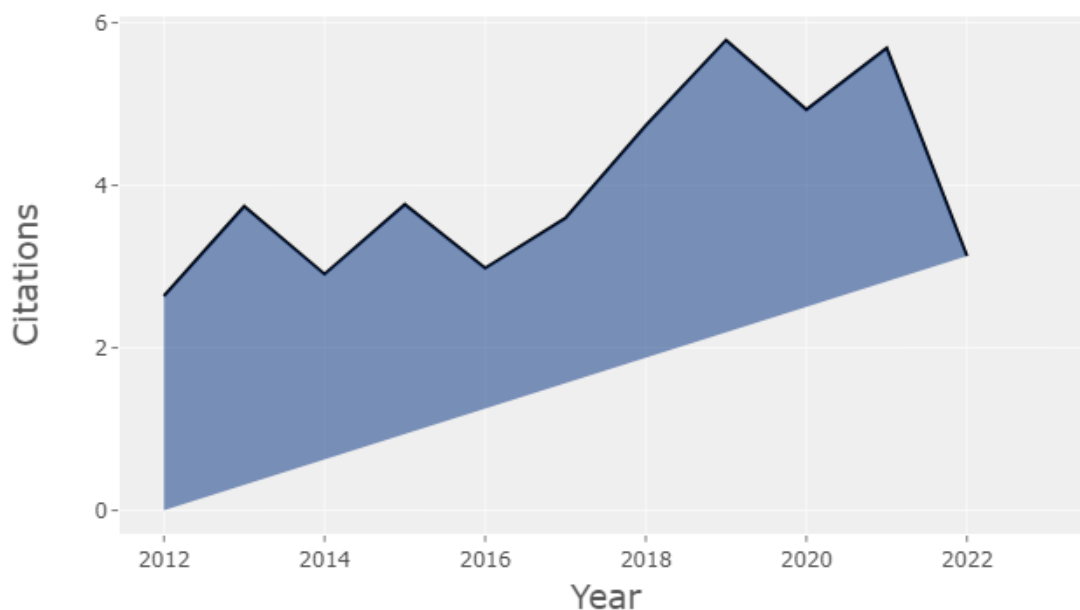


Figure 3. Average article citation per year on lean construction (2012 – 2022)

3.2. Co-Word Analysis

3.2.1. Analysis of Titles

Employing a tree map representation, the prevalent vocabulary within the titles of lean construction research was explored. The findings are graphically presented in Figure 4. Notably, the term "Management" exhibited the highest recurrence, accounting for 148 instances (9%). Additionally, "Performance," "Construction," "Implementation," and "Design" emerged as the foremost quintet of frequently utilized words within the research titles, with frequencies amounting to 132 (8%), 117 (7%), 104 (6%), and 89 (5%) respectively, in the domain of study.

3.2.2. Analysis of Most Relevant Keywords

The analysis of the relevant keyword plus (ID) and the keywords designated by the authors (DE) is showcased in Table 3. Notably, the predominant keyword plus (ID) was "management," attaining a frequency of 148 occurrences (12.3%), whereas "lean construction" emerged as the prevailing author-designated keyword (DE), noted 192 times (24.7%). However, a common thread emerged between these two sets of keywords, with seven terms overlapping in both the keyword plus and author-designated keywords. These terms are "management," "performance," "construction," "lean construction," "design," "model," and "framework."

Within the scope of keyword analysis, a total of 13 terms were distinct, including "management," "performance," "construction," "implementation," "design," "model," "framework," "impacts," "simulation," "innovation," "behavior," "sustainability," and "barrier." Similarly, 13 terms exhibited uniqueness within the author-designated keywords, encompassing "lean," "productivity," "simulation," "waste," "management," "last planner system," "lean productivity," "case study," "lean manufacturing," "prefabrication," "value stream mapping," "building information modeling," and "barriers."

It is noteworthy that the most noteworthy distinct author-designated keywords were centred around construction management, performance, productivity, sustainability, and innovation. Meanwhile, the preeminent distinct keyword plus predominantly revolved around management, performance, construction, implementation, design, model, and framework. In the keyword plus, "lean construction management" (n = 148, 12.3%) and "performance" (n = 132, 11.0%) were particularly prominent. Conversely, in the author-designated keywords (DE), "Lean" (n = 87, 11.2%) exhibited a connection with lean construction. Within the construction industry, "design" (n = 89, 7.4%) in keyword plus (ID) and "sustainability" (n = 38, 4.9%) in author-designated keywords (DE) were notably associated with research concerning lean construction.

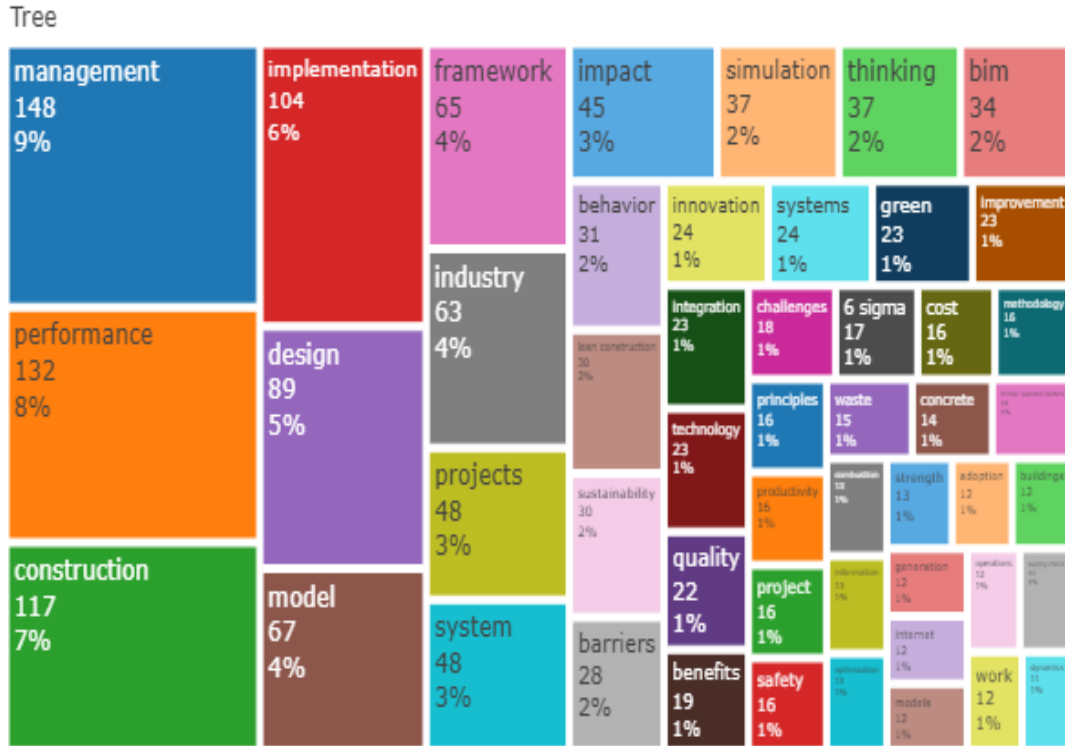


Figure 4: Treemap analysis of terminology employed in research titles within the lean construction literature

Table 3. The predominant keyword plus and author keywords on lean construction (2012 – 2022)

Rank	Keyword Plus (ID)	Frequency (%)	Rank	Author Keywords (DE)	Frequency (%)
1	Management	148 (12.3%)	1	Lean Construction	192 (24.7%)
2	Performance	132 (11.0%)	2	Lean	87 (11.2%)
3	Construction	117(9.7%)	3	Construction	85 (10.9%)
4	Implementation	104 (8.7%)	4	Sustainability	38 (4.9%)
5	Design	89 (7.4%)	5	BIM	34 (4.4%)
6	Model	67 (5.6%)	6	Construction Industry	29 (3.7%)
7	Framework	65 (5.5%)	6	Construction Management	29 (3.7%)
8	Industry	63 (5.2%)	7	Productivity	26 (3.3%)
9	Projects	48 (4.0%)	7	Project Management	26 (3.3%)
9	System	48 (4.0%)	8	Simulation	25 (3.2%)
10	Impact	45 (3.7%)	8	Waste	25 (3.2%)
11	Simulation	37 (3.1%)	9	Management	24 (3.1%)
11	Thinking	37 (3.1%)	10	Last Planner System	23 (3.0%)
12	BIM	34 (2.8%)	10	Lean Productivity	23 (3.0%)
13	Behaviour	31 (2.6%)	11	Case Study	22 (2.8%)
14	Lean Construction	30 (2.5%)	12	Lean Manufacturing	20 (2.6%)
14	Sustainability	30 (2.5%)	12	Prefabrication	20 (2.6%)
15	Barrier	28 (2.3%)	13	Value Stream Mapping	17 (2.2%)
16	Innovation	24 (2.0%)	14	Barriers	16 (2.1%)
16	Systems	24 (2.0%)	14	Building Information Modelling	16 (2.1%)

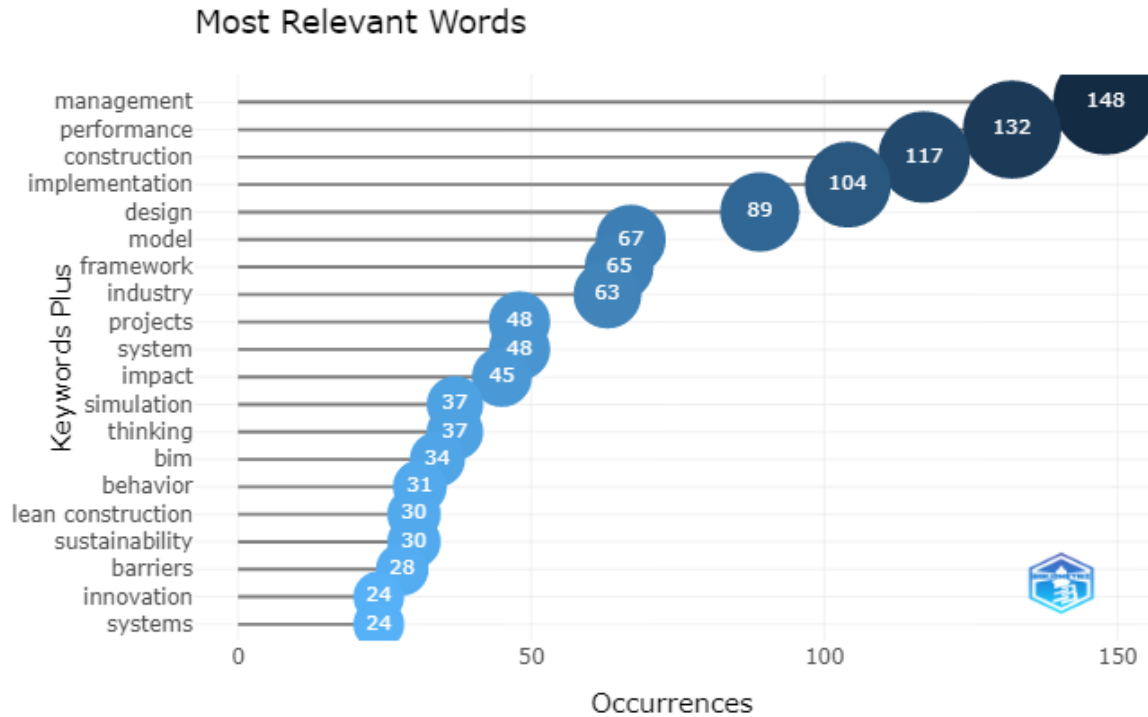


Figure 5: Most Relevant Keywords Plus in the literature on lean construction

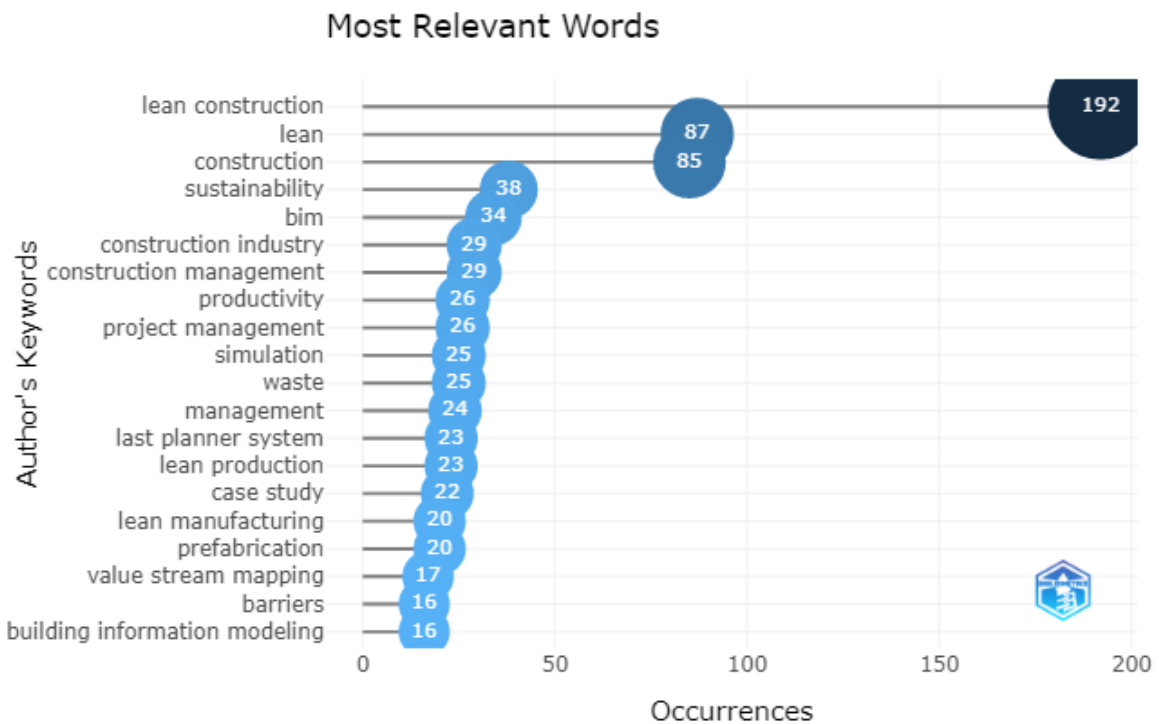


Figure 6: Most Relevant Author's Keywords in the literature on lean construction

3.2.3. Analysis of Thematic Evolution

Bibliometrics is the quantitative assessment of specific occurrences within scholarly literature, distinct from analysing and interpreting its content. In the context of the present investigation, the utilisation of bibliometrics aimed to succinctly synthesise the most insightful outcomes from an assemblage of bibliographic papers. This analytical approach furnishes insights into evolutionary patterns and shifts across distinct periods (Xie et al., 2020). A thematic analysis was conducted for lean construction spanning 2012 to 2022 to discern these evolutionary shifts. Visualisation and comprehension of this analysis were facilitated by implementing a Sankey diagram. This diagram encompasses nodes representing distinct subjects, with their dimensions dictated

by keyword frequencies. Lines illustrate the connection between diverse nodes, the thickness corresponding to the involvement of various keywords. The period under investigation (2012–2022) was categorized into three distinct periods: 2012–2015, 2016–2020, and 2021–2023, as visually depicted in Figure 7. An analysis of thematic evolution was conducted employing author-provided keywords. During the initial phase (2012–2015), which corresponds to the first category, eight spheres of research experienced thematic evolution: Behavior, combustion, modelling, technology, administration, simulation, performance, and construction. Nonetheless, the subsequent phase (2016–2020) unveiled the emergence of three novel thematic domains—industry, design, and decision-making—while behaviour, technology, administration, performance, and construction endured as core themes. The augmentation in the count of thematic domains implies an underlying escalation in the number of scholarly articles focused on lean construction, thus serving as evidence of the continuous occurrence of thematic evolution.

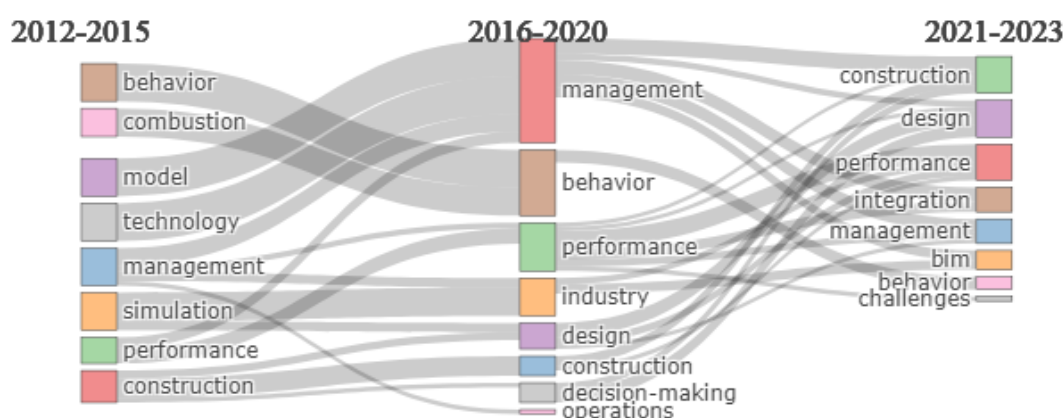


Figure 7. The analysis of how thematic keywords in lean construction research articles evolved between 2012 and 2022. NOTE: Color distinguishes various research themes, and thicker lines indicate greater significance between the two periods.

3.3. Analysis of Authors

The analysis encompassed a group of 2237 researchers, who collectively contributed to 872 research articles throughout the designated study duration. Within this cohort of 2237 researchers, 40 individuals presented their work as single authors, while the remaining 2197 collaborated as co-authors, as previously outlined in Table 1. The highest-ranking authors, as indicated in Figure 8, include Wang X, Wang Y, Tommelein ID, LI X, WU P, Alarcon, LF, Chafi, A, Sacks R, Wang J, and Bajjou MS, with respective article counts of 14, 13, 11, 10, 10, 9, 9, 9, 9, and 8. Notably, Wang X emerges as a predominant author in article publication, as highlighted in Figure 9.

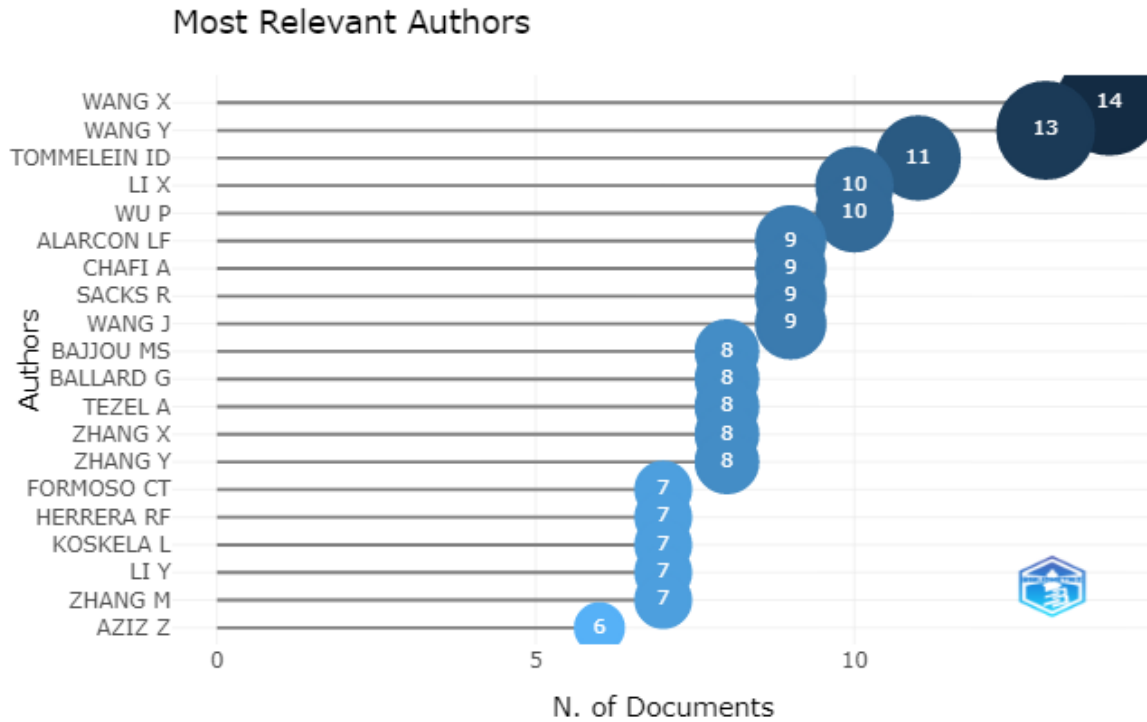


Figure 8. Analysis of the most relevant authors in lean construction (2012 – 2022)

Likewise, the graphical depiction in Figure 6 illustrates the temporal evolution of authors' scholarly output concerning lean construction. Notably, in 2014, Wang X. exhibited the most prolific publication record with 14 scholarly works and a commendable average citation count of 17.82 per item. A similarly distinguished figure within this domain is Wang Y., who also garnered prominence due to a substantial publication count of 13 works. Noteworthy advancements continue to be attributed to Wang Y., evidenced by a peak publication count of 16 in 2022 and a zenith in citations during 2021, with a count of 19, as visually depicted in Figure 9. Most of Wang Y.'s research contributions have found their place in esteemed journals renowned for their high impact factors. China, USA, UK, Brazil, India, Australia, Italy and Canada had the highest number in term of either multiple-country publication or single-country publication for the corresponding authors analysis (Figure 10). This is in agreement with the result of a similar studies carried out by Thilakarathna & Senaratne, 2012 and Singh & Kumar, 2019.

Top-Authors' Production over Time

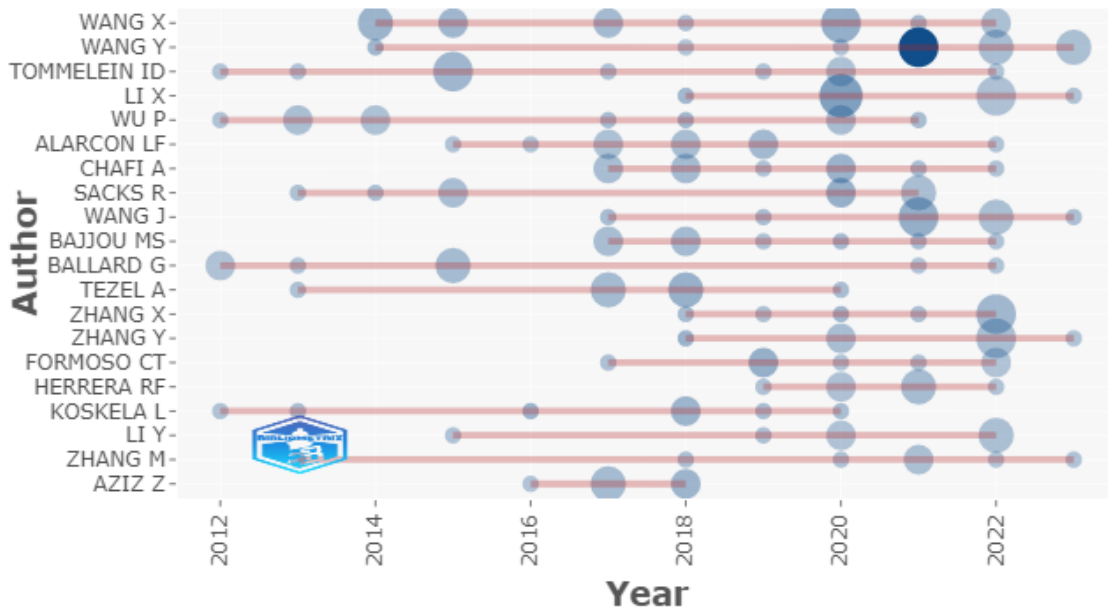


Figure 9. The authors' research output in lean construction. It's important to note that larger circles correspond to a more significant number of documents, and darker colours signify a higher volume of citations.

Corresponding Author's Country

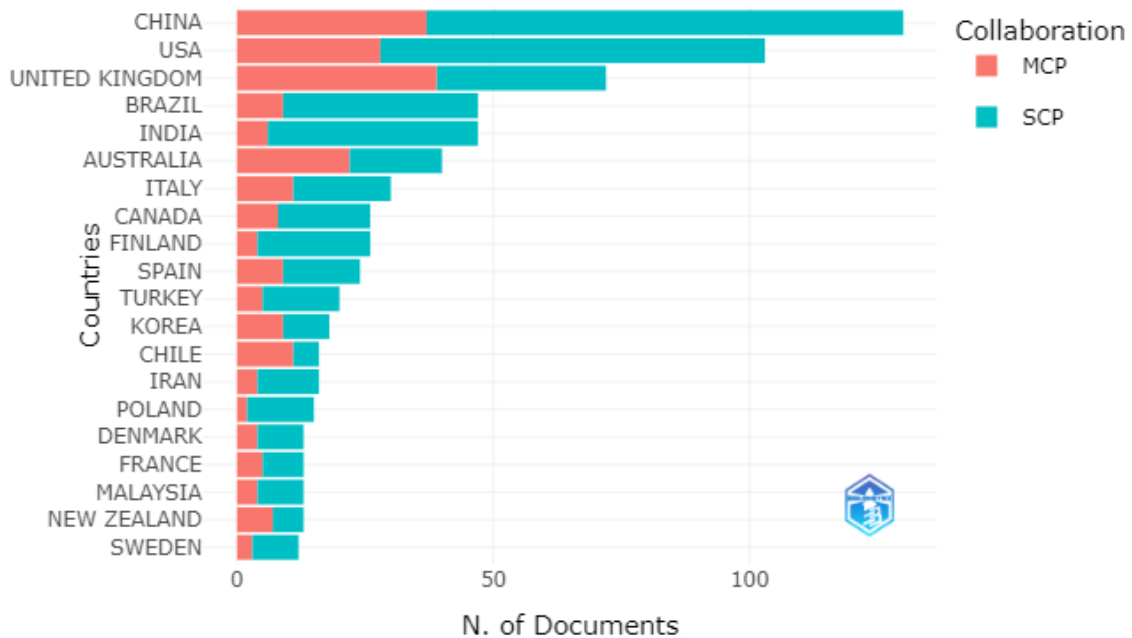


Figure 10. Analysis of the corresponding author's country in lean construction (2012 – 2022). Multiple-Country Publication (MCP); Single-Country Publication (SCP)

3.4. Performance Analysis

3.4.1. Top Publishing Journals

Regarding publication performance assessment, the focus lies on prominent journals exhibiting the highest output volume in a specific research domain during a designated timeframe. Visual representation of the top 20 journals, renowned for their prolific contribution to lean construction research, is provided in Figure 11. The investigation period encompassed the publication of 872 articles centred around lean construction, distributed across 293 distinct journals. Notably, the Journal of Construction Engineering and Management

emerged as a leader, generating 6.3% (55) of these articles and securing its position as the foremost journal in lean construction publications. Among the top five journals, Engineering Construction and Architectural Management, Buildings, Automation in Construction, and Sustainability made notable appearances, contributing 4.1% (36), 3.8% (34), 3.5% (31), and 3.4% (30) of the total articles, respectively. These findings align with the observations made by Singh & Kumar in 2019.

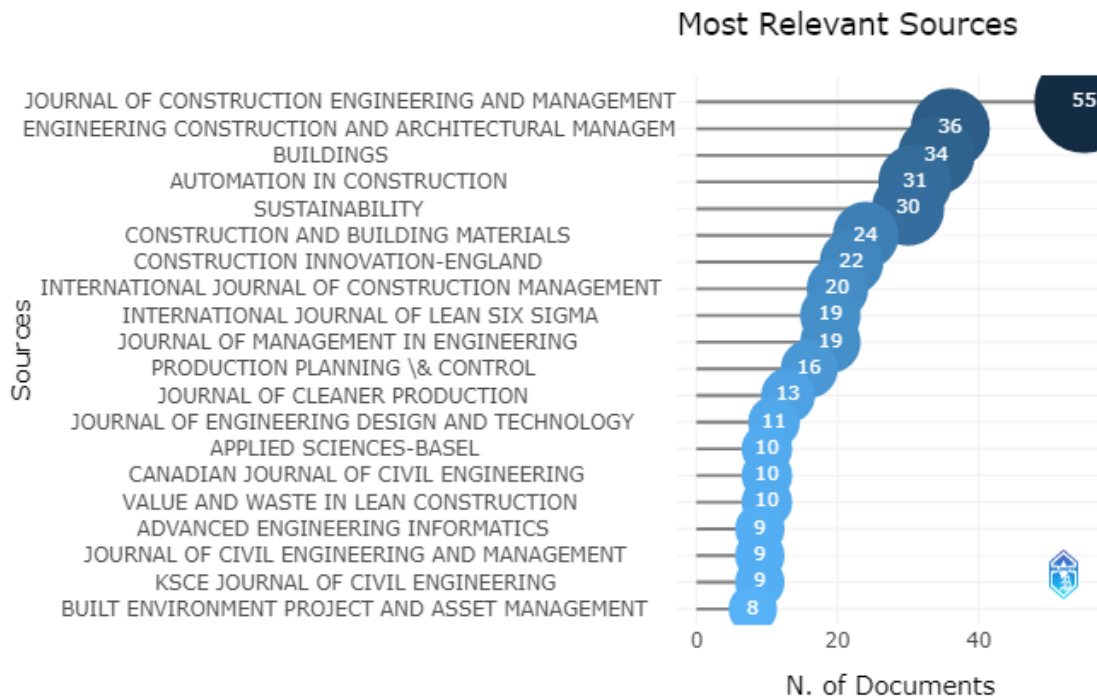


Figure 11. Analysis of the most relevant sources in lean construction (2012 – 2022)

3.4.2. Country Performance

On a global scale, journal publications of lean construction between 2012 and 2022 involved a network of 76 countries spanning various continents. The active participation of these countries in disseminating scholarly work underscores the substantial relevance of lean construction within the research domain. Table 4 showcases a compilation of literature pertaining to lean construction research across the top-performing nations. Notably, Europe, South America, North America, Asia, and Australia emerged as principal contributors, manifesting their commitment through disseminating numerous articles.

The roster of leading countries in research output comprised a diverse array of 20 nations. Among these, 9 European countries (Poland, Germany, France, Finland, Italy, Spain, Denmark, Turkey, and the United Kingdom), 4 Asian nations (China, India, South Korea, and Iran), 2 South American countries (Brazil and Chile), 2 North American countries (United States of America and Canada), 2 Australian nations (Australia and New Zealand), along with 1 African nation (South Africa) demonstrated notable research output.

With the highest publication count in the field of interest, China unsurprisingly occupied a prominent position, consistent with its leading role in authoring articles over time, as evidenced in Figure 9. This dominance can be attributed to China's substantial intra-national and international collaborative efforts. Furthermore, regarding citations gathered, China maintained its position at the top with an impressive total of 2,226 citations, closely trailed by the United States of America with 1960 citations.

It is worthy to note that 1 African country (South Africa) made the list of countries based on productivity in term of number of articles published with 47 (1.9%) articles (Table 4). Similarly, 1 African country (Morocco) made the list of most cited countries with total citation of 219 (Figure 12). This is not good enough and effort needs to be redoubled in this area of study in the construction industry for proper awareness and enlightenment, in order to enjoy the full benefits of lean construction as previously stated in the introduction. This is in accordance with the results of a similar study by Singh & Kumar but not in total agreement. The reason that could be advanced for this variation could be as a result of different study periods and numbers of countries considered each study.

Table 4. Most productive countries in terms of publications in lean construction (2012–2022).

Rank	Country	Articles (%)	Country	Total Citation
1	China	499 (20.5%)	China	2226
2	USA	389 (16.0%)	USA	1960
3	UK	244 (10.0%)	UK	1350
4	Brazil	170 (7.0%)	Australia	1320
5	India	154 (6.3%)	Brazil	995
6	Australia	146 (6.0%)	Italy	591
7	Italy	95 (3.9%)	India	455
8	Spain	83 (3.4%)	Spain	442
9	Canada	79 (3.2%)	Canada	370
10	Finland	72 (3.0%)	Turkey	352
11	South Korea	67 (2.8%)	Korea	323
12	Chile	64 (2.6%)	Finland	308
13	Turkey	52 (2.1%)	Singapore	275
14	Denmark	50 (2.0%)	Germany	273
15	Poland	47 (1.9%)	Israel	231
16	South Africa	47 (1.9%)	Morocco	219
17	Iran	45 (1.8%)	Iran	209
18	France	43 (1.7%)	France	192
19	Germany	41 (1.6%)	Sweden	188
20	New Zealand	40 (1.6%)	Denmark	168

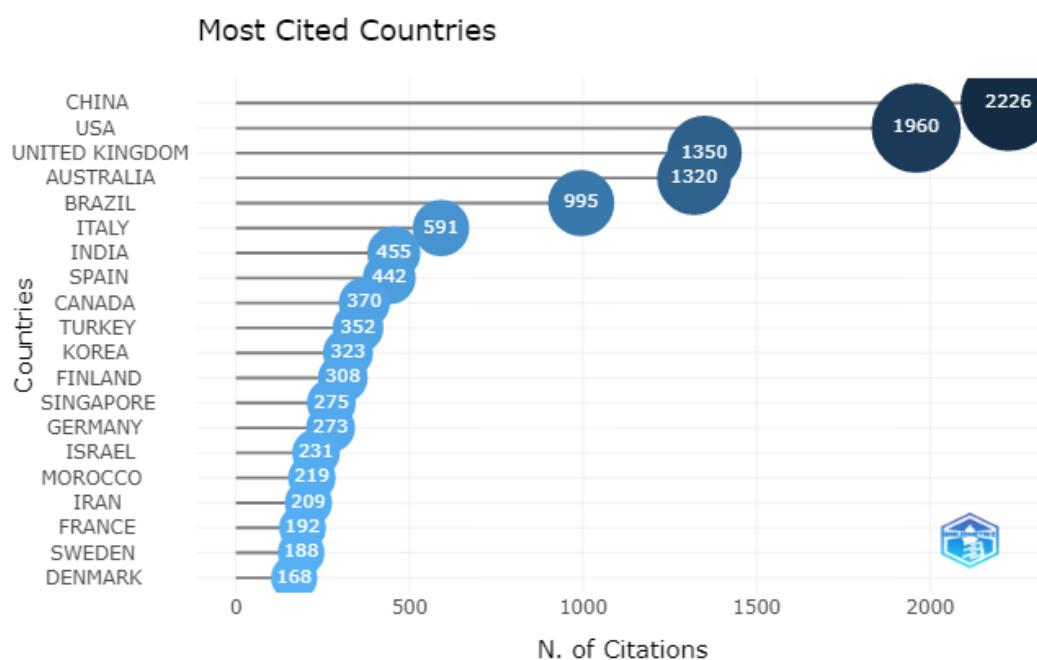


Figure 12. Analysis of most cited countries in lean construction (2012 – 2022)

3.5. Strength and Limitations

During this investigation, a bibliometric analysis was executed employing the R tool, complemented by its interface, biblioshiny, encompassing the temporal span from 2012 to 2022. This represents the pioneering endeavour concentrating on the bibliometric assessment of lean construction discourse utilizing the R tool throughout the designated study interval (2012–2022). It is worth noting that this current inquiry is not without its limitations. Primarily, a solitary database, WoS, was employed to retrieve publications. Nevertheless, it should be acknowledged that, due to the comprehensiveness of the WoS in comparison to Scopus and PubMed, this singular database exploration yielded a more distinctive collection of datasets than would have been obtained through the utilization of multiple databases. Furthermore, it's essential to acknowledge that outcomes linked to specific institutions or countries could be inflated since the WoS registers a document for each contributing author. However, meticulous endeavours were undertaken to extend the search beyond its initial scope by examining the reference sections of the complete articles, thus minimizing the possibility of omitting

potential articles. Despite these inherent limitations, it's worth emphasizing that the insights derived from bibliometric analysis, as exemplified in this study, possess the potential to delineate the progression, configurations, trajectories, and influence of scholarly research spanning various research domains and disciplines.

IV. Conclusions

In this study, we conducted an in-depth analysis and assessment of the worldwide scientific research productivity within lean construction literature. Our approach involved utilising data sourced from the Web of Science, thereby enabling the identification of preeminent authors and the geographical dispersion of research contributions and documentation. This document presents the findings from bibliometric analysis centred on lean construction, employing the R tool in conjunction with its affiliated interfaces, bibliometrics and biblioshiny. The outcomes distinctly revealed a notable upsurge in the number of published articles spanning the preceding decade. The implications of these findings extend to creating a structured framework that can be harnessed for identifying pivotal focal areas and forthcoming trends within the scope of this field. It is imperative to acknowledge that these insights cater to the current cohort of researchers and extend their utility to aspiring scholars with vested interests in lean construction. Beyond serving as a medium for depicting and visually presenting the output of lean construction research, these outcomes undertake a pivotal role in assessing its influence. Furthermore, the far-reaching impact of these results is projected to stimulate the attention of global policymakers, thereby prompting the development of strategies and the consolidation of resources aimed at fostering research endeavours within the domain of lean construction.

References

- [1]. Arashpour, M., Abbaasi, B., Arashpour, M., Hosseini, M. R. and Yang, R. (2017). Integrated management of on-site, coordination and off-site uncertainty theorizing risk analysis within a hybrid project setting. *Int. J. Proj. Manag.* 35 (4), 647 – 655.
- [2]. Aria, M. and Cuccurullo, C. (2017). Bibliometrix: An R-tool for comprehensive science mapping analysis. *J. Informetr.* 2017, 11, 959 – 975.
- [3]. Aziz, R. and Hafez, S. (2013). Applying Lean Thinking in Construction and Performance Improvement. *Alexandria Engineering Journal*, 52, 679 - 695. <https://doi.org/10.1016/j.aej.2013.04.008>
- [4]. Deng, Z.; Chen, J.; Wang, T. (2020). Bibliometric and visualization analysis of human coronaviruses: Prospects and implications for COVID-19 research. *Front. Cell. Infect. Microbiol.* 10, 529.
- [5]. Deng, Z.; Wang, H.; Chen, Z.; Wang, T. (2020). Bibliometric analysis of dendritic epidermal T Cell (DETC) research from 1983 to 2019. *Front. Immunol.* 11, 259.
- [6]. Dixit, S. (2018). Analysing enabling factors affecting the on-site productivity in Indian Construction Industry. *Period Polytech. Archit.* 49(2):185 - 93.
- [7]. Dixit, S., Mandal, S. N., Thanikal, J. V. and Saurabh K. (2019). Evolution of studies in construction productivity: a systematic literature review (2006–2017). *Ain Shams Eng J*, no. xxxx; 2019.
- [8]. Li, C., Ojeda-Thies, C., Renz, N., Margaryan, D., Perka, C. and Trampuz, A. (2020). The global state of clinical research and trends in periprosthetic joint infection: A bibliometric analysis. *Int. J. Infect. Dis.* 2020, 96, 696–709.
- [9]. Maruyama, Ú., Braumb, L. L., Stendera, G., Martinezc, P. and Augusto, Reisa (2016). “Lean e-health care: its performance improvement based on Brazilian university case study”, *Brazilian Journal of Operations & Production Management*, Vol. 13, No. 4, DOI: <http://dx.doi.org/10.14488/BJOPM.2016.v13.n4.a4>. (Accessed on July 31, 2017).
- [10]. Ogunbiyi, O., Goulding, J. S. and Oladapo, A. (2014). An empirical study of the impact of lean construction techniques on sustainable construction in the UK. *Constr. Innov.* 14(1):88 -107.
- [11]. Ogunsakin, R. E.; Ebenezer, O.; Ginindza, T. G. (2022). A Bibliometric Analysis of the Literature on Norovirus Disease from 1991–2021. *Int. J. Environ. Res. Public Health*, 19, 2508.
- [12]. Roth, G. A., Johnson, C., Abajobir, A., Abd-Allah, F., Abera, S. F., Abyu, G., Ahmed, M., Aksut, B., Alam, T. and Alam, K. (2017). Global, regional, and national burden of cardiovascular diseases for 10 causes, 1990 to 2015. *J. Am. Coll. Cardiol.* 70, 1–25.
- [13]. Saieg, P., Sotelino, E. D., Nascimento, D. and Caiado, R. G. G. (2018). Interactions of building information modeling, lean and sustainability on the architectural, engineering and construction industry: a systematic review. *J. Clean Prod.* 174:788 - 806.
- [15]. Senna, P., Gomes, A. M., Pinha, D. C. and Monteiro, A. (2016). “Study on techniques and tools used in the lean healthcare implementation: a literature review”, *Brazilian Journal of Operations & Production Management*, Vol. 13, No. 4, DOI: <http://dx.doi.org/10.14488/BJOPM.2016.v13.n4.a1>.

- [16]. Singh, S and Kumar, K. (2019). Review of literature of lean construction and lean tools using systematic literature review technique (2008 – 2018). *Ain Shams Engineering Journal*, 11, 465 – 471. doi.org/10.1016/j.asej.2019.08.012
- [17]. Unkel, S., Farrington, C.P., Garthwaite, P. H., Robertson, C.; Andrews, N. Statistical methods For the prospective detection of infectious disease outbreaks: A review. *J. R. Stat. Soc. Ser. A Stat. Soc.* 2012, 175, 49–82.
- [18]. van Eck, N. J., & Waltman, L. (2013). {VOSviewer} Manual. Leiden: Univeriteit Leiden, (November). http://www.vosviewer.com/documentation/Manual_VOSviewer_1.6.1.pdf
- [19]. Xie, H., Zhang, Y., Wu, Z. and Lv, T. (2020). A bibliometric analysis on land degradation: Current status, development, and future directions. *Land* (9), 28.
- [20]. Xu, G., Li, M., Chen, C. H. and Wei, Y. (2018). Cloud asset-enabled integrated IoT platform for lean prefabricated construction. *Autom. Constr.* 93:123–34.