Viewing Digitalisation in Construction through the Lens of Past Studies

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Abstract

With the fourth industrial revolution come issues surrounding the digitalisation of the construction business. While studies on the digital transformation of industries such as manufacturing, banking, telecommunication, education, and the likes continue to emerge, the story is not the same for construction. The industry has been known for its slow adoption of digital technologies and paucity of information exists in the area of its digitalisation. It is based on this notion that this study conducted a bibliometric review of digitalisation research in construction-related fields with a view to understanding the area of focus of past studies. Data used were gathered from Scopus database (conferences and Journals), and only materials with digitalisation/digitisation/digital transformation and construction in their title, abstract and/or keywords were extracted for further assessment. VOSviewer was used to prepare a co-occurrence map based on the bibliographic data gathered. Findings revealed that increase publication on digitalisation started in 2015, most of which exists in conference proceedings. Majority of these publications emanated from Asian and European countries, with none evident within African countries. Research on digitalisation within construction-related fields have placed focus on construction project delivery, BIM and project design, the digital transformation of the construction industry, and BIM in construction project management. Furthermore, the current research focus is tending towards more of modeling of information to deliver the best possible construction. This study contributes to the body of knowledge as it reveals areas for possible research in digitalisation in construction, particularly in African countries were lack of literature in this regard exist.

Keywords: Construction, Digitisation, Digitalisation, Digital technologies, Digital transformation

1. Introduction

Technological advancements are increasing at an alarming rate, thus, constantly altering the way in which the society lives and functions. One such advancement is the fourth industrial revolution (4IR) which incorporates the use of digital technologies (DTs) and processes in a bid to achieve more efficient service delivery. Evidence of this has been noted within the manufacturing industry (Dall'Omo, 2017; De Carolis *et al.,* 2017), banking sector (Mladenovic, 2018), education sector (Sheikhshoaei *et al.,* 2017), telecommunication (Khin and Ho, 2018; Valdez-de-Leon, 2016) etc., of most developed and some developing countries around the world. Traces of the adoption of the concept of 4IR are equally becoming evident within the construction industry of developed countries and immense benefits are promised. However, the situation is different for most developing countries as their construction industries faces diverse challenges that impede the adoption of new concepts (Aghmien *et al*., 2018).

It has been observed that digitalisation is a key driver of the 4IR (Bienhaus and Haddud, 2017). However, it is imperative to state at this point that the word "digitalisation" has come with diverse meaning since the advent of the 4IR. Words such as digitisation, digitising, and digital technology, have been used in place of digitalisation. In most cases, these exchanges have been made wrongly (I-Scoop, 2016). Rouse (2017) viewed the term "digitisation" as the process of transforming information into digital format. I-Scoop (2016) described digitisation as simply the conversion and/or representation of something non-digital into a digital format, which can then be used by a computing system for diverse

purposes. On the other hand, the term "digitalisation" according to Kalavendi (2017) is the increased use of DTs in the operations of an organisation. Simply put, digitalisation is the incorporation of DTs into everyday life, through digitising anything that is capable of being digitised (Ochs and Riemann, 2018). Thus, while digitisation is seen as the digital transformation of specific processes that were not originally digital, through the use of DTs, digitalisation is the deployment of these transformed processes into the business life of the organisation. Based on the aforementioned descriptions, in the context of this study, the term digitalisation is conceptualised as *the innovative use of digital technologies in the delivery of tangible and intangible services within a construction organisation with a view to gaining a competitive advantage over other competitors and provide better service delivery*.

Despite the immense benefits that come with the digitalisation of services, the adoption of DTs in the construction is still slow in most developing countries (Building Radar, 2015; Castagnino *et al.,* 2016; Osunsanmi *et al*., 2018). One key culprit of this lack of adoption is the lack of investment in research and development (R&D) (Aghimien *et al*., 2018). Aghimien *et al.,* (2019), Chilipunde (2010), and Fadhi and Tan (2001) all noted that the construction industry in developing countries rarely supports R&D and this has significantly affected the industry's development particularly in the aspect of adopting innovative technologies. This shortcoming is bound to affect the knowledge and understanding of the existence and applicability of available DTs needed for the attainment of digitalisation of the industry. It is based on this knowledge that this study set out to identify research focus in digitalisation within construction-related fields.

2. Overview of Digitalisation in Construction

Digitalisation is described as the most important current technological advancement, whose impact will be faced by all levels of society (Leviakangas *et al*., 2017). Dall'Omo (2017) observed that digitalisation has found an abode in every aspect of human life, be it simple personal devices or complex industrial systems. Ochs and Riemann (2018) noted that digitalisation incorporates digital technologies into everyday life, through digitising anything that can be digitised. According to Leviakangas *et al.* (2017), a unique technological base for metasystems of products is created through the use of DTs such as intelligent sensors, robotics, and automation. Rüßmann *et al.* (2015) highlighted some significant DTs that are driving the 4IR. Examples include Building Information Modeling (BIM) which is described as "utilises cutting-edge digital technology to establish a computable representation of all the physical and functional characteristics of a facility and its related project life-cycle information, and it is intended to be a repository of information for the facility owner/operator to use and maintain throughout the life-cycle of a facility" (Ashcraft, 2007). There is also the Internet of Things (IoT) which is an overall system of network, linked to each other and uniformly addressed objects by means of standard conventions (Vaidya *et al.*, 2018); augmented reality, which is an innovation that gives an augmented view of objects or designs using specific gadgets (Celaschi, 2017); and big data analytics which is viewed as the most vital technology in relation to the large collection, preparation, and investigation of unorganised and organised information with savvy algorithms (Petrillo *et al*., 2018). There is also the use of autonomous robots in performing autonomous production (Bahrin *et al.*, 2016), cloud computing wherein scalable IT-related capabilities are provided as a service over the internet to multiple external customers (Kumar and Ravali, 2012), 3D printing which is the process of creating a physical object from a 3D digital model in a layer by layer process (Lim *et al.,* 2012), and many other technologies which are gradually gaining recognition within the construction industry.

It has been noted that for digitalisation to be attained, structures within an organisation, management views, as well as organisations business strategies need to be transformed digitally. Matt *et al.* (2015) noted that organisations that desire to be digitally transformed needs to formulate a strategy that will cut across other business strategies and allows management to properly coordinate business activities, identify priorities, implement and at the same time oversee transformations that occurs as a result of new technologies. Despite the immense contribution digitalization proposes to the development of construction organisations, these organisations still face challenges that deter their digital transformations. Examples of these challenges include; lack of technical know-how (Bédard-Maltais, 2017), expensive associated cost of implementation and training of workers (Oke *et al*., 2018), data security issues (Redmond *et al.,* 2012; Zeng *et al.*, 2012) issue of interoperability (Eastman *et al*.,

2011), and fear and resistance to new technologies (Bédard-Maltais, 2017) just to mention a few. Thus, for the successful attainment of the strategies for the transformation of organisations through the use of new technologies as suggested by Matt *et al.* (2015), construction organisations need to first solve the existing problems that may obstruct their smooth transitioning into becoming a digitalised organisation

3. Research Methodology

The study assessed the areas of research focus in published works on digitalisation within construction-related fields. Due to the newness of the concept of digitalisation in construction, a bibliometric technique which according to Olawumi and Chan (2018) allows a concise identification and mapping of scientific knowledge area through the identification of research patterns and boundaries, was adopted. A literature search was conducted using the Scopus database which has been identified as one of the major databases that cover different scientific fields (Guz and Rushchitsky, 2009). Since its introduction in 2004 by Elsevier Science, Scopus has rapidly become a leading choice for literature search and has been adopted in most review works (Chadegani *et al*., 2013). Also, Olawumi *et al.* (2017) have earlier noted that no clear distinction exists between Scopus and Web of Science which is considered as the two major science research databases. It was further stated that there exists considerable overlap in the records of both databases. While the study of Olawumi *et al.* (2017), assessed BIM literature using information gathered from the web of science, the study of Vuksic *et al.* (2018) on digital transformation case studies adopted information from both Scopus and Web of Science. This current study, however, focused on research works from Scopus which is a more recent and fast-growing database recognised among scientific researchers as observed by Chadegani *et al*. (2013).

The search for relevant literature focused on published journal articles and conference proceedings within construction-related study areas. More specifically, these study areas include engineering (which include construction), energy, material science, environmental science, and business management. The choice of selecting journal articles was premised on the fact that articles from journals are considered more reliable sources of knowledge and are deemed more concise and detailed than other sources of information (Zheng *et al.,* 2016). Similarly, Webster and Watson (2002) have earlier recognised the importance of conference proceedings as reliable sources of literature review, hence their inclusion in this study. A similar approach was taken by Vuksic *et al.* (2018). The key search words adopted for the study were "digitalisation" AND Construction, "digitisation" AND Construction, and "digital transformation" AND Construction. Only research having these search words in their title, abstracts and keywords were considered for review. In searching, no restriction was placed on the range for publication year due to the assumption that digitalisation is only becoming a recent concept within the construction industry. Thus, placing a restriction on year might significantly reduce the number of revealed literature. Only articles published in the English language were considered and the literature search was conducted in January 2019. The initial search using the stated keywords revealed a total of 116 articles published between 1981 and 2019. After careful analysis of the papers extracted, 2 were deleted due to repetition leaving a total of 114 articles.

The results are presented based on co-occurrence in terms of a number of publications per year, the number of publications per country, and the co-occurrence of keywords. A co-occurrence map was developed based using VOSviewer which is literature review software that offers the basic functionality needed for visualising bibliometric networks in the easiest way possible. The software displays only the nodes in a bibliometric network and in its visualisation (Van Eck and Waltman, 2014).

4. Results and Discussions

4.1 Publication per year

The result in figure 1 reveals the number of articles published from 1981 to 2019. From the figure, it is clear that from 1981 up to 2014 less research emanated around issues on digitalisation. This result can be attributed to the fact that the concept of digitalisation became stronger with the advent of 4IR

which was first established at the Hannover Fair in 2011 in Germany (Sung, 2018). Since then, issues surrounding 4IR have become topical in most industries (Crnjac *et al.*, 2017). Interestingly, Bienhaus and Haddud (2017) have earlier noted that digitalisation features such as the Internet of Things, Industrial Internet of Things, cloud based manufacturing, and smart manufacturing are important drivers of 4IR. Thus, with the focus on 4IR came the research attention on digitalisation. A significant rise is evident in the year 2015 with 6 publications higher than the 3 observed in 2014. In 2016, a drop from 9 publications experienced in 2015 to 7 publications can be seen. 2017 saw an enormous increase from 7 publications in 2016 to 19, and this continued into 2018 were 27 publications were derived. The year 2019 has recorded 1 research so far and this was because the review was done in the first month (January) of the year. It is believed that more researches will emanate as the year goes by. The finding of this study is similar to the submission of Reis *et al.* (2018) and Vuksic *et al.* (2018) that discovered an increase in literature on digital transformation from 2016 to 2018. In terms of the type of publication, the result revealed that 75 out of the 114 extracted articles came from conferences, while the remaining 39 were journal articles. This can be as a result of the rigor and long duration taken in the publication process of journal articles when compared to conferences papers.

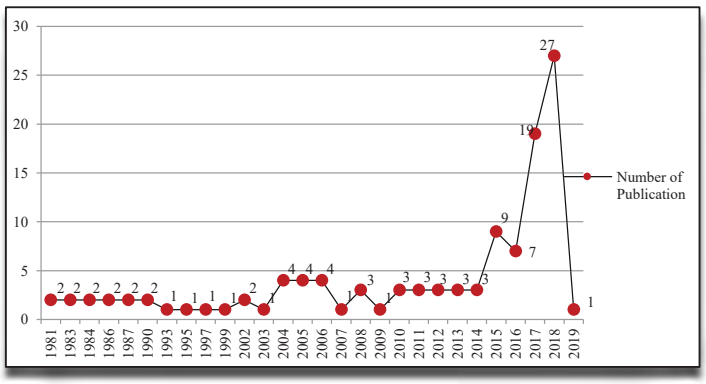

Figure 1: Publications per publication year

4.2 Publication per country

Assessing the number of articles per country of origin, the result revealed that the 114 extracted papers emanated from 28 different countries, of which 13 had just 1 publication each. Figure 2 shows the list of countries with at least 2 publications. China tops this list with 23 research articles. This is followed by Germany, the USA and the United Kingdom with 13, 12 and 8 articles respectively. Sweden, Italy, and South Korea all shared the fifth position with 7 articles each. This implies that most articles on digitalisation in construction-related fields emanated from Asia and European countries. This submission is in tandem with the submissions of Olawumi *et al.* (2017) who noted that most research on BIM (a crucial digitalisation feature) published between 1990 and 2016 emanated from Asia and Europe. The findings are also in line with that of Vuksic *et al.* (2018) which noted that digital transformation research is more from European countries (such as Germany and Baltic), USA and Canada. However, while Canada revealed a considerable number of literature in their study, it revealed only one in this current study. Reason for this disparity can be associated with the difference in the database used in both studies. Findings of this study are also consistent with the Institute of Management Development (IMD) "world digital competitiveness" ranking which revealed that the top 10 most digitally competitive countries in the world are USA, Canada, Hong Kong, and 7 European countries (IMD, 2018). A look at the figure revealed that there is no study emanating from Africa. This shows a knowledge gap in the area of digitalisation in Africa.

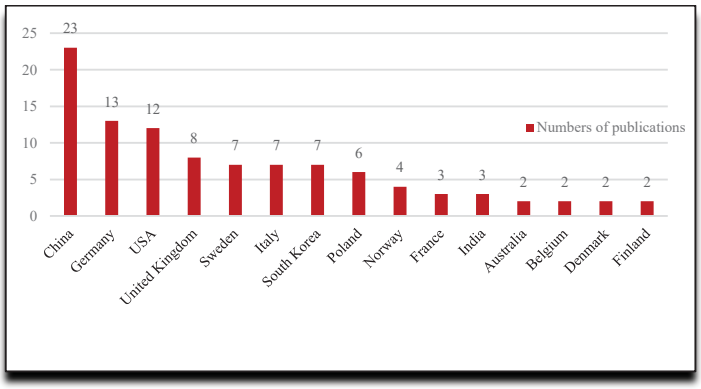

Figure 2: Publications per country

4.3 Co-Occurring Keywords

Using VOSviewer, a co-occurrence map was created. With the minimum number of co-occurrence of keywords set at 5 (VOSviewer default), out of a total number of 1296 Keywords generated, 22 co-occurred 5 times. These 22 co-occurring keywords were grouped into 4 clusters. It is important to note that the closer the keywords to each other the higher their co-occurrence (Van Eck and Waltman, 2014). A look at Figure 3 shows that **Cluster 1** which is the red region has keywords such as construction industry, construction projects, computer-aided design, product design, information technology, and automation. This cluster can be seen as keywords relating to *Construction project delivery.* **Cluster 2** which is represented in green has keywords such as architectural design, BIM, information theory, structural design, and construction. This cluster considers issues relating to *BIM and Project Design*. **Cluster 3** which is represented in blue shows keywords such as analogue to digital conversion, digitisation, digital technologies, information management, and life cycle. This cluster is seen to encompass issues relating to *digital transformation*. **Cluster 4** which is the last cluster is seen in yellow and has keywords such as BIM and project management. It is clear that this cluster focuses on the use of *BIM in construction project management*. Base on the co-occurrence of these keywords, it is evident that researches on digitalisation in construction-related fields have placed focus on applying digitalisation concepts for the successful delivery of construction projects, adopting BIM for the designing of construction projects, the digital transformation of construction activities, and using BIM for effective project management. This finding further confirms Ibem and Laryea (2014) assertion that BIM has made the use of DTs a popular concept within the construction industry. This is because the findings revealed a major emphasis on BIM in past studies. Olawumi *et al.* (2017), Kovacic *et al.* (2015), and Won *et al.* (2013) all noted that the attention being given to BIM in the construction industry is as a result of its ability to provide easy use and reuse of project data across the project development phases. At the same time, it prevents unnecessary replication of project or design tasks.

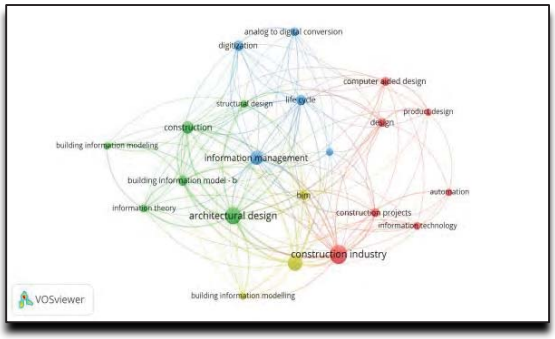

Figure 3: Network visualisation map for co-occurring keywords

Figure 4 is the overlay visualisation map generated from VOSviewer showing the different co-occurring keywords in the different years. With a threshold of 5 occurrences, it is evident that the identified keywords started co-occurring from 2013 with words such as analogue to digital conversion, design, and automation being evident. This means that as of 2013, digitalisation researches were concentrating on the conversion of some basic function from analogue to digital, and the use of automation for project delivery. The year 2014 saw keywords such as structural design, computer-aided design, and product design co-occurring. This implies that in that year, more attention was placed on using these digital conversions in designing construction projects. Researches in 2015 were more on construction information management related, with keywords such as construction industry, information management, and information theory being evident. In 2016 more issues on project management were evident. Keywords such as project management, construction, digitisation, lifecycle, architectural design, BIM can be seen to co-occur. This co-occurrence of BIM continued into 2017 up on-till 2018 as BIM and DTs are the evident keywords.

This review shows that the trend in digitalisation researches within construction-related fields has earlier involved viewing digitalisation in terms of the transforming of construction-related activities into digital formats, and the usage of digital tools for construction project design. From then on, research has placed focus on effective management of the enormous information emanating from construction projects in order to deliver successful projects. From the management of information, research focus on modeling this information through the use of DTs to deliver best possible construction projects is now evident.

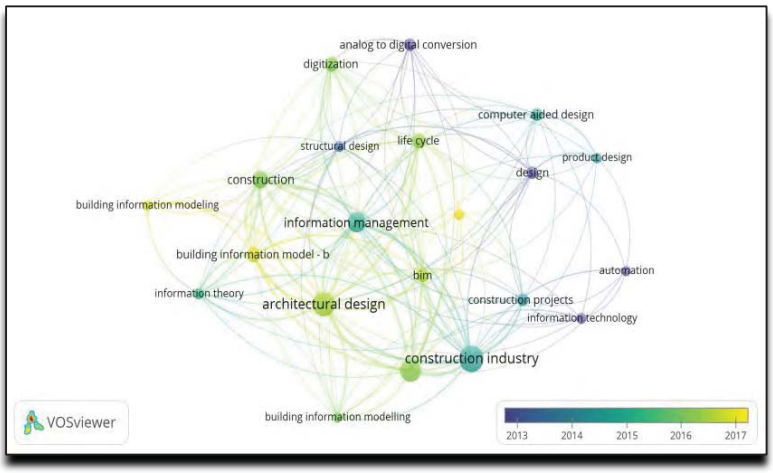

Figure 4: Overlay visualisation map

5. Conclusion

Based on the extracted studies published and indexed in the Scopus database, the study has been able to identify the key area of concentration in research relating to digitalisation within the construction-related fields. The findings have revealed that increase publication on digitalisation started in 2015, most of which exists in conference proceedings. Majority of these publications emanated from Asian and European countries such as China, Germany, USA, and the United Kingdom, with none evident within African countries. Based on the different clusters extracted, research on digitalisation within construction-related fields have placed focus on construction project delivery, BIM and project design, digital transformation, and BIM in construction project management. Furthermore, current research focus in this area is tending towards modeling of information to deliver the best possible construction projects. It can be concluded that there exists a knowledge gap in African countries in terms of researches on digitalisation of their construction industry. Researchers can, therefore, seize the opportunity to add significantly to the body of knowledge with regard to the digitalisation of the

construction industry in Africa. Similarly, findings of this study have revealed that while several DTs are driving the 4IR, BIM is given more attention within the construction-related fields. While the use of BIM is good, a holistic digital transformation of the construction industry can only be attained when diverse DTs are put together for effective service delivery. Thus, more focus needs to be placed on other DTs and how they can better improve the delivery of construction projects particularly in developing countries where construction projects have been adjudged as being poor.

This study contributes significantly to the body of knowledge on digitalisation in construction as it reveals areas wherein research focus has been placed on issues relating to digitalisation within construction-related fields. Its findings have also mapped out possible areas for research in digitalisation in construction particularly in African countries were lack of literature in this regard exist. However, while this study contributes immensely to the body of existing literature on digitalisation, care must be taken in generalising its results since data used were gathered from only Scopus database. Although significant overlap is believed to exist between Scopus and some other databases, further studies can be conducted using other databases or the combination of several others in order to compare results and have a broader view of the research topic.

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