Review

A Scientometric Review of Bim in Facility Management Research

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A Scientometric Review of Bim in Facility Management Research

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Abstract: The spate of BIM adoption and implementation in facility management in Africa has been regarded as a developmental discourse gradually gaining grounds. While several studies have focused on manual review of the intellectual progression of BIM research, this confined review however understates the evolution of BIM in facility management. This approach therefore is not always representative of the picture of BIM in facility management at its formative stage. This paper aims to present a scientometric review of BIM in facility management exploring the intellectual progress made so far by authors. The state of the art of BIM in facility management research and practice and the challenges debilitating against BIM in facility management research. The review revealed a considerable amount of research endeavours limited by inadequate collaboration acorss organizations and institutions. The study also revealed the low degree of awareness amongst researchers in the AEC sector. While North America and China were leading countries due to the activity of few universities, Africa wasn't as visible in research endeavours. The study recommended an increase in awareness drive across countries and increased government effort, joint funding for research to include gaps in practice issues.

Keywords: building information modelling (BIM); facility management; scientometric review; Africa; construction industry; barriers; awareness

1. Background of Study

With its innovative new features and improved workflow, Building Information Modeling (BIM) is quickly becoming the standard for the AEC (Architecture, Engineering, and Construction) sector of the global construction industry. (Eastman, Teicholz, Sacks, & Liston 2008; Saka & Chan, 2019). To develop and manage building data, BIM is not a product or a software program but rather a process. It has been touted to solve current dilemmas in the construction industry such as incessant building collapses in Africa, poor communication flow among construction professionals, and low productivity amongst others (Oladiran and Onatayo, 2019). However, with the advantages of BIM in the construction industry and on projects, its level of awareness is still relatively low across countries (Saka & Chan, 2019; Olawumi & Chan, 2018). While advances in research have evolved over the years, it compares low with adoption in practice, especially in the African continent. This lag has been blamed on several factors such as economic-related barriers, technology-related barriers, and inadequate or absent government support (Saka & Chan, 2019; Lok & Baldry, 2015).

The introduction of BIM into the built environment had marked a paradigm shift in the workflow and communication processes in the industry from conceptualization of a project through its execution and lifecycle. It is therefore a promising future for the built industry. Lack of initiative, expertise, and training; a fragmented construction sector; varying market preparedness across organizations and regions; and industry opposition to changing established working patterns are all challenges that have slowed the adoption of BIM in the built environment of developing nations (Aboushady and Elbarkouky, 2015; Saka & Chan, 2019). For emerging innovations like the BIM to be successfully adopted, meticulous focus must be paid to identifying gaps in learning, developing competencies, highlighting strengths and weaknesses to be improved. Education and learning is imperative as it has been discovered that competence training and reskilling is essential in BIM implementation (Onososen, 2019; Ikediashi, Ogunlana & Boateng 2014). Concerted effort and

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collaborative strategies must be implemented across board by construction professionals, construction stakeholders and the client in embracing the advantages of the BIM system than the conventional building system.

Design, construction, and facility management may all benefit greatly from BIM, since it is a strong set of design management tools that can be used throughout the whole building lifecycle (Olawumi & Chan, 2018; Ikediashi, Ogunlana & Boateng (2014). Its compatibility with other systems provides a framework for coordinating efforts among participants and enhancing final results. According to Becerik-Gerber and Rice (2010), building information modeling (BIM) helps the construction industry boost efficiency by facilitating open lines of communication and teamwork amongst all parties involved in a project from its genesis to its completion. Another definition is a digital archive that facilitates project-wide data management.

2. Literature Review

Building Information Modeling (BIM) is used to represent a process rather than a product, as it is not a physical item or a specific piece of software (Eastman et al., 2008). By tracking the rate of BIM adoption inside a company, Bew & Richards (2010) were able to create a model for BIM maturity. Gupta et al. (2014) further enhanced this by including its usage with Renewable Energy systems (RES) tools, which is a big deal. Demian and Walters (2014) modeled the usage of BIM for project information management on a construction site and argued that the adoption and application of BIM in the construction sector has delivered more benefits than drawbacks. While Antón and Daz (2014) and Kivits and Furneaux (2013) have noted the low acceptance and implementation of BIM in numerous countries, Clevenger and Ozbek (2016) have highlighted the use of BIM and parametric change technologies. Concerns about BIM interoperability have been raised in the architecture, engineering, and construction (AEC) industry. Current practice issues have been recognized by researchers including Nanajkar and Gao (2014), Axon (2013), Antón and Daz (2014), Oladiran et. al. (2018) and Kivits and Furneaux (2013), who have also advocated for future changes.

Arif, Egbu, Alom, and Khalfan (2009) designed a knowledge retention maturity model with a four-stage knowledge retention process that includes; socialization, codification, knowledge building, and knowledge retrieval. The use of distance education to gain knowledge of Building Information was also investigated by Poh, Soetanto, Austin, and Adamu (2014).

Building Information Modelling is essential in facility management in order to leverage facility data through the facility lifecycle in an effort to avail sustainable, safe and healthy built environment infrastructure for users. BIM process commences from the conceptualization of a project throughout its lifecycle. This usage is imperative to facility management which requires these facility data in its infrastructure maintenance. The process will enable and efficient and effective maintenance, renovation, and operation of building infrastructure (GSA, 2011; Adegoke & Adegoke, 2013; FM World, 2010). The built industry is essential in aiding the economic growth of a state, however, post-built execution of work, the facility is in need of constant maintenance and operation carried out by the facility manager. Facility management is however currently burdened by inefficiencies in tracking facility components accurately, identifying defaults and ineffective systems. BIM is imperative in avoiding cost overruns, inefficient building operations and delay in resolving clients' complaints as it will avail information on accurate equipment inventory which is essential for budgeting repair/ replacement (GSA, 2011).

Facility management therefore requires BIM for visualization of building components in identifying defaults, granting ease of access to identifying location and relationship of building components and systems alongside identifying state of the condition of building systems. Its edge over traditional 2D drawings is its data-rich, object-based, intelligent and parametric representation of the facility (GSA, 2011). The need for BIM in facility management according to GSA, 2011 has been ascribed to;

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Table 1. Need for BIM-enabled facility management.

	Need for BIM-enabled facility management
Maintenance Workers	Time is saved by avoiding repeat visits to the same site to complete unplanned work orders, which is made possible with the use of up-to-date maintenance information provided before the worker leaves the office.
Building Operators	Enhances PM order completion via a more precise inventory of tools and machinery Helps save money on maintenance by getting workers at urgent tasks more quickly. Locating and cataloging building storage facilities and machinery
Spatial Data Managers	The process of identifying all building elements that impact energy consumption, needs maintenance, and aid in safe operations. Locating and identifying hard-to-find building elements to lessen potential problems and guesswork when carrying out maintenance requests. Data used throughout the design and implementation phases of a project can be accessed. The accuracy of current state data is improved. Streamlines the process of drafting spatial programs made out of polylines to save time.
Building Users	Customer contentment due to expedited problem solving

3. Research Method

This section outlines the research method used in conducting a scientometric analysis of literature in BIM Facility management in integrated AEC sector. The methodology is detailed in providing a guidelines of approach adoption and conduct of analysis.

3.1. Scientometric Analysis in extant review

The study set out to appropriate the state of the art of BIM enabled facility management in the AEC sector. To effectively map out previous efforts and future directions, scientific mapping was adopted to effectively narrate the state of the art of BIM enabled facility management. Scientometric analysis unlike manual reviews is more suitable in analysing and describing working linkages between researchers, keywords, countries, and research organizations on a subject area (Wuni, Shen, & Osei-Kyei, 2019; Cobo, López-Herrera, Herrera-Viedma, & Herrera 2011). Scientific mapping comprises of informatics, bibiliometric and scientometric analysis, however, scientometric analysis scientifically maps out extant literature using bibliometric data and approaches (Wuni et al, 2019).

3.2. Software Tools for Scientometric Analysis

Scientometric involves the mapping and visualization of the characteristics of scholarly datasets. This cannot be achieved manually and require software tools such as CitNetExplorer, CiteSpace, Gephi, BibExcel, VantagePoint and VOSviewer (Wuni et al, 2019). The VOSviewer software version (1.6.15) was used for this study as it permits science mapping from diverse databases such as Scopus, Dimensions, and Web of science used in visualizing bibliometric networks (Van Eck & Waltman 2014). VOSviewer has also been used extensively in mapping scholarly datasets in building Information modelling (Saka & Chan, 2019; He, Wang, Luo, Shi, Xie, & Meng, 2017). It also supports direct export of data from academic databases such as Scopus, Web of Science and Dimensions. Dimensions was selected for this study.

3.3. Bibliometric data query

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Following the precedent of Saka & Chan (2019); Wuni et al (2019) the study's keywords were queried on the Dimensions Academic Publications Database As "Building Information Modelling AND Facility Management" OR "BIM AND Facility Management" In Order To Extract A Large And Reliable Dataset Of Search Findings. Without Defining the Limit, 28,436 results were generated as of July 2020. The query was restricted to articles with the exclusion of conference papers proceedings and books as these have been found to impair the datasets results with little or no significance (Saka & Chan, 2019; Hosseini, Martek, Zavadskas, Aibinu, Arashpour,. Chileshe, 2018). In the source title, the top journals in construction were selected while other journals from fields irrelevant to construction were excluded to refine the search. Papers published in English were selected and refined to a period of 2010 to 2020 in line with Saka & Chan, (2019). A total of 82 document results were adopted after the final search query.

4. Results and Findings

4.1. Co-Authorship Network

Overlay visualization was used in analysing the Co-Authorship Network, each author in the item density visualization has a colour that points to the density of items at that point. The minimum number of documents selected per author was 5 while number of citations was selected at 3. A pool of 73 Authors met the threshold. There was a steady increase in co-authorship network between 2015 and 2019 with the yellow clusters indicating the recent publications in this regard (Meho & Rogers, 2008). 2020 is notably reduced due to the year still being in progress and the global coronavirus pandemic. The Authors with the strongest links and clusters identified are; Wang X who is more proficient than other Authors (Wuni et al, 2019). Other Authors are; Cheng, J.C,P, Li H, Wang, J; Kim, H; Sacks, R, Zhang, J; Luo, H; Ding,L; Matthews, J; Chong, H.Y and Eastman, C.M respectively. The difference in colours illustrates authors with similar clusters. The analysis shows that BIM enabled Facility management has witnessed a steady increase notably in the last five years but evolved slowly between 2010 and 2015. This indicates a growing interest and commitment to BIM enabled facility management amongst researchers in the AEC sector. According to Wuni et al (2019), co-authorship analysis is imperative as it indicates the collaboration between researchers and institutions in facilitating knowledge exchange, ideas and sharing of innovations. Figure 1 displays the co-authorship collaborations amongst researchers on BIM driven facility management in the AEC sector. However, the item density visualization also shows the collaborations are sparsely inter-continental and more intra-institutional.

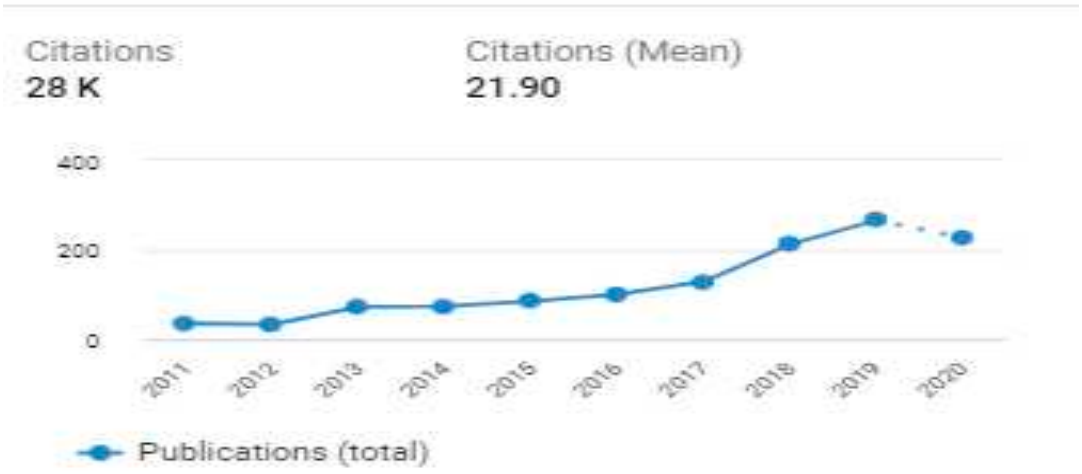

Figure 1. Distribution of publications between 2010 and 2020.

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Table 2. Active Researchers in BIM-enabled Facility management research.

RESEARCHERS	INSTITUTION	PUBLICATIONS
Xiangyu Wang	Curtin University, Australia	31
Heng Li	Hong Kong Polytechnic, China	17
Charles M Eastman	Georgia Institute of Tech, United States	15
Carl Thomans Haas	University of Waterloo, Canada	15
Lie-Yun Ding	Huazhong University of Science and Technology, China	14

4.2. Active countries in BIM-enabled Facility Management

Further analysis was conducted on co-authorship distribution by countries with a minimum number of 5 documents per country giving a total of 35 countries meeting the threshold. China and the United States were identified as the leading countries. Also, in the network visualization shown in Figure 2, other countries such as United Kingdom, Canada, Australia and Taiwan had considerable collaborations. Africa was however sparsely identified with Egypt having mild collaborations. This shows countries contributes unevenly to research in BIM and Facility management. These could be as a result of differing awareness and research interests between researchers and Authors in countries. As stated by Wuni et al (2019), inter-continental collaborations could foster future collaborations, promote sharing of technology and emerging innovations and facilitating joint research funding programmes (Hong & Chan, 2018).

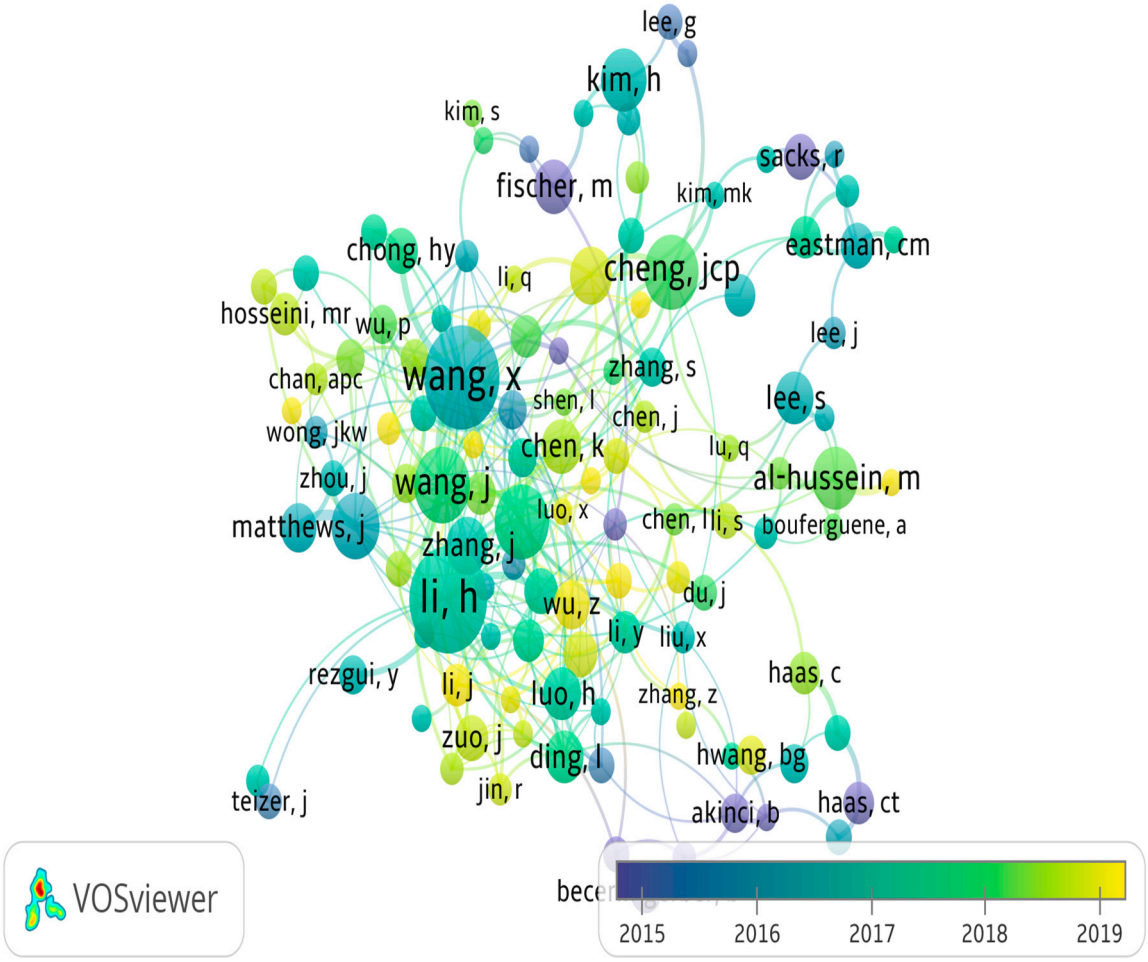

Figure 2. Item visualization of Co-Authorship Network.

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4.3. Science mapping of Institutions

Institutions and organizations publish articles by identifying gaps and emerging research areas in a subject area. It is imperative for innovation, curriculum development and improving productivity. The map was generated with overlay visualization and shown below in Figure 3. The minimum number of documents from an organization was set to 15 with 22 meeting the threshold. The most prominent organizations identified are institutions such as; Curtin University which was shown to be more active than other institutions. Hong Kong Poly U, Georgia Institute of Tech, University of Hong Kong, Huazhong University and Stanford University also had moderate activities respectively. The research outlets are those who have published at least 15 journals on BIM-enabled Facility management in the AEC sector. The research focus of the institutions were also grouped together in clusters using varying colours as shown in Figure 3 below. University of Alberta, University of Hong Kong, Hong Kong Poly U and National University of Singapore are in a cluster signified by the yellow colour. Also, Stanford University and Georgia University were grouped under a different cluster. Curtin University and Huazhong University also belonged to a different cluster of research focus.

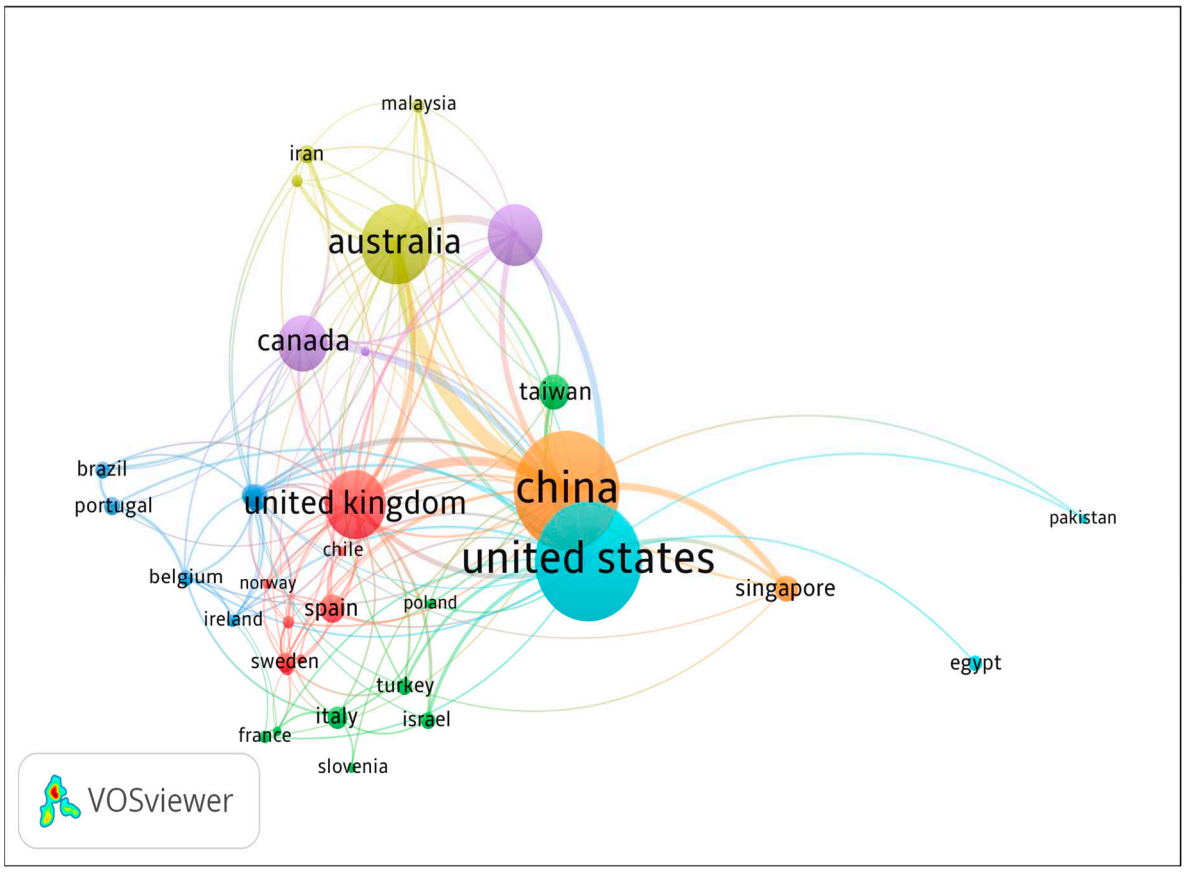

Figure 3. Network Visualization of Active Countries.

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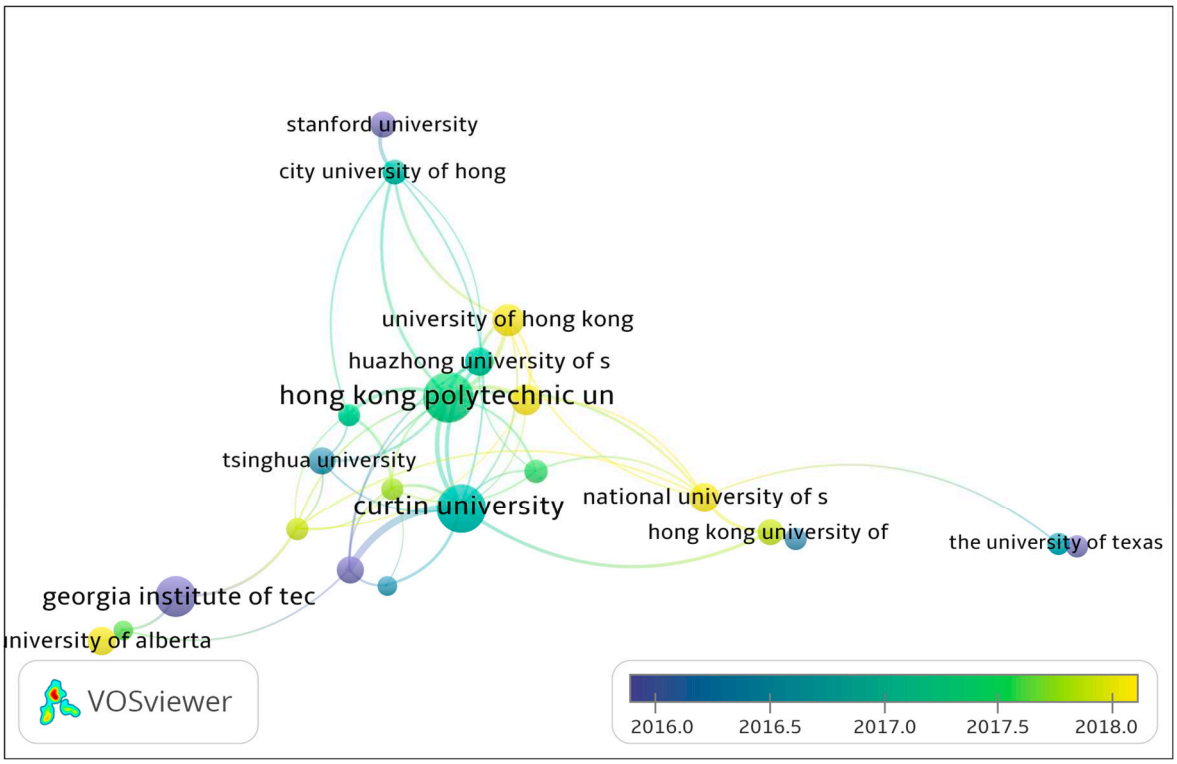

Figure 4. Overlay Visualization of Active Institutions in BIM-Facility management research.

4.4. Co-occurrence network of keywords

In Overlay visualization, the size and label of an item is determined by the weight of an item, which means an item with more weight would appear with a larger circle. The minimum number of occurrence of a term was set at 10 with 46 meeting the threshold. As stated by Wuni et al (2019) keywords are essential in indexing research articles in academic databases which gives an idea of the direction and theme of the publication. The priority areas of research in a specific subject field can therefore be identified through scientific mapping of related keywords. The top keywords identified are Construction, planning, optimization model, sustainability, information model, impact and cost. The different colour in nodes sizes illustrates the keywords that closely co-occur. Other keywords identified are; interoperability, Visualization, Augmented Reality, Life assessment and knowledge (Adegoke & Adegoke, 2013). The knowledge of co-occurrence of keywords is essential to researchers in facilitating keywords indexing appropriately in the retrieval of articles.

4.5. Author Co-Citation Network

The impact of an Author's publications can be measured by the number of citations recorded by the publication. In analysing the author co-citation network, a minimum number of 20 citations were selected. Wang, X had the most co-cited amount of publications as shown in the density map represented in Figure 5. Clusters of other authors include: Akinci, Bl Lu, Weisheng; Lee, G and Li, H respectively amongst others.

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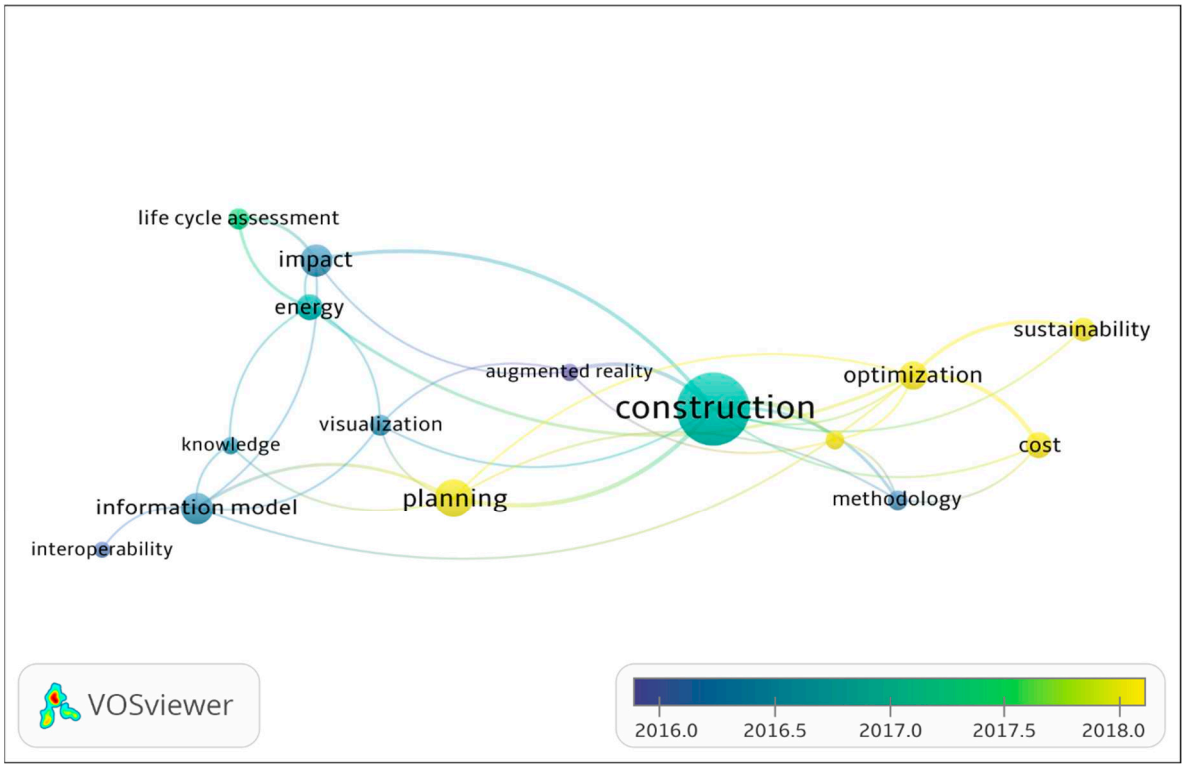

Figure 5. Co-occurrence network of keywords.

Figure 6. Author Co-Citation Network.

4.6. Document Co-Citation Network

This is the network of cited references in the documents that were analysed. It provides a similar trend of the research themes and related works as often cited in documents. The minimum number of citations of a cited reference was set to 5 with 72 meeting the threshold. The density map reveals a

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cluster of co-citation between Succar, B (2009), Bryde, D et al (2013); Volk, R, et al (2014) and Azhar et al (2011). Another cluster also appeared between Tang et al (2010) and Golparvar-fard, (2013). There was also a cluster between Eastman (2009) and Sacks et al (2010). These clusters showed a dearth of inter-institutional and inter-continental collaboration of documents as most documents collaboration with the most influence were collaborated within institutions or across departments. A huge gap was also noticed in collaboration with African institutions which is lagging behind in BIM-enabled facility management research. The sparse regional commitment of Africa is easily attributed to governmental efforts, attitudinal differences, awareness, market, cost and risk factors (Saka & Chan, 2019). This huge deficit in BIM-enabled facility management amongst researchers on the African continent which indicates a low rate of implementation or adoption can be spurned through commitment by professionals' stakeholders and researchers in the academia

Consequently, to improve research and practise, different strategic approaches is imperative for each region. While Asia led by China, Hong Kong, and Singapore with North America led by the United states and Canada needs a collaborative frontier in exchange of Knowledge, advances made and emerging areas, Africa needs an awareness drive to hasten the rate of implementation in research and practice. Regional commitment is imperative in driving local policies and approaches to the success of BIM-enabled facility management (Adegoke & Adegoke, 2013). The experiences and peculiarities associated with the AEC sector of different regions also provides a more robust method to improving the effectiveness and efficiency of the BIM-enabled facility management on integrated AEC projects. (FM World, 2010). The awareness of this result is therefore instructive in aiding research funding and for researchers prominent in this field and for collaborative exchange and partnership between would be researchers and established Authors in the field of BIM-enabled facility management.

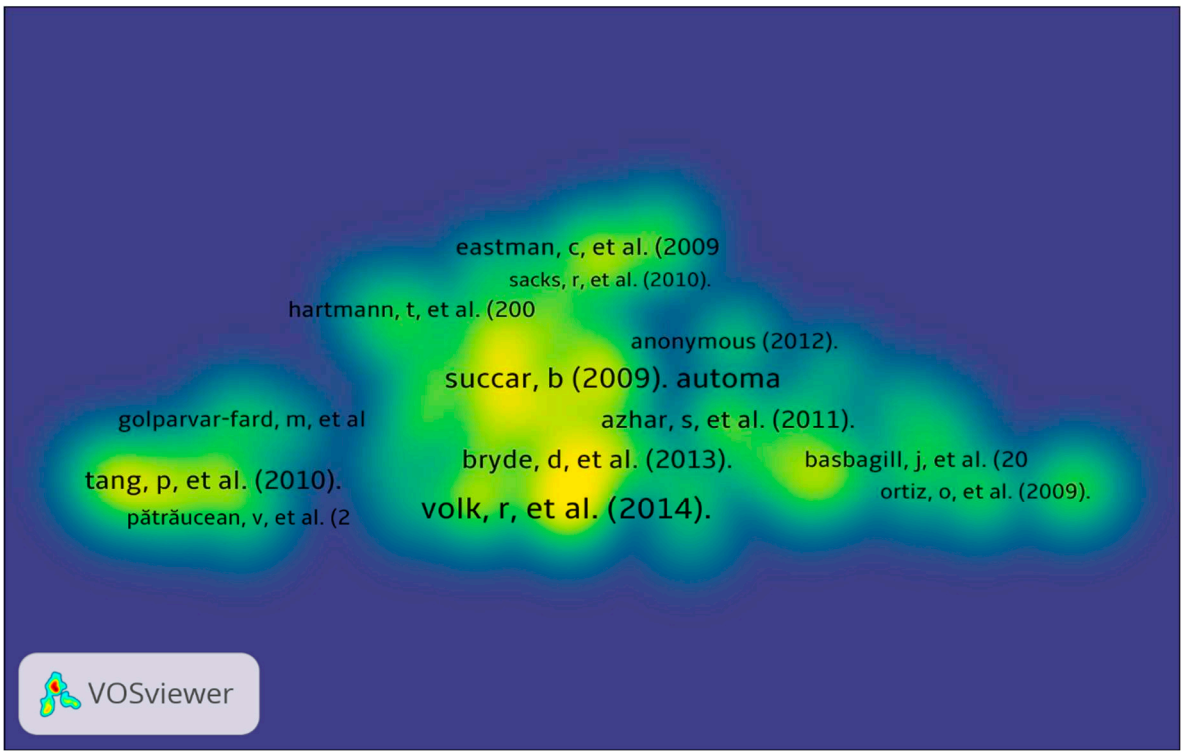

Figure 7. Density visualization of Document co-citation.

5. Conclusion

The state of facility management has brought increasing concerns in the performance of buildings in the AEC sector. BIM has emerged as a veritable process to improve the efficiency and workflow of facility management of buildings. This interest has brought about varied publications over the years and across diverse themes. This study therefore appropriated the state of the art of

research in BIM-driven facility management in the AEC sector. Scientometric analysis of bibliometric data extrapolated from Dimensions academic database was analysed for co-authorship networks, keywords indexation, co-citation networks, and distribution across countries and institutions.

The study's population was distributed over ten years with restriction to article publications in English language. A large disparity was observed amongst nations on publications in BIM led facility management. While Africa had little contribution, China and United States had a large group of publications that placed Asia and North America moderately on the scientific mapping. The disparity in publications across continents and countries is attributed to an evolving level of awareness which has grown considerably over the years but in need of more awareness drive. Technology-related barriers, economic barriers and governmental efforts are some of the hindering factors affecting the awareness of BIM-enabled facility management.

The analysis further shows that the most active researchers with influential research clusters are; Wang Xiangyu from Curtin University, Heng Li from Hong Kong Polytechnic, China, Charles M Eastman from Georgia Institute of Tech, United States, Carl Thomans Haas from University of Waterloo, Canada and Lie-Yun Ding from Huazhong University of Science and Technology, China respectively. Also, Wang X had the most co-cited number of publications followed by Akinci, Bl Lu, Weisheng; Lee, G and Li, H respectively amongst others. The network of cited references revealed that with a minimum number of 5 citations, author such as Succar, B (2009), Bryde, D et al (2013); Volk, R, et al (2014) and Azhar et al (2011) had the most active clusters. Other clusters identified occurred between Tang et al (2010) and Golparvar-fard, (2013), Eastman (2009) and Sacks et al (2010). These clusters revealed a slow growth in collaboration between authors across countries and organizations as authors were more disposed to collaborating within the department and institution. While awareness drive is imperative, joint collaboration through research funding is critical in advancing the practice and research of BIM-enabled facility management.

The study is limited despite its significance in solely basing its analysis on articles published in English language on the Dimensions academic database. However, further studies could focus on other databases covering more language and detailing regional experiences in BIM-enabled facility management on research and practice.

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