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Building Information Modelling From a Bibliometric Perspective

***[1]BOLADE-OLADEPO, F. A., [1]FASUYI, O. A. and [2]MAKINDE, A. A.**
[1]Department of Quantity Surveying, School of Environmental Studies,
[2]Department of Estate Management, School of Environmental Studies,
Federal Polytechnic, Ado - Ekiti, Ekiti State, Nigeria
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Abstract
Recently studies on building information modelling have become a significant area of consideration by researchers. Currently, bibliometrics analysis increasingly plays a significant role in combining previous studies' outcomes to effectively advance the current information to develop a line of study and result-oriented understanding. Though numerous studies have been reported on building information modelling, limited research has explored the publication trends in this area of sustainability. Therefore, the objective of this study was to fill the void by conducting a bibliometrics analysis of publication trends in building information modelling. The Web of Science database was hunted for publications from 2012 to 2022 with "building information modelling" in the heading. Microsoft Excel 2016, VOSviewer, R Bibliometrix and Biblioshiny packages were deployed for the statistical analysis of published research articles. A total of 35,589 published documents were identified in the Web of Science database for this ten years study period (2012 – 2022). The analyses disclosed that the annual scientific production growth rate stood at 10.21% with the highest number of 781 articles in 2021. Zhang Y and Wang J were the two top authors in term of production in building information modelling publications with 72 published articles each and had the most intense authors' collaboration network. Sustainability was the leading journal in publications on building information modelling studies with a total of 686 published articles followed by Remote Sensing with 540 articles. This study can help researchers in the construction industry obtain a comprehensive understanding of the state-of-the-art of building information modelling research.

Keywords: Building information modelling, bibliometric analysis, construction, sustainable environment, publication trend, Web of Science

I. Introduction

Effective communication is very important for success of any particular project. Problems and conflicts are not farfetched whenever there is communication gap among stakeholders in construction project execution in other sectors as well. A lot of challenges such as construction cost, time overrun and poor quality jobs have bedeviled construction industry in recent time. This is usually as a result of incomplete information, assumptions and personal experiences of construction professionals that most often operate in a compartmentalized manner rather than through an Integrated Procurement Delivery (IPD) platform as a team (Olorunkiya, 2017).

However, moving towards IPD involves team integration and effective communication through the application of Building Information Modelling (BIM) to overcome these challenges that has be deviled construction industry. However, BIM bridges the gap by providing a very reliable, dependable and regular knowledge exchange among various stakeholders in construction industry.

Building Information Modelling (BIM) is defined as the use of ICT technologies to streamline the building lifecycle process in order to provide a safer and more productive environment for its occupants, to affect the least possible environmental impacts from its existence and to be more operationally efficient for its owners throughout the building lifecycle (Arayici et al., 2012). Building Information Modelling (BIM) is effectively defined as the process of creating an information database for a project in which lifecycle information is expressed in an interoperable manner to create, engineer, estimate, illustrate and construct a construction project (Schwelgler et al., 2001).

Building Information Modelling (BIM) systems have the potential to revolutionize current practices and to automate the measurement of quantities from construction drawings. BIM may be considered as the current state of art in Computer Aided Development (CAD) and it enhances CAD capabilities with an improved ability to link design information with construction supply chain processes such as estimating, offsite fabrication

of elements, construction scheduling and cost control, materials procurements and tracking and general site operations (Olorunkiya, 2017)

BIM is currently being used by a significant number of stakeholders in construction industry and it has the potential to revolutionize the industry and opens opportunities for multiple discipline to share and exchange data (Tse et al., 2005). It facilitates multiple functions such as preparation of bill of quantities automatically from BIM data. The importance of BIM cannot be overemphasized because of its relevance, use, value and commercial opportunities in contemporary construction industry (Gao & Fisher, 2008).

The adoption of BIM will remove the issues of fragmentation and compartmentalization of work in construction industry, improve productivity and mitigate wastages of resources.

Bataw et al., 2010 also reported that BIM enable multidisciplinary team to remain synchronized in order to improve accuracy and enable a more informed and knowledgeable approach to decision making. It also help project designer by supporting them with new means of technological tools throughout the design processes, this can make their work easier, smoother and faster.

BIM also help in creating visual data for the costs, materials and construction sequences within a shared collaborative model. This is because immediately data were inputted within the BIM it can automatically present itself in floor plains, elevations and specifications work sequence and quantity takeoff.

Building Information Modelling (BIM) will improve the current fragmented and highly uncoordinated way of working among stakeholders in construction industry. It reduces cost overrun and eliminates resources and time wastages. It brings about reduction in designing errors, insurance costs, professional liabilities, and request for information, conflicts, and variations claims because errors are detected on time.

Building Information Modelling (BIM) is a contemporary model for sustainable construction practices. It is the process of creating a digital parametric model which represents the physical and functional characteristics of a building in full details and further shared knowledge pool which can be used to form reliable decisions during the designs, construction phase and throughout the life cycle of the facility (Suranga and Weddikkara, 2012).

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Some of the limiting factors to the usage of BIM include the following amongst others an inherent conflict of interest among stakeholders in construction industry (Khosrawshashi et al., 2012), lack of enabling environment (Abubakar, 2014), lack of trained professionals to handle the tools (Volt et al., 2014), social and habitual resistance to change (Chengshuang et al., 2015) and lack of current procurement policy on BIM (Yang et al., 2016).

Currently, bibliometric analysis increasingly plays a significant role in combining these previous studies' outcomes to effectively advance the current information to develop a line of study and result-oriented understanding. However, bibliometrics studies on BIM are scanty and only few have performed to the best of our abilities in evaluating published patterns on the subject matter. Based on the search emanated from this study, more than 63,869 documents associated with BIM have been printed in the literature (Web of Science). Studies emanating from such investigation have provided information about the informed nature of such research and discovered breaches.

The termed bibliometrics analysis is a statistical approach deployed to evaluate the essential evolving inclinations and features of a specified study subject built on the printed studies (Li et al., 2020). Bibliometrics and visualization have been conveyed as an essential way to detect evolving concepts in the construction industry, and it is an imperative technique of scientific research evaluation. This observation is correct considering the situation of the present age, where multiple amounts of information is being exchanged among stakeholders in construction industry (Zhang, 2019).

Furthermore, bibliometrics is usually used in various disciplines to appraise scientific research quantitatively and qualitatively (Deng, 2020). Therefore, to systematically divulge associates within the BIM family, our study deployed bibliometrics and visualization approaches to analyze BIM-linked publications and citations, countries, and author impact. Based on the evidence gathered through the research, and to the best of our knowledge, this is the first bibliometric study on trends in BIM research covering up to year 2022 in the

world; 5365 published articles were repossessed and statistically analyzed in the present bibliometric analysis. Findings from this study brought to light the BIM studies' hot spots and can benefit the development of a national and institutional research strategy. Additionally, the resulting data or evidence from the visualizations can be used to study the scientific history of investigation outputs in a definite discipline and recognize the potential future investigation path and prospects for collaboration (Roth et al., 2017).

II. Data Search and Research Methodology

2.1. Data Search

Data used for this study were retrieved from Web of Science (WoS) database. Web of Science (WoS) was chosen because presently it is the world's largest and most comprehensive database of information resources. It contains over 11,000 authoritative academic journals that significantly impact the environmental sciences, engineering, applied and natural sciences, medical and biomedical sciences etc. We explored the Web of ScienceTM core collection within the WoS database as a data source for this study. The document type is the article, the search method is a title search, and the language is all languages. The keyword "Building Information Modelling" was used as a topic term to search documents that contained this word in the title or keyword. A total of 63,869 documents were found from the database, while a total of 49,927 documents published from 2012 to 2022 were found from the database, with the following types of documents: article (36,915; 73.94%), proceedings (10,038; 20.11%), review article (2,805; 5.62%), early access (730;1.46%), letter (95; 1.58%), editorial (429; 0.86%), meeting abstract (101; 0.20%), book chapter (988; 1.98%), correction (62; 0.12%), letter (49; 0.10%), book review (41; 0.08%), news item (29; 0.06%), data paper (27; 0.05%), others (40; 0.08%). Hence, we chose articles for the final analysis because articles contain a description of complete research and results. Data around these articles and the total annual citations for each article were downloaded. Comprehensive document lists thereafter were exported as BibTeX.

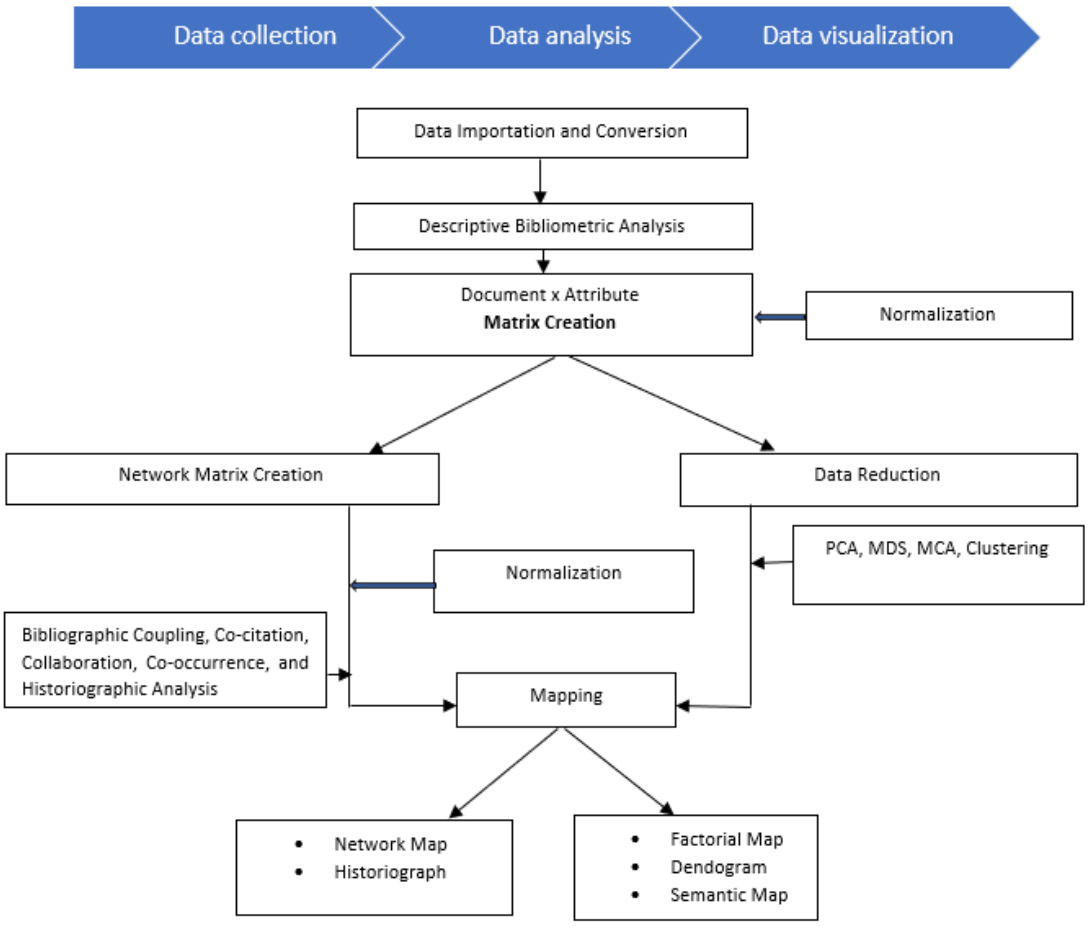

Figure 1. Bibliometrics processing of information and science mapping
Adapted from Ogunsakin et al., 2022

In order to ensure that the extracted data were properly analyzed and the needed results gotten, five important steps that allow quantitative and qualitative analysis used for a bibliometric analysis were considered, these are, data importation and conversion, descriptive bibliometric analysis, matrix creation, normalization and mapping.

2.2. Research Methodology

Bibliometrics analyses allow us to find a vast array of perception from an averagely comprehensive study. Bibliometrics tool in R package is designed to be used in quantitative scientometrics and informetrics (Aria and Cuccurullo, 2017). The tool provided various measures for the importation of bibliographic data from various database such as Social Science Citation Index (SSCI), Science Citation Index Expanded (SCI-EXPANDED), PubMed, Scopus, Clarivate Analytics Web of Science, MedLine, Digital Science Dimensions, Lens, and Cochrane Library. In addition, the bibliometric packages allow for classification and analyzing vast quantities of historical data from research spanned over a specified period to acquire metadata from the database. Following the importation of the documents, data pre-processing and bibliometric analysis on the sources, authors, citations, scientific collaboration and keywords analyses were performed and the graphs obtained were then visualized. The VOSviewer package of R language was applied to visualize the collaboration network of high-producing countries and authors in BIM research (Van and Waltman, 2013). The command vos.path = ““, type = “VOSviewer”, size = T, delete; multiple = T has been used to call the VOSviewer software application and generate cooperative maps for both countries and authors. The visualization maps were created with the help of VOSviewer 1.6.17 (Centre for Science and Technology Studies, Leiden University) to analyze and visualize any relationships among authors, countries, and the terms used in the papers (Van and Waltman, 2013).

III. Results and Discussion

A total of 63,869 documents were identified from the database as published documents since inception of the concept of BIM. When it was limited to cover the scope of this study, that is, ten (10) years span, 2012 – 2022, a total of 49,927 documents were gotten and out of this, 36,915 were identified as published articles, these were categorized and a total of 5,365 were under environmental sciences and further restricted to published articles in English Language. Eight articles not published in English Language were then removed. This was done by restricting the results to English Language only during the research. Finally, 5,357 relevant papers were eligible for the final bibliometric analysis. This was further categorized in descending order as, articles (3,960; 73.94%), proceedings (1,077; 20.11%), review articles (301; 5.62%), book chapters (106; 1.98%), letters (85; 1.58%), early access (78;1.46%), editorial (46; 0.86%), meeting abstracts (11; 0.20%), corrections (6; 0.12%), letters (5; 0.10%), others (14; 0.27%).

3.1 Annual scientific production

This is shows the trends of research within a year, that is, publication year trend, based on the statistics from our data analysis, it shows that from the time of collection of articles about published articles on BIM, a total of 3,960 articles were published within the study period. Fewer articles were published in this area at the beginning of the study period; this is because the study on BIM was just gathering momentum.

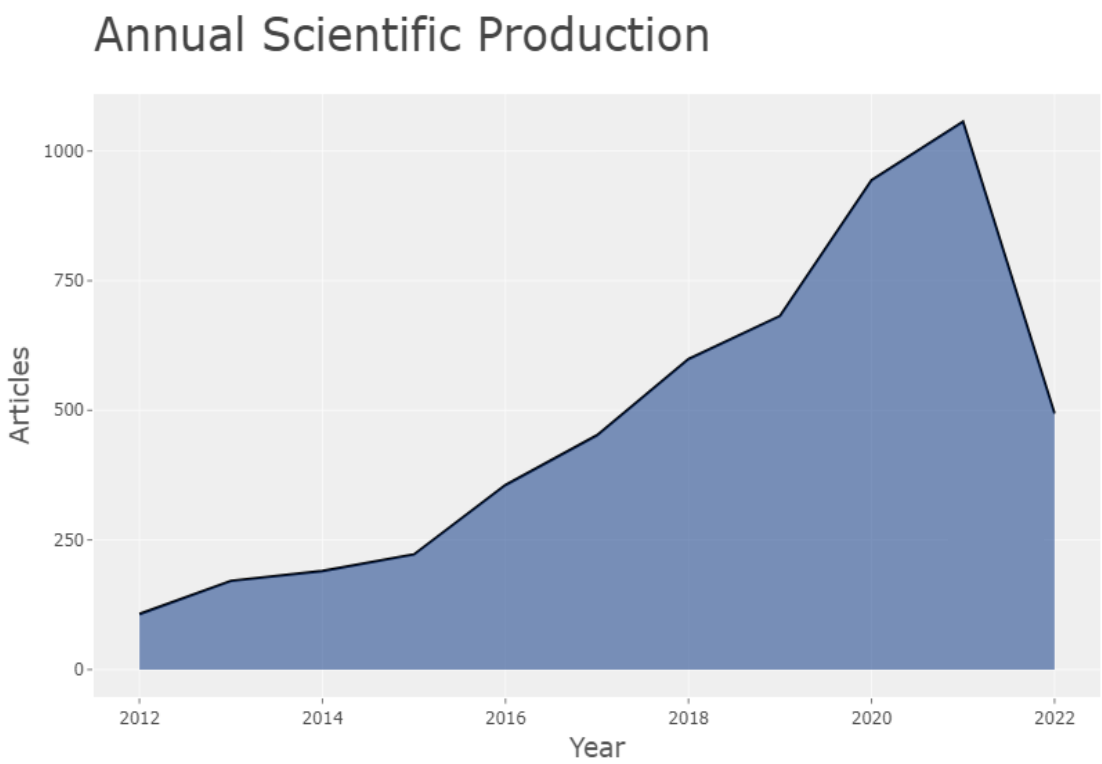

Figure 2. Annual scientific production of literature on BIM

It is worthy to note that from 2012 to 2015, the number of published articles on BIM increase steadily; the implication of this was that, the research on BIM attracted minimum attention of most researchers within this period. However, the published articles on BIM increased drastically in 2016 – 2020 (Figure 2), this indicates that BIM has attracted the attention of many scholars from various countries. Between 2020 and 2021, which can be described as the active high-performance period, recorded a sharp increase, reaching a maximum of 1,057 in 2021. Though the number of publication for 2022 was 494 as at May, 2022 when the data were extracted the projected figure for the whole year of 2022 wil be 1,186, which is higher than that of 2021. This shows an upward trend within the years under review and this in agreement with other authors in separate and similar studies such as Zhao et al., 2016; Zhang et al., 2019; Li et al., 2021 and Chen et al., 2022 have reported.

3.2. Top authors' production over time and their relevance

Considering the number of papers published (Figure 3) the top 10 authors were Wang Y, Zhang Y, Zhang X, Llu Y, Wang J, Zhang J, Wang X, Ll Y, Ll J, and Llu X with 96, 76, 75, 68, 65, 63, 62, 59, 54, and 48 articles, respectively. The Chinese scholar, Wang, Y. is the first influential author regarding BIM in document numbers with h-index and g-index of 21, and 36, respectively. Most of his reported papers were published in high-impact factor journals of high quality.

Figure 3. Top-authors' production over time in BIM

Interestingly, Wang Y obtained the highest number of published articles and the highest frequency peak of average citations per item in 2020. Zhang Y is another leading outstanding researcher when it comes to research on BIM. The author has 76 articles; h-index and g-index of 20 and 34, respectively. Most of the reported papers from this author also were published in high-impact factor journals of high quality.

3.3 Academic Collaboration Network

A collaborative network is a network that shows a link among authors and co-authors in particular field of study. Collaborations of authors are part of the strength that accelerates expertise and discussion, it widens the vision of a particular subject area and this is also applicable to BIM. It is worthy to note that, there are collaborations between the authors at multiple levels on BIM. VOSviewer was used to visualize the graph from the R studio software interface. Figure 4 shows node, which signifies the authors, the size of the node signifies the number of articles, the lines denote the strength of collaboration between the authors, and each color signifies a cluster (group of items with comparable attributes within a network) (Xie et al., 2020). The network is positioned on Wang Y, Zhang Y, Zhang X, Zhang J, Wang J and Llu, respectively. The network represented by Wang Y and Zhang Y has a high clustering density, and the authors have a significant influence in the field of BIM.

Figure 4. Authors' collaboration network in BIM publication

Besides, Zhang Y and Zhang J are influential authors in the subject area of BIM. Wang's h-index and g-index values are 21 and 36, respectively. Wang Y and co-workers did a collaborative network to bring together the relevant data from around Asia Countries to focus on the increase in BIM reports. The collaborative effort led to the combination of data from ten Asia countries, which indicated that there is high increase and distinctive interest in BIM.

3.4 Productive Journals in BIM

The research articles were analyzed based on journal sources during 2012 – 2022 for researchers to identify a reliable reference and when searching for journals to publish their research manuscripts.

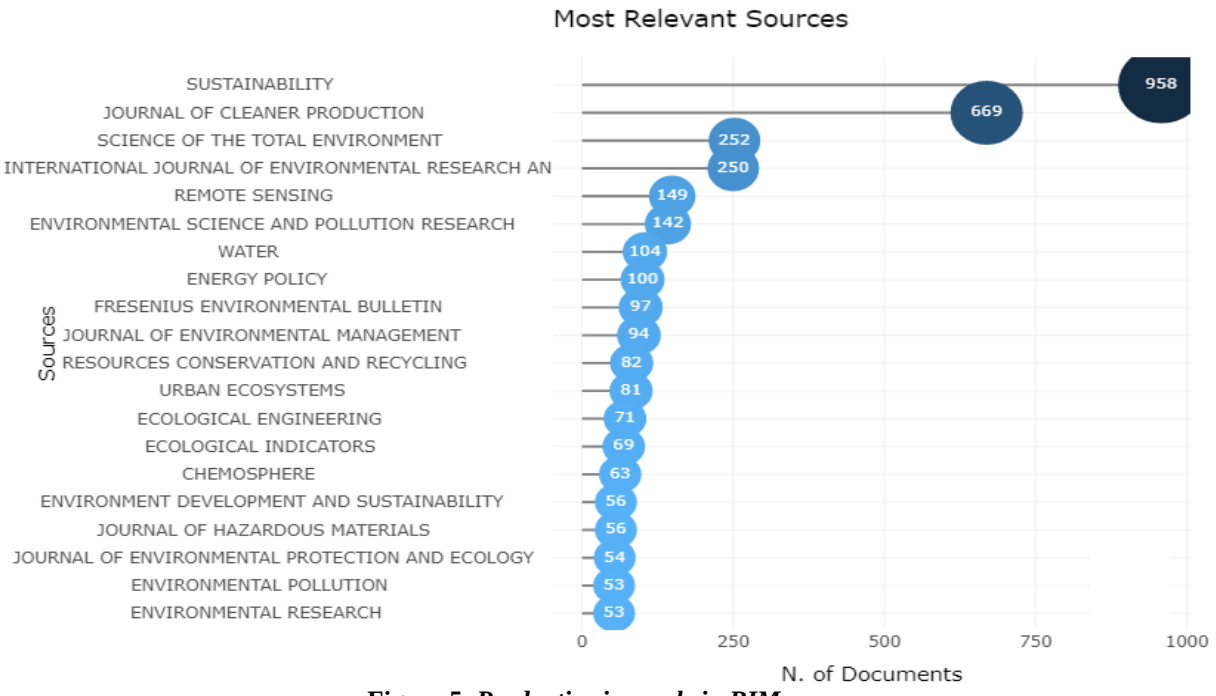

Figure 5. ***Productive journals in BIM***

The top 20 journals with high numbers of published BIM-related articles were presented in Figure 5. Among the journals, Sustainability published the most (958), followed by the Journal of Cleaner Production (669), Science of the Total Environment (252) and International Journal of Environmental Research and Public

Health (250). Other core journals include Remote Sensing, Environmental Science and Pollution Research, Water and Energy Policy. The study of BIM may be concluded to include multidisciplinary research, such as environmental pollution, urban ecosystem, built environment, chemosphere, energy policy, resources conservation and recycling, remote sensing and environmental science.

IV. Future Perspective

Research in BIM in recent times has drawn the attention of many scholars. Bibliometrics analyses of research trends in this area give a broad view of area of coverage in BIM in terms of strength and limitations. Though the research team emphasized on the core areas of bibliometric analysis such as annual scientific production, top authors' production and their relevance over time, academic collaboration network and productive journals. It is however worthy to note that carrying out Bibliometrics analysis on BIM in exhaustive details will require covering every aspect of the analysis and this is recommended for future consideration.

V. Conclusions

The current study conducted on BIM between 2012 and 2022 through bibliometric analysis provides a quantitative representation of studies conducted and data gathered in the past and present, bridging the gap historical gaps and forecasting the future on BIM thereby providing valuable insights for building research agenda and policymakers could use the results to strengthen investment policies in BIM research and development.

VI. Recommendations

The following are the recommendations:

- Awareness about BIM
- Education/Advocacy about BIM

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