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A Framework for Lean Construction Supply Chain; Bibliometric Analysis Approach

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Abstract

Lean construction supply chain is a project management technique adopted from the manufacturing sector aimed at improving the performance of the construction industry. However, its implementation is confronted with some barriers in the construction industry such as; poor understanding of lean concept and absence of framework explaining the application. Therefore, this study developed a framework for lean construction supply chain adopting a bibliometric analysis approach. Bibliometric analysis is a statistical analysis of articles for revealing the school of thought, issues and problems in an area of study. The articles adopted for the analysis of this study were extracted from Scopus, Google Scholar and other online databases. The retrieved articles were inputted into VOS viewer software to reveal the network analysis. The analysis showed the significant countries and school of thought supporting the lean construction supply chain. The findings from the analysis showed that the construction industry in most African countries is slow towards the adoption of the lean concept. The network analysis showed that the practice of lean construction supply chain revolves around waste reduction, just in time, integration and pre-fabrication. This practice formed the variables used for developing the framework. The study recommends that further research should be conducted to validate the framework developed from the study. The study contributes to improving the practice of lean thinking within the construction industry.

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1. Introduction

Balaji and Senthil Kumar [1] indicated that lean thinking is a management concept adopted from the manufacturing industry. The idea originated from the manufacturing of Toyota cars that were designed by engineer Ohno. According to Koskela, et al. [2], the term "lean" was developed by a research group conducting research on cars production to reflect the nature of waste reduction adopted by Toyota manufacturing in comparison with mass car production system. The comparison was made with Ford cars that made mass production system. But Ohno aimed at delivering cars to meet customer demand. The idea was to eliminate waste through shifting focus from the activity to the overall delivery system. Ohno perceived waste as the failure to meet the specific requirement of a customer with zero inventory [2]. It is reasonable to envisage that lean thinking was used in the manufacturing sector for waste reduction with a view to adding value to clients.

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The inherent waste experienced in construction sites made lean thinking suitable for the construction industry [3]. Although Saurin [4] stipulated that the construction industry has rejected multiple ideas from the manufacturing sector but lean fits into the agenda of the industry. For instance, delivering a project to meet the client's needs while eliminating waste and the unnecessary cost is the goal of every construction project manager. Yunus, et al. [5] asserted that construction waste occurs due to activity centre thinking of construction professionals, therefore, an idea that supports change in thinking will be appropriate for the industry. Murata, et al. [6] asserted that applying lean thinking will improve the management of construction projects.

The adoption of lean thinking for managing construction project activities was referred to as lean construction supply chain in this study. Jung [7] submitted that construction supply chain management is complex when compared to other sectors due to the project-based nature of the industry. Also, Meng [8] specified that the complexity of the construction supply chain is enormous due to the numerous dissimilar consultants. The consultant includes; designers, suppliers and many others who come together to work on a short-term basis for a project with this organisation having their supply chains. Mandeep, et al. [9] discovered that the complexity of the construction supply chain can be revealed in its structure as it contains a minimum of 3 tiers. The tiers have each specific functions assigned to them the first tier is responsible for preparing the project. The second undertakes the managerial activity during the project construction phase and the last tier is responsible for supplying the materials needed for the construction project. This implies that managing the construction supply chain can be broken down into numerous process and activities.

The management of the construction process can either be driven by a pull or push system [8]. In the push system, the construction project is planned, controlled and delivered without any regards to the customers' needs and wants with the assumptions that all construction projects (housing) will be disposed or sold on the market. However, as time changes coupled with high competition, the push system became outdated and it moved towards the pull system. This system is characterised by construction production triggered by the customers thereby requiring on-time delivery of construction project, integration of construction project team members and many others. The change to the pull system in the construction industry leads to the adoption of lean thinking as a project management technique for meeting client needs at a reduced cost [2].

The application of lean within the construction industry has attracted numerous research such as; [10-12] but most of the research is focused on hinderance, benefits for implementing lean construction. However, there is a lack of research regarding the school of thought supporting the lean construction supply chain. The understanding for the school of thought is significant because to implement lean thinking for CSC fully it requires the proper knowledge of the underlying concepts. Also, the school of taught or knowledge base will provide the opportunity for developing a framework for the lean construction supply chain.

2. Methodology

The methodology adopted by this study is the review of existing literature related to the subject topic (lean thinking and construction supply chain). The literature was retrieved from Scopus database, Google Scholar, Web of science and other databases like Emerald and Jstor. The literature was searched online using keywords such as "Lean thinking" "lean production" "lean construction" "lean supply chain" "construction supply chain management techniques" and "lean construction supply chain". Through using these keywords, initial literature of 12,583 was retrieved from the database. A review of the literature shows that the majority of them concentrated on lean within the manufacturing sector. To further refine the articles "lean construction" was inputted into the search within the bar and it produced a total of 2,038 articles. However, since the aim of the research is focused on construction supply chain lean construction supply chain was inputted, and it produced a total of 850 articles. Therefore, a total of eight hundred and fifty literature were extracted and used for the analysis.

The articles were analysed with VOS viewer software to provide the citation, co-citation, journals and author analysis. The citation and journal analysis assist in revealing the essential authors and journals that have contributed significantly to the development of lean construction supply chain. The important authors were ranked based on their total strength link that represents the connectivity of the authors to other authors within the subject area. The important articles were further subjected to content analysis of the literature review to reveal the school of thought guiding lean CSC. Whereas

co-citation provides the understanding of the external impact of citations on a subject matter. van Eck and Waltman [13] affirmed that co-citation analysis comes in various format author citation, journal citation and sources citation. This study adopted author co-citation because it believes that authors that are co-cited in literature imply that they conduct literature in a similar research area.

3. Analysis of literature

The analysis of the literature extracted from the database is presented in this section. The analysis reveals the countries and authors that contribute mostly to lean construction supply chain. Also revealed are the significant school of thought related to lean construction supply chain. The school of thought were used to develop the framework for this study.

3.1 countries contributing to lean construction supply chain publication

The top countries contributing to a lean construction supply chain are presented in Table 1. A look at the table shows that the countries are ranked according to their total link strength. The Vos viewer software produces the total strength link and it functions as a standard for weighing an attribute [13]. Also, the weight of an item also represents the level of importance given to such item. The countries were ranked based on the highest number of total strength link. Therefore, the country with the highest number of total strength link represents the most important country concerning the publication of lean construction supply chain.

Table 1. countries contributing to lean construction supply chain

Country	documents	citations	total link strength	Rank
United Kingdom	107	2623	305	1
United States	155	2353	240	2
India	68	1190	159	3
Brazil	64	561	90	4
Sweden	33	387	76	5
Israel	13	346	62	6
Canada	28	515	58	7
Malaysia	28	224	58	8
Australia	27	460	53	9
Denmark	13	324	50	10
Germany	28	197	48	11
Italy	25	257	46	12
Hong Kong	13	112	41	13
China	24	180	38	14
Finland	23	304	38	15
Singapore	16	200	38	16
Norway	21	107	36	17
Spain	14	384	36	18
New Zealand	22	116	30	19
Iran	11	120	28	20
United Arab Emirates	10	152	20	21
Chile	25	269	15	22
South Korea	13	23	15	23
Netherlands	12	213	11	24
Portugal	11	60	7	25

Table 1 shows that the top countries responsible for publishing lean construction supply chains are; United Kingdom, United States, India, Brazil, Sweden, Isreal, Canada, and Malaysia. This implies that sufficient articles related to the lean construction supply chain can be found in the database of the countries aforementioned. It can also be deduced that the countries efficiently adopt lean construction supply chain.

3.2 Influential authors

Another strength of the bibliometric analysis is the ability to identify prominent scholars within a field of study. Table 2 presents the list of prominent authors, and it shows the number of articles including the Scopus citations of each author. A cursory look at the table revealed that all the authors have a minimum of 5 articles that are index in Scopus with a minimum number of 0 citations in Scopus. The total link strength of the authors is presented in the third column which shows the overall strength of the authors within the lean construction supply chain. The total link strength represents the connectivity of the authors to other authors within the subject area, therefore, their level of influence was ranked based on that.

Table 2. Influential authors

Author	Number of articles published	citations	Total link strength	Rank
Koskela, I.	31	422	57	1
Tezel, A.	13	36	49	2
Aziz z.	7	19	26	3
Tzortzopoulos p.	8	18	25	4
Saurin T.A.	10	186	22	5
Matt, D.T.	7	51	21	6
Rauch, E.	7	38	21	7
Sacks, R.	12	339	21	8
Dallasega, P.	7	26	20	9
Pasquire, C.	14	137	18	10
Ballard, G.	20	347	17	11
Marodin, G.A.	5	154	15	12
Tommelein, I.D.	12	259	14	13
Al-hussein, M.	10	152	10	14
Emuze, F.	5	0	2	15
González, V.	8	87	2	16
González, V.A.	5	22	2	17
Bulhões, I.R.	6	24	1	18
Lidelöw, H.	5	7	0	19
Stehn, I.	5	102	0	20
Formoso, C.T.	11	63	10	21

Table 2 shows that the topmost authors are Koskela with 31 Scopus document, 422 citations and a strength link of 43. Other influential authors are Tezel, Aziz, Tzortzopoulos, Saurin, Matt, and Rauch. A further investigation into this authors reveals that they are from developed countries like Germany, United Kingdom, United States of America and Australia. Whereas authors with low total link strength like Emuze are from Africa, this represents the poor adoption of lean thinking within the Africa context.

3.3 Framework and School of thoughts for lean construction supply chain

This study adopts co-citation analysis to reveal the intellectual structure or school of thoughts underlying lean construction supply chain. The findings from the school of thoughts were used to develop the framework used for this study. This study adopted the author co-citation analysis that visualizes the similarities in the scholarship of authors. Zupic and Čater [14] opined that co-author citations analysis presents a network diagram showing the structure of the knowledge base and different author's school of thoughts. Figure 1 presents the author co-citation analysis map calculated by VOSviewer software. The co-citation map shows the nodes that represent different authors. The size of the nodes depicts the number of co-citations of the author while the author with the biggest node indicates the number of times the author has been cited. A look at the map reveals that the authors are grouped into different coloured clusters that serves as the school of thoughts for each author. Figure 1 shows that the author is grouped into four colours namely; blue, green, yellow and red and it represents the school of thought surrounding lean construction supply chain.

Fig. 1. Co-citation analysis

In support of the co-author citation, a content analysis was conducted to review the articles published by the authors. The finding from the analysis reveals that the school of thought can be broken down into waste reduction, Just in time, Integration and prefabrication. The first school of thought depicted by colour green perceived that the major aim of the lean construction supply chain is targeted at waste reduction. The leaders in this school of thought are [2, 10, 15] depicted by the large nodes in figure 2. The authors in this category modelled waste in the construction according to Engineer Ohno of Toyota production. They revealed that waste in construction occurs due to the concentration on each activity of construction project alone. Whereas a majority of the waste is experienced at the construction stage due to inadequate information, poor design and weak integration of construction activities.

The second school of thought is depicted by the colour red, and it is dominated by authors such as [4, 16, 17]. Authors in this school of thought recognise waste as the main core of lean construction supply chain but they believe that waste cannot be eliminated without the integration of construction activities. The third school of thought is depicted by colour yellow, and it is championed by [18-20]. According to this school of thought, engineering to order or prefabrication must be put in place to ensure effective lean construction of supply chain. The fourth school of thought is presented by colour blue from the review of articles published in this category believed that for effective lean construction Just in time techniques must be put in place.

waste reduction, Just in time, Integration and prefabrication

Fig 2. Lean construction supply chain framework

Figure 2 provides the framework for lean construction supply chain for the construction industry. The framework shows that waste reduction, integration just in time and prefabrication are the variables supporting lean construction.

4. Conclusion

The construction industry is responsible for providing the infrastructures needed for the development of any country. Unfortunately, the construction project management techniques used for producing the infrastructures are characterised with numerous shortcomings causing project delays and wastage. These shortcomings made the industry adopted lean thinking for managing the construction supply chain. Lean thinking is a concept that has strived successfully in the manufacturing sector and is presently utilized within the construction industry.

Towards improving the practice of lean thinking for managing construction supply chain this study conducted a bibliometric analysis of its knowledge base within the construction industry. It concludes that lean thinking for managing construction supply chain is effectively adopted within the construction industry but is implementation in Africa is low judging from a few research conducted in the study area. The primary school of thought supporting lean construction supply chain includes waste reduction, just in time, integration and pre-fabrication. Therefore, a framework was developed using the variables from the school of thought. The study recommends that further research should be conducted on validating the framework based on the school of thought extracted from the analysis of the journals

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