Systematic Review

Building Information Modelling Diffusion Research in Developing Countries: A User Meta-Model Approach

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Abstract: Building information modelling (BIM) has become a common denominator for information management, efficiency, collaboration, and productivity in the construction industry. The adoption of building information modelling has been assessed to be unequal in the construction industry the world over. It has been observed that developing countries are struggling with BIM adoption and are at a beginner stage in the process. Meanwhile, there have been different research efforts focused on advancing BIM diffusion in developing countries. This study focused on reviewing the research trend and knowledge domains of BIM research in developing countries. The study analysed scholarly publications from selected developing countries sourced from the Scopus database from 2005 to 2019; the study covered BIM research efforts since their commencement in developing countries. The study identified the different research trends and the current focus through visualisations using VOS viewer software. The most influential and productive researchers were also identified. This research contributes to the extant body of knowledge by synthesizing the state of the art of BIM research in developing countries. Furthermore, it provides the pre-COVID-19 BIM diffusion status in developing countries.

Keywords: building information modelling (BIM); developing countries; literature review; scientometric analysis; user meta-model

1. Introduction

Building information modelling (BIM) is the new yardstick for collaboration and value delivery on construction projects in the construction industry. Its benefits to the industry have been established by many studies both theoretically and via case studies [1–11] BIM was established to promote cost efficiency, reduce conflict, aid accelerated project completion, enable more efficient designs, and promote collaboration among stakeholders, among other benefits. The adoption of this revolutionary technology in the construction industry has witnessed an upsurge in recent times as the UK, the US, and some other countries have witnessed a good level of adoption and implementation. These countries are referred to as BIM adoption leaders due to their initiatives and implementation strategies to achieve BIM implementation. These countries include the USA, UK, Finland, and Norway, among others. The adopted implementation strategies, however, vary between these countries [12]), as they are tailored to the prevailing economic situation and other factors in the country. These strategies are tailor-made in order to harness the BIM benefits in their respective construction industries for seamless project delivery and client satisfaction.

However, the adoption of BIM has not been observed to be same in every construction industry around the globe. Jung and Lee [13] revealed that while some continents are ahead in the pursuit of BIM adoption, others are still at the beginner phase. Table 1 gives an adoption rate among some countries; this table reveals an unequal BIM adoption rate among various countries. The BIM adoption rates presented in this table were obtained

from various studies conducted in these countries. Although these adoption rates might have changed since the year of assessment, many developing countries are still struggling to overcome the barriers associated with the adoption of BIM. Some notable barriers to BIM adoption have also been established in literature [4,7,11,14–24]. Perceived barriers to BIM adoption include (but are not limited to) the high initial cost, a lack of awareness, inadequate training, resistance to change in the current construction industry culture, insufficient governmental support, legal issues, a lack of interest and demand from clients and contractors, a lack of support from top management, doubts about ROI, a lack of BIM experts, data ownership issues, a lack of sub-contractors interested in using BIM, the absence of the contractual requirement for BIM implementation, the perceived complexity of the BIM model, interoperability between software programs, and a lack of standardized tools and protocols, amongst others.

Table 1. BIM adoption rate among countries compiled by [24] sourced from various studies in these countries.

Country	BIM Adoption Rate	Year of Assessment
Poland	23%	2015
Czech Republic	25%	2016
Japan	46%	2016
Estonia	51%	2015
Australia	67%	2016
China	67%	2014
United Kingdom	74%	2018
Canada	78%	2018
Denmark	78%	2016
United States	79%	2015

In spite of the development witnessed in other parts of the world, studies have shown that many developing countries are struggling and are faced with diverse challenges [25] These challenges have made BIM adoption a challenge in developing countries. Consequently, if these challenges are not eliminated, the developing countries will not be well positioned to compete globally. [25] identified, among others, culture and globalization; the culture of working in isolation prevalent in developing countries is counterproductive for them to compete globally or achieve technological adoption. Moreso, BIM implementation is a collaborative process; hence, the prevailing culture must be eliminated. This is imperative, as technology has broken down international borders and globalization has made it possible for foreign firms with superior resources to compete with indigenous firms. Consequently, the construction business does not have locational boundaries, as construction firms can operate beyond their country of location.

Meanwhile, there has been an upsurge in research efforts and publications focused on BIM diffusion in developing countries. Researchers have published on diverse BIM topics in many peer-reviewed journals, conference proceedings, editorials, book chapters, and books. These scholarly publications focused on different topics directed at achieving BIM diffusion and implementation in these countries. Thus, this study was embarked upon to unearth the trend and scope of these studies systematically. Furthermore, this study summarized the existing studies in developing countries and outlined the research's trends and limitations; it also provides the areas for the present research focus. To achieve this, a scientometric analysis approach was adopted for this study. This is because the scientometric analysis is objective: It relies on the analysis of large data and it is rigorous in nature. This approach has been adopted in different studies to achieve similar objectives, including in the field of sustainability of megaprojects [26], robotics and automation research [27]), ontology research in construction [28], IT application in construction and

demolition waste management [29], and in some BIM-related studies. These include (but are not limited to) [30] (who applied it in the study of 276 articles related to BIM application in Construction Engineering and management sourced from Scopus), [31] (who applied this approach in the mapping of managerial areas of BIM through the analysis of 126 publications published between 2007 and 2015), and [23] (who applied it in the study of BIM research trends in Africa). This study contributes to the research knowledge base in developing countries by identifying the BIM research trends and scope as well as current research focuses and influential authors in the BIM diffusion research space of developing countries. Hence, the study provides stakeholders a state of the art status of BIM diffusion and it provides a basis for comparison with the BIM diffusion status of developed countries. Consequently, it helps for the proper channelling of diffusion efforts to achieve optimal diffusion in developing countries.

2. BIM Adoption in Developing Countries

Evidence from literature reveals that developing countries struggle with BIM adoption. This is due to the fact that developing countries are considered to be struggling with its implementation and diffusion (see [13]). However, this can be said to be in tandem with the technological adoption rate of the construction industry. Generally, the construction industry is known to be slow in terms of technological adoption. This tradition has been established to affect the construction industry in general ([32] since inception when compared to other industries like the manufacturing industry. Defending this tradition, [33] claimed that the uptake of new tools, techniques, and methods requires significant time, skills and capital investment. These factors outlined by [33] were discussed in a cursory manner in the context of BIM adoption in developing countries. This study viewed the three factors under two perspectives: capital investment (an economic-related factor) and time and skills (actor-dependent factors).

2.1. Capital Investment

Capital investment is an economic-related factor. It has been cited in various studies as a hurdle necessary for the seamless adoption of BIM. There are different dimensions to cost; this includes the acquisition of BIM software, the cost of training, and infrastructure setup costs, among others. For instance, cost is identified as one of the barriers to BIM adoption in Algeria [34], Malaysia [35] and Nigeria [36], among others. However, cost should not be an excuse to neglect BIM adoption, since the implementation of BIM has been established to increase profit [37] and its full implementation ensures a great return on investment (ROI) [38]. Hence, the adoption of BIM flattens out the capital requirements with its returns on investment. Construction industry stakeholders in developing countries are encouraged to look beyond the huge investment and set their sights on the returns.

2.2. Actor Dependent Factors

Many prevailing factors require time to align with the BIM adoption requirements. They include a lack of collaboration, a lack of skills, and resistance to change by stakeholders, among others. Early adopters (US) and a developing nation (Vietnam) [39], as well as the UK [37], also experienced these as hurdles required for BIM adoption. Most of the factors requiring time are human-centric; they are dependent on the human factors or actors in the construction industry. This can otherwise be termed as the prevailing culture among the stakeholders in the construction industry.

Meanwhile, [36] opined that the factors affecting ICT adoption in the Nigerian construction industry (NCI) include national and organizational culture. The South African construction industry is not any different, as a lack of BIM education, rigidity and reluctance to change, low levels of commitment, and lack of skills and knowledge [19,40] have been identified as the key barriers to BIM adoption. These barriers (especially rigidity and reluctance to change) are central to the problem of undelivered value in the South African construction industry [41]. Overall, these prevailing actor centric factors are dependent

on the efforts of the actors focused on overcoming them. According to the structuration theory [42], structures do not exist independent of the actors. The actors determine the success of a structure (or otherwise). Thus, these existing barriers to BIM adoption in the construction industry (particularly in developing countries) can be overcome speedily if the actors change the existing structures to support and align with BIM requirements.

2.3. Peculiar BIM Barriers to Adoption

The barriers to BIM adoption are different between BIM users and non-users. Eadie et al. [43] analysed the barriers to BIM adoption in the UK by comparing the perspectives of BIM users and non-users. It was observed that BIM users ranked ROI related doubts, rigidity/lack of flexibility and BIM training cost as the top three barriers while lack of supply chain buy-in, lack of flexibility, lack of technical expertise and cost of Software were the top three barriers by non-users [43]. Most developing countries are still struggling with BIM adoption, they are at infancy [13] due to the bottlenecks inherent in BIM adoption [44]. Consequently, developing countries cannot be referred to as outstanding BIM users for now. Although few BIM studies exist in developing countries, the research efforts focus on BIM implementation and diffusion. These studies identified different barriers to adoption, among other BIM adoption issues, as regards BIM implementation in developing countries.

From the studies identified in Table 2, it can be inferred that most BIM studies in developing countries employ the quantitative approach. Case studies are rarely employed in developing countries; this might be attributed to the prevalent low BIM maturity level. Furthermore, cost and lack of expertise are observed to be the common barriers to BIM adoption. This is in tandem with the findings of [43] regarding barrier to BIM adoption by BIM non-users.

3. Methodology

This study mapped out BIM diffusion research efforts in developing countries via data collected from the Scopus database. There are diverse literature databases adopted for bibliometric studies, such as Google Scholar, Scopus, Web of Knowledge, and PubMed, among others. Similarly, the analysis tools adopted for the visual analysis of the data from these databases are varied (for instance, VOS viewer and Citespace are commonly used, among others). Hence different scholars adopt a combination of these two methods (literature database and analysis tools) based on the peculiar characteristics of the databases and tools, as well as the aim of their study. To achieve the objective of this study, a systematic approach was employed to select research publications from the Scopus database. The Scopus database was chosen because it provides a wider coverage of research publications and it is organized in nature [45,46]. Hence, it provided a robust and detailed data collection source. To achieve an in-depth analysis of the collected data, the visualization of similarities (VOS) viewer was adopted. VOS provides a low-dimensional visualization between pairs of objects whereby their proximity reflects the level of association between them [47]. VOS viewer is a freely available software and provides a high-quality output. It provides an interface for the analysis of data from databases by creating maps based on the network data [48]. There are two standard weight measurements in VOSviewer; links and total link strength (TLS). The links represent the number of links of an item has with other items, while the TLS is the total strength of the links of an item with other items. Another essential feature of this software output is clustering. Clustering refers to the grouping of items into what can be described as a community. A cluster refers to a set of items that are included in a map and are not necessarily exhaustive [48].

The process of conducting bibliometric and scientometric studies in order to achieve objective knowledge mapping in scientific domains is divided into six steps; the collection of raw data, the selection type of the item, the extraction of relevant data from the collected data, the calculation of items' similarities, and the visualization of the low-dimensional space [49,50]. This can be summarized basically into two steps: the collection of raw data

and analysis to extract the required information from the data. This approach was described as a user meta-model by [49].

The collection of raw data necessitates the definition of the data, the refining of the data, and data review. To achieve the collection of the right data set for the study, the retrieved data sets must be articulately defined using the query string. The data must be refined using the necessary parameters; this includes the year, country, and publication type, among others (depending on the study objective). Afterward, the data are reviewed to ensure that the retrieved data conform to all of the parameters applied during the search.

The data for this study were retrieved from the Scopus database. BIM-focused scholarly publications in developing countries were retrieved from the Scopus database by searching for the query "BIM" or "Building information modelling". All scholarly outputs/publication types (journals, book chapters, books, and conference outputs, among others) from developing countries were considered in order to achieve a non-restrictive and holistic result. Consequently, this provided the study with robust and articulated results on all BIM diffusion research in developing countries. The output spanned the year range from 2005 to 2019 and it was filtered to be limited to the engineering field. The selected developing countries for this study were India, Malaysia, Chile, Jordan, Brazil, the Taiwan Province of China, Mexico, Pakistan, Thailand, Turkey, Egypt, Nigeria, South Africa, Ghana, Morocco, Algeria, Cameroon, Central African Republic, Ivory Coast, and Zambia [51]. Figure 1 represents the geographical location of these countries on the globe.
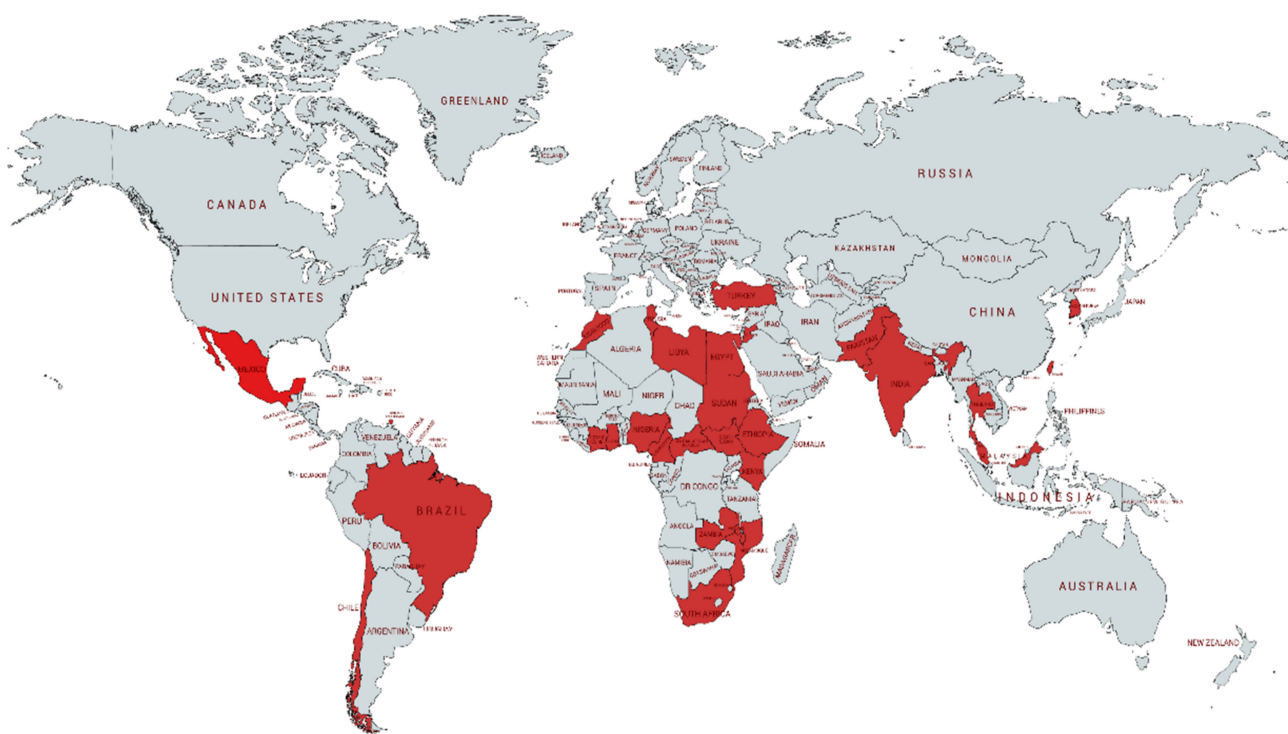
Figure 1. BIM publication distribution in developing economies.

The search returned a total of 823 documents. After refinement through the review of all document titles and abstracts, the study was left with 742 documents. It is worthy of mention that the search field in Scopus was set to title/abstracts/keywords to have a rich result from all abstracts, keywords, or title containing the query ("BIM" or "Building information modelling") (Appendix A shows the search string for the study). Thus, the study is based upon these 742 refined documents. Figure 2 presents the research framework.

Table 2. Selected BIM studies in developing countries.

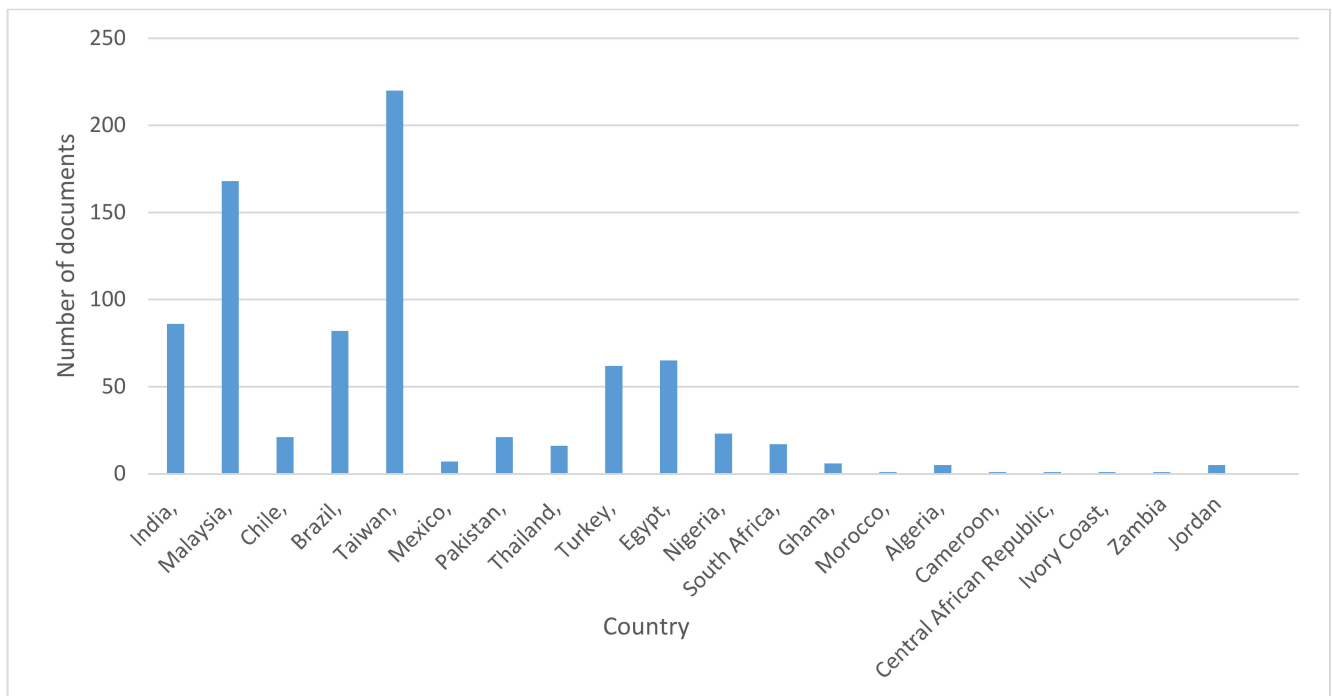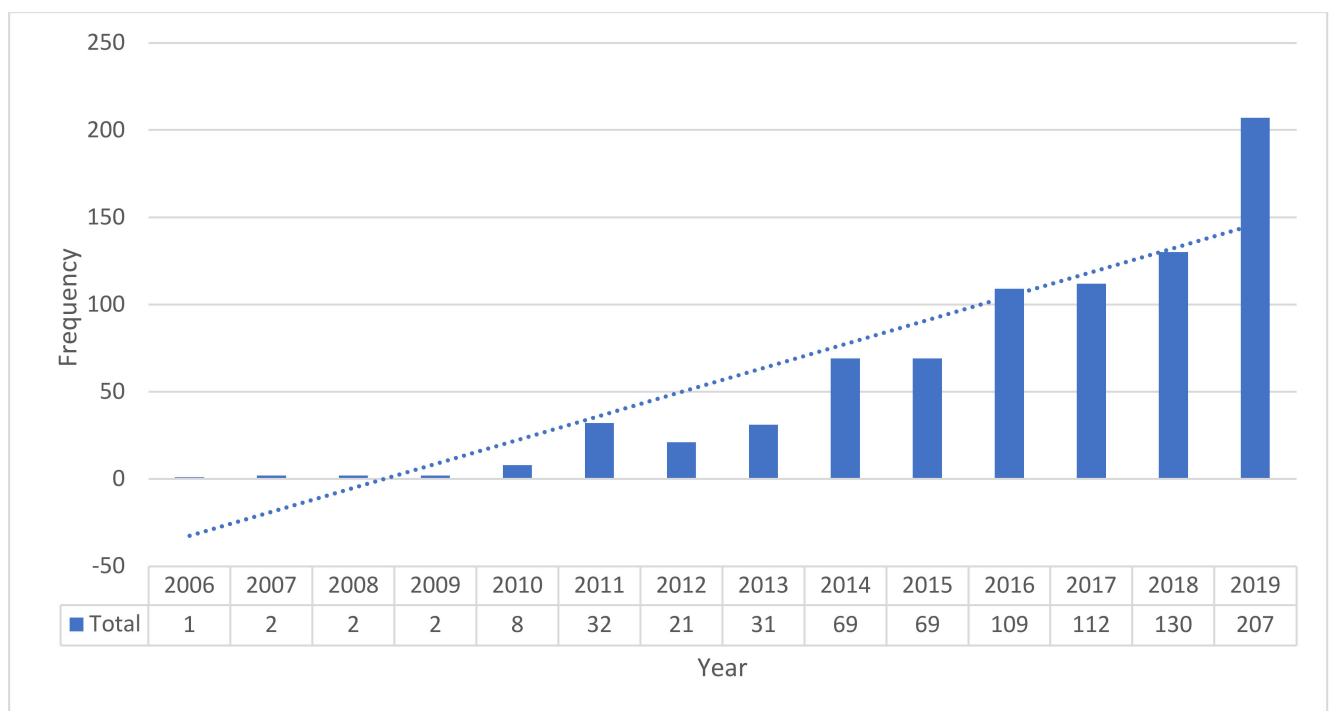| Country	Study	Approach	BIM Maturity	Barriers to Adoption
Nigeria	Diffusion of Innovations: The Status of Building Information Modelling Uptake in Nigeria [52]	Questionnaire survey	59.5% BIM awareness level; 22.8% BIM adoption level 17.7% are aware nor using BIM	-lack of experts -lack of collaboration by other stakeholders -lack of Standardised tools and protocol -Cost
	Assessment of BIM Implementation among MEP Firms in Nigeria [53]	Fieldwork survey using structured questionnaires.	MEP firms have a relatively high level of BIM awareness	-lack of technical expertise on BIM tools utilisation -lack of awareness -high investment cost in training staff -process change -software/hardware upgrade
Ghana	Acceptance of Building Information Modelling: a survey of professionals in the construction industry in Ghana [54]	Questionnaire	The study observed a positive intention to adopt BIM by professionals using the technology acceptance model (TAM). The study also posits that a change in professionals' perception will ensure a change in attitude. It can be inferred that the barriers to adoption are summountible through a change in their perception and attitudes.	
	Guideline for building the capacity of Contractors for adoption and implementation of Building Information Modeling (BIM) in Ghana [55]	Quantitative approach. Non-probability sampling technique.	Low BIM maturity level.	-high set up cost -software and personnel training -legal issues in relation to the ownership of the model -lack of knowledge of the enormous benefits of BIM.
South Africa	Understanding Building Information Modelling in the South Africa construction industry [19]	Questionnaires	Low BIM maturity; BIM is scarcely used hence professionals have minimal exposure to it.	-lack of skills -education -knowledge of BIM
	A study on the BIM adoption readiness and possible mandatory initiatives for successful implementation in South Africa [40]	Questionnaire survey	Low BIM maturity level	-BIM experience and education -reluctance to change current work practices -low levels of commitment from public sector clients.
India	State of BIM Adoption and Outlook in India [56]	Online survey and Semi-structured interviews	22% uses BIM; 27% considering BIM usage. 43% aware of BIM but are not sure about implementing 8% respondents are not aware of BIM	-Mind-set issues -Difficulties in adapting to frequent changes in design -No mandate from government for BIM implementation -interoperability -High cost -lack of practical knowledge
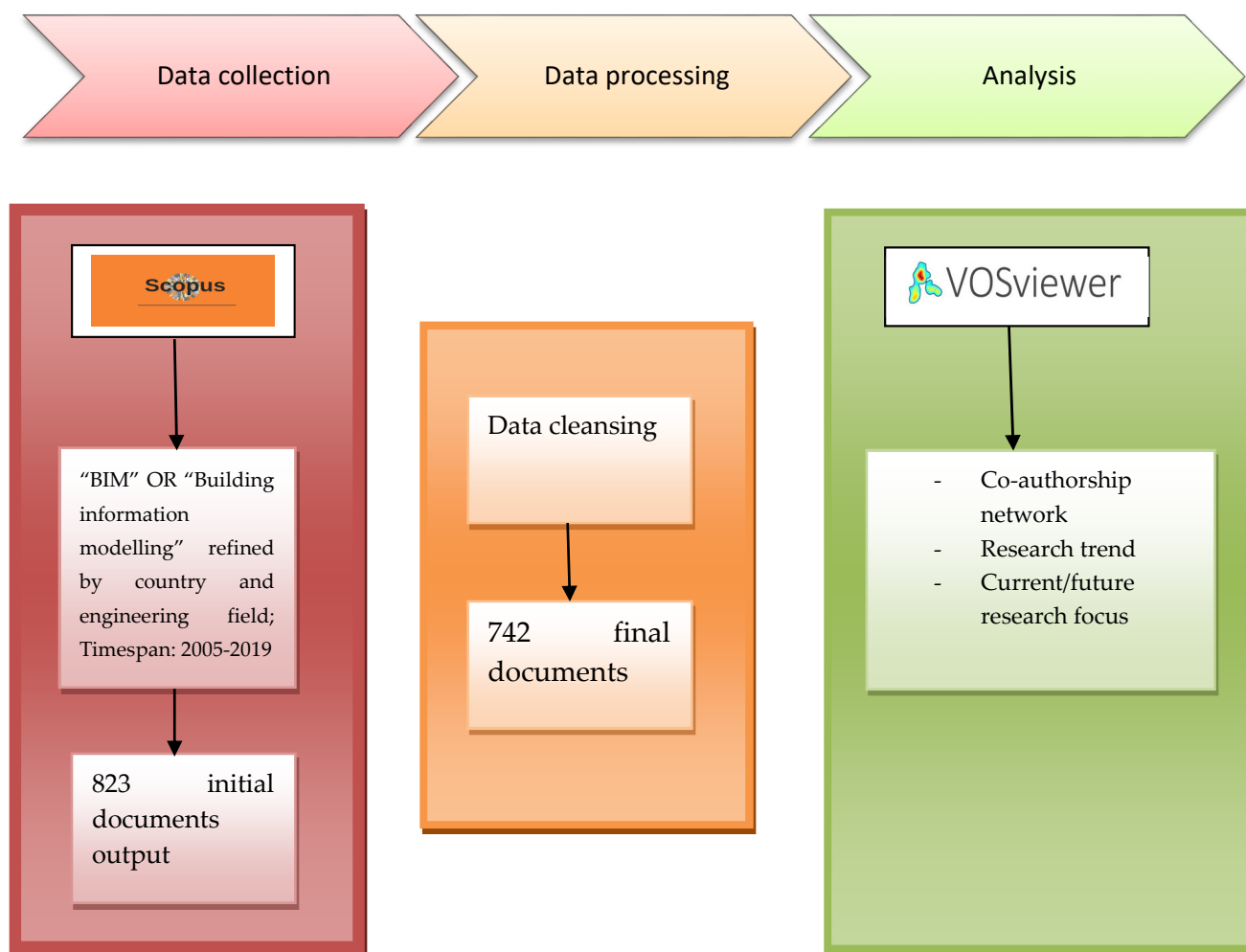
Figure 2. Research framework.

The BIM diffusion research in developing countries started in 2006 (Figure 4) with the publication by [57]. This was 2 years after the first BIM publication in the developed world in 2004 [58]. Figure 3 shows the contribution of each country to the BIM research in developing country. From the data (Figure 4), it is clear that BIM research in developing countries has been fluctuating, but has been on a steady increase in the last 5 years. The publication trend is thus divided into two parts; the infancy period and the steady development period. The infancy period is the period from 2006 to 2013. During this period, the BIM research in developing countries was at the introductory stage, where the researchers were trying to find their foothold in this area. Hence, the publication output during this period was fluctuating. The period starting from 2014 experienced a steady increase in publication output. There was a steady increase, from 62 publications (in 2015) to 207 (in 2019). This is termed a steady development period.

However, to date, the most productive year has been the year 2019, with 207 publications. The 2019 output consisted more of BIM journal articles than other research outputs types (Figure 5); it consists of 69 conference papers, 133 journal articles, 3 literature reviews and 2 book chapters. It is observed that the bulk of BIM publications in developing countries are from published journal articles and conference papers.
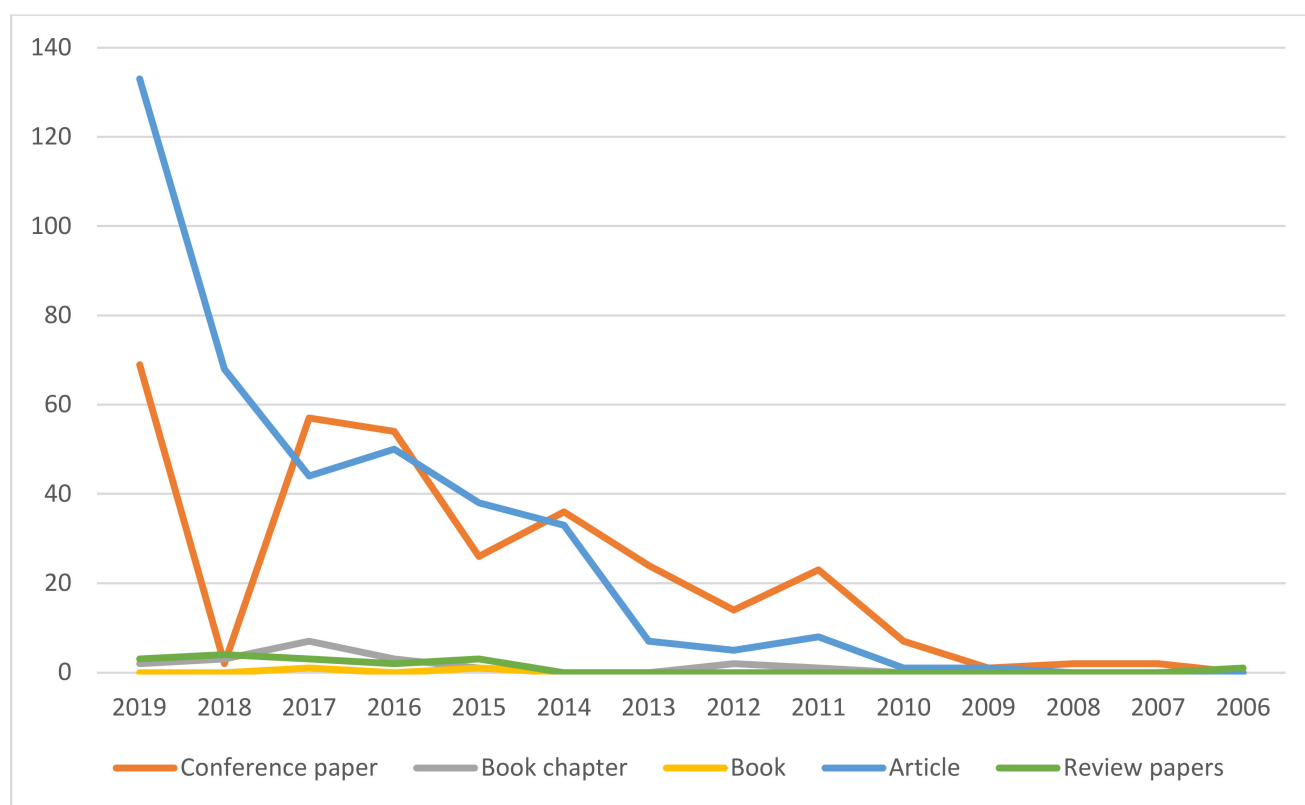
Figure 3. BIM scholarly publication in developing countries.

	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
■ Total	1	2	2	2	8	32	21	31	69	69	109	112	130	207

Figure 4. Annual BIM publication output in developing countries.

**Figure 5.** Annual BIM publications based on document type.

4. Data Analysis

4.1. Research Publication Network and Co-Authorship

A network of countries was generated to gain an insight into the BIM research status of developing countries. The network Figure 6 has 114 links and a total link strength of 315, consisting of 7 clusters. The size of the nodes is determined by the weight of the item; by implication in this study, the node size in the network denotes the number of publications from the country. The links between countries are indicative of the number of co-authorship relationships between these countries. The link colour represents the trend based on the timeline at the bottom right corner of the figure. Considering the colour bar shown at the bottom right corner of the figure, it is evident that Malaysia, the Taiwan Province of China, India, and Brazil have more publications and do not really have recent publications. Unlike South Africa, Nigeria, and Ghana from the African continent, all of which possesses a colour tending towards yellow (meaning that the BIM research in these countries is more recent). By implication, these countries are at their infancy stage in BIM research and thus possess fewer BIM publications. On the other hand, by implication, Malaysia, India, Brazil, and the Taiwan Province of China have many publications and are more advanced in BIM diffusion research when compared to other developing countries. Consequently, they can be said to be BIM leaders in the developing countries.

The co-authorship network shows the authorship collaboration of two or more authors in a subject area. It shows the relationship based on the number of publication output; this is revealed in the node sizes and the number of links among the items. The links between nodes are indicative of the number of collaborations between researchers. In a nutshell, it can be said to be a measure of collaboration in a certain space within a research domain under focus. Figures 6 and 7 show the author and country co-authorship networks in BIM research in developing countries, respectively. In order to obtain a broader network that is more accommodating, the minimum number of documents per author was set to two documents. The choice of a minimum number of two documents against the default five

documents allows for a wider and more inclusive capture of authors with at least two documents. Out of the 1907 authors in the BIM research space of developing countries, 430 met the threshold. The network had 95 clusters, 696 links, and a total link strength of 1273. The cluster around Marzouk M indicates them as the highest contributor to BIM research in developing countries, with 28 documents, 264 citations, and a total link strength of 33. From the network, there exist few collaborative efforts in the developing countries as regards BIM research. This is evident from the many outlying authors without links. It is safe to say that the BIM research domain in developing countries is carried out in silos. This is similar to the non-collaborative culture in the industry. This prevailing culture among the researcher requires a change in order to achieve effective BIM diffusion research in developing countries.
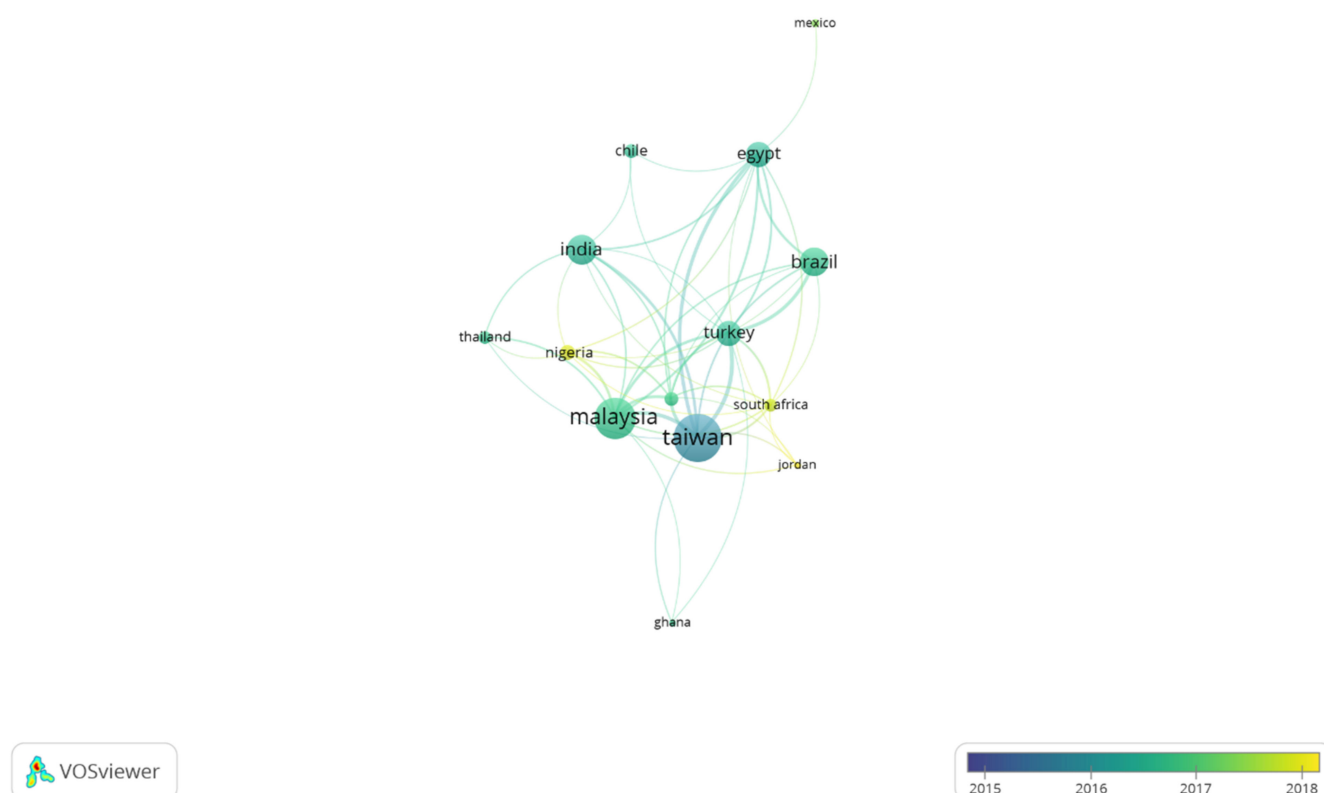
Figure 6. Network of countries.

Although Marzouk is the highest contributor to the BIM research publication in developing countries, there are other publications with much influence due to their high citation counts. Table 3 shows the top four most cited documents in BIM diffusion research in developing countries.

Co-authorship based on countries reveals that authors from the Taiwan Province of China, India, Brazil, Egypt, and Malaysia are collaborating more with other countries (Figure 8). However, Malaysia is observed to have further reaching collaborations that are intercontinental. It is also heart-warming to see that most countries have recent publications and are thus promising. It shows that there are recent BIM research efforts and the industry is making efforts towards achieving a busy BIM research space. Hence, they are exiting the infancy stage.
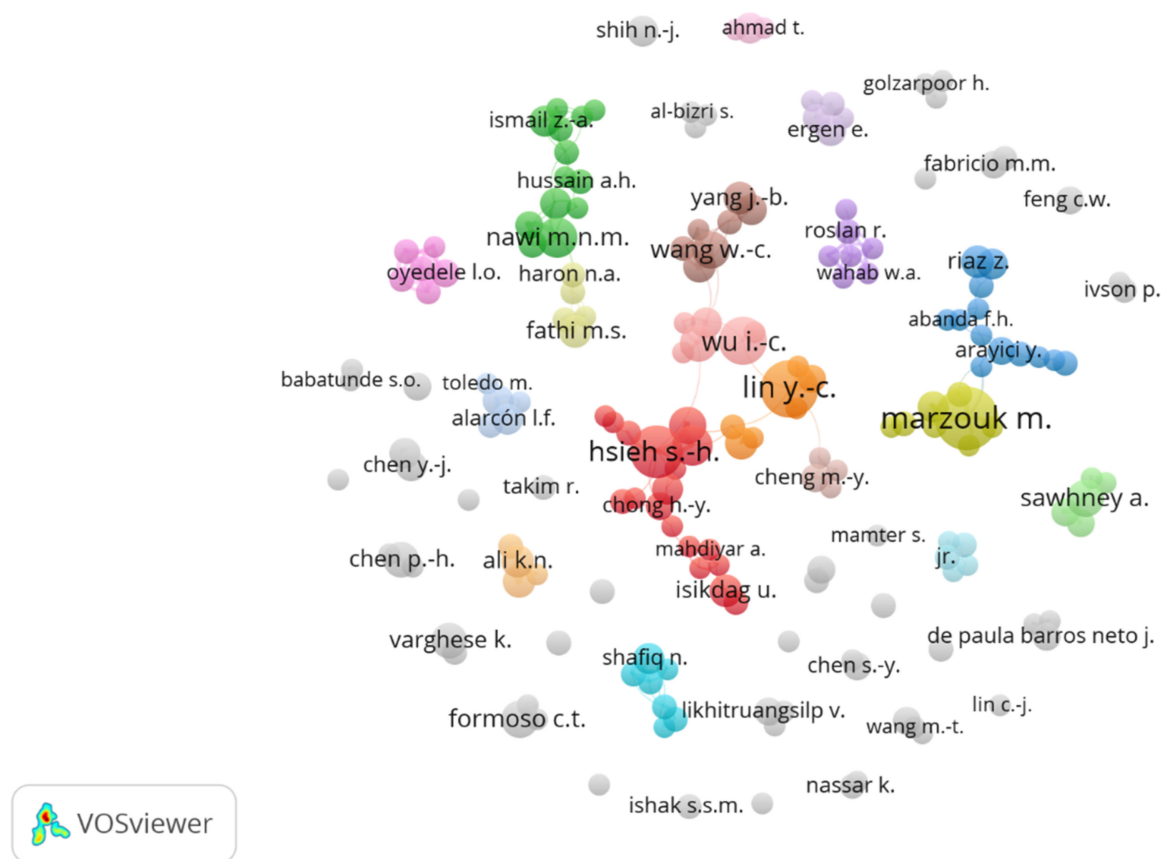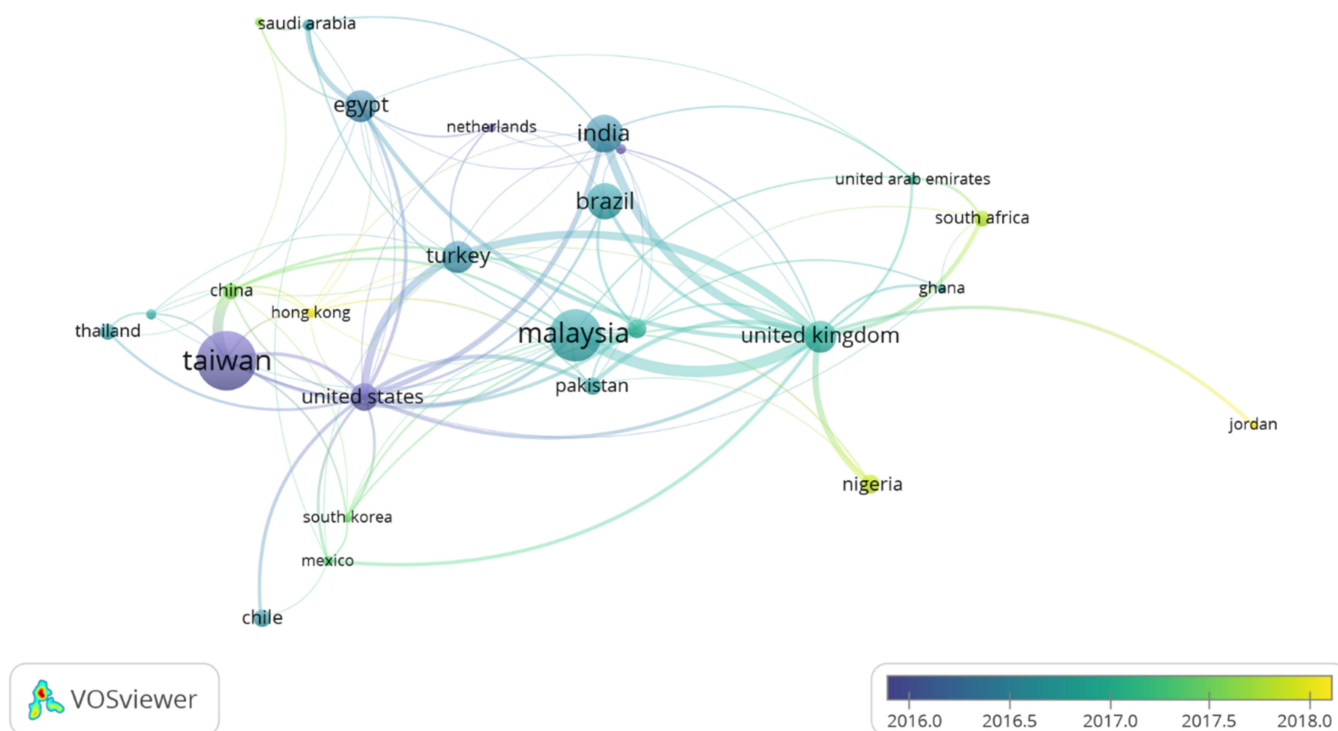
**Figure 7.** Co-authorship network.

Figure 8. Country co-authorship.

Table 3. Most cited BIM publications.

Document Title	Citation Counts
Analysis of modelling effort and impact of different levels of detail in building information models [59]	111
Adoption of Building Information Modelling technology (BIM): Perspectives from Malaysian engineering consulting services firms [35]	69
BIM for building refurbishment and maintenance: current status and research directions [60]	68
Completing the missing link in building design process: Enhancing post-occupancy evaluation method for effective feedback for building performance [61]	67

4.2. Analysis of Sources

Figure 5 shows the annual scholarly document types constituting the sources for BIM research in developing countries. In order to identify the major sources of documents in this space, the frequency of citation of publication sources was analysed. This provides an insight into the importance (visibility and impact factor, among others) of the source. Figure 9 shows a density visualization of the cited publication sources.

Figure 9 shows that automation in construction is the most-cited BIM publication source; it has 1017 citations and has a total of 50 BIM publications. Another important source is the Institute of Physics (IOP) conference series: material and science and engineering. This conference has 38 documents and 34 citations, but a TLS of 15. Although it possesses the second-highest number of documents, it does not command the same success in terms of citations and in the extension of TLS. Thus, the number of documents published in a research space does not automatically make the source influential unless it commands wide acceptance based on its citations.
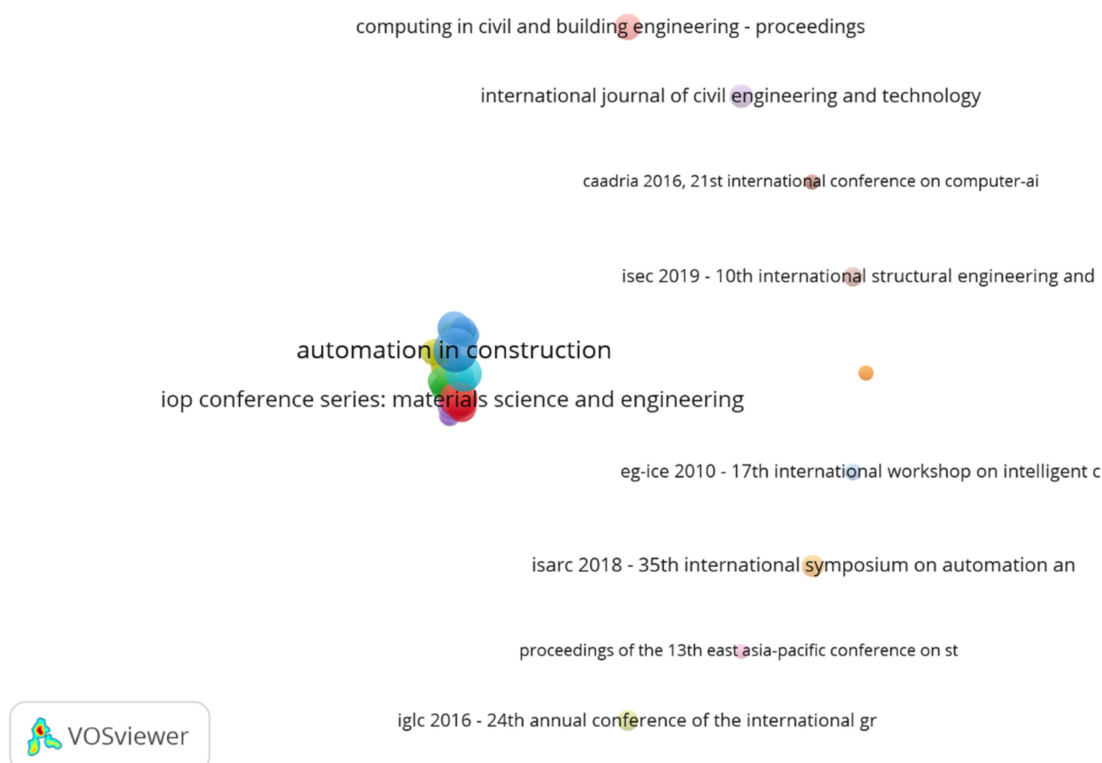
Figure 9. Publication sources.

5. Research Trends

To gain insight into the knowledge trend of BIM diffusion research in developing countries, the keywords were analysed. This enabled the observation of keyword occurrence trends over the years studied (2006–2019). This approach was applied in recent review studies (for instance, [27,62]. This analysis, as presented in Figure 10, contains 134 keywords and six clusters.

The six clusters represent the knowledge domains prevalent in the BIM research space in developing countries. Based on each cluster's keywords, the clusters can generally be organized into the following clusters representing the knowledge domains. Cluster one presents BIM for sustainable construction; cluster 2 consists of BIM adoption, Cluster 3 represents studies on BIM and other technologies required to digitize the construction industry (AR/VR, digital storage, IoT, robotics, and wireless sensor networks, among others). Cluster 4 dwells on the BIM for the safe and effective construction process, cluster 5 is focused on BIM for facility management. Cluster 6 focuses on BIM tools interaction and integration.
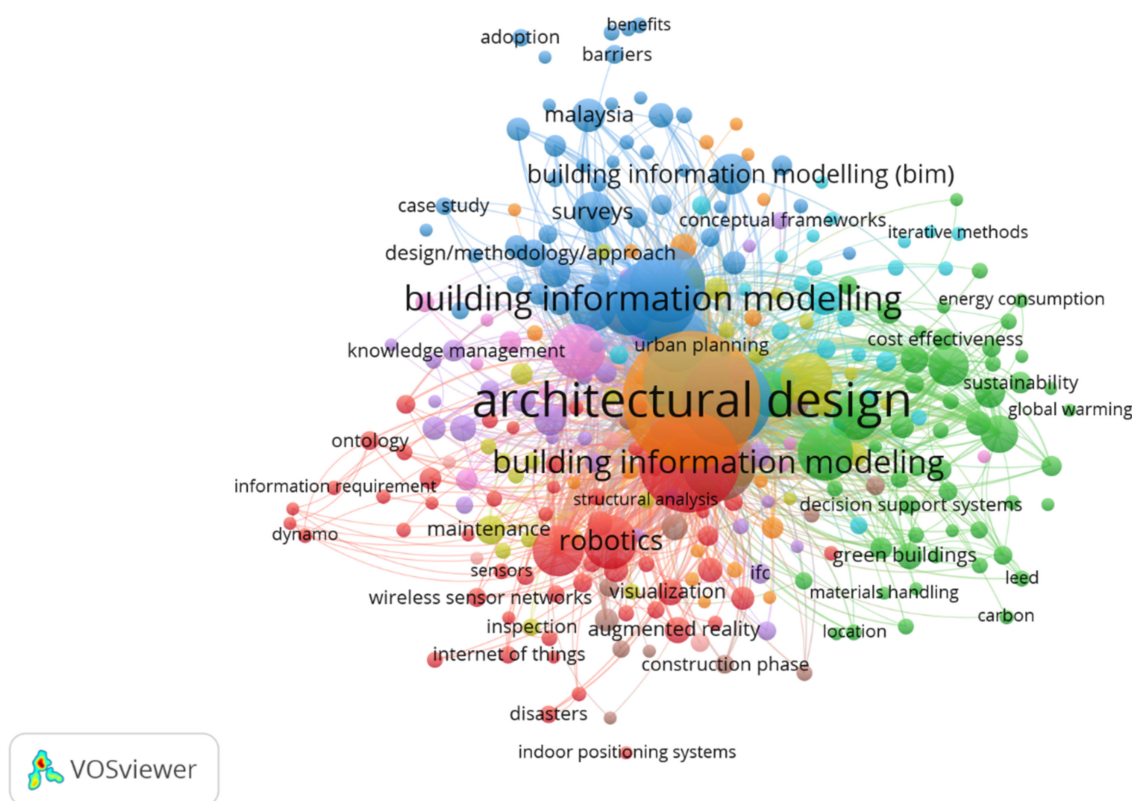

Figure 10. Keyword citation mapping.

5.1. BIM for Sustainable Construction

This cluster is the largest cluster. The most occurring keywords are artificial intelligence, budget control, building control, building lifecycle, climate change, carbon dioxide, cost–benefit analysis, cost-effectiveness, the decision-making process, energy conservation, energy efficiency, cost reduction, environmental impact, building energy performance, embedded systems, smart city, urban growth, urban planning, environmental performance, global warming, green building, lifecycle analysis sustainability, and sustainable construction. Sustainable construction has become popular and widely sought after in order to curb the negative impacts of construction on the environment. The application of BIM to achieve sustainable construction (especially in the area of building energy performance and fighting global warming) is essential. BIM allows the early integration of sustainable benchmarks by the project team. Furthermore, BIM supports and performs functions that

support sustainable construction even though it suffers from low industry application and acceptance [63]. Some other challenges regarding the use of BIM for sustainable construction is the interoperability of the software [64,65] and a deficient supply chain/procurement system [64] among others. In order to provide a pathway for integration, frameworks and tools have been developed for the integration of sustainable building and BIM; one of those tools is the SBTool^{BIM} ([66] Green Building assessment tool (GBAT) [67].

5.2. BIM Adoption

The adoption of BIM involves diffusion and implementation. To achieve complete BIM adoption and harness its benefits, the barriers to its adoption must be identified and its benefits well articulated, among other requirements. These are important processes required to achieve BIM adoption in line with the innovation–decision process as outlined by Rogers [68]. Under this cluster, some of the keywords are adoption, barriers, benefits, BIM technologies, collaborative design, critical success factors, curricula, human resources management, implementation, and intellectual property rights. For instance, [69] studied the status, advantages, barriers, and strategies to enhance BIM implementation level in the Malaysian construction industry. The study focused on the prevailing maturity level and the strategies necessary for enhancing and achieving higher maturity levels. By implication, it can be said that BIM studies in developing countries have articulated the BIM adoption dynamics and are striving to enhance BIM maturity in developing countries. However, moving forward studies focusing on this research area should conduct case studies where real-life adoption of BIM is tested. This is to enable "triability" and "observability" in the persuasion phase of the innovation adoption process [68] to be achieved. These are central to the innovation adoption or rejection decision.

5.3. BIM and Other Technologies

The integration of BIM with new technologies ensures efficient data collection and processing. The keywords in this cluster are big data, complex networks, data handling, database systems, digital storage, information analysis, RFID, robotics, sensors, virtual reality, wireless sensor, wireless sensor networks, and internet of things (IoT). The interaction and interdependence of BIM with other technologies is the focus of this cluster. Through the use of sensors, as-built BIMs have been observed to be generated faster [70]. Studies in this area are few, although it is a viable future research area in developing countries. It is safe to say that the number of studies in this area is few because it is relatively new.

5.4. BIM for the Safe and Effective Construction Process

The drive for a more effective construction process requires the integration of the different efficiency principles into BIM. Hence, different studies have been conducted to integrate these principles with BIM. [71] focused on a BIM-enabled construction safety culture through the lens of grounded theory. Meanwhile, [72] conducted a study on integrating BIM with lean principles in the Indian construction industry. Additionally, [73] adopted a case study approach in establishing the link between the BIM maturity and the success of the lean process on a construction project. In this cluster, the keywords are accident prevention, benchmarking, clash detection, construction progress, construction process, lean construction, lean production, prefabrication, process control, visual management, waste management, knowledge based management system, large scale project, supply chains, and cost engineering, among others.

5.5. BIM for Facility Management

BIM is adopted throughout the building's lifecycle from inception till demolition. The studies have the following keywords building maintenance, damage detection, defects, facility management, laser applications, quality control, and structural analysis. Although lean production and facility management are categorized under different clusters, some studies have attempted to integrate BIM, FM, and lean principles [74]. The studies in this

cluster focused mainly on the application of BIM in the facility management phase of the project.

5.6. BIM Tools Interaction and Integration

The BIM software ecosystem contains different software with different design interfaces, supported file formats, functions among other distinct features. The seamless collaboration of various softwares in a collaborative design environment has been an area of constant research. For instance, [75] studied the feasibility of information exchange during the conversion process with a particular interest in object integrity. The keywords in the research cluster are interoperability, information exchange, IFC, electronic data exchange, and user interfaces.

6. Current Research Directions

This is represented in the network diagram in Figure 11; the keywords shown in yellow are indicative of recent publications, as depicted in the bar at the bottom right of the figure. Some of the keywords in current studies are shown in Table 4. The BIM diffusion research in developing countries is still grappling with the barriers to BIM adoption research. This is considered to give credence to the beginner status and the fact that BIM adoption is still a great challenge in developing countries. Currently, the research in developed countries is about exploring higher dimensions of BIM and its application in relatively new areas, among others. It can thus be said that developing countries are far behind regarding BIM adoption and research. It is worth noting, however, that the seamless integration of BIM with other emerging technologies is an area of focus, although it is still at its nascent stage. The case study research approach is also observed to be in use, although few studies have focused on it. Generally, the present research focus is a pointer that developing countries are improving strongly on the BIM diffusion research area. This is quite heart-warming because of the rave of megaprojects and smart city developments on the rise in developing countries. For instance, on the African continent, countries like South Africa, Kenya, Ghana, and Nigeria have all embarked on smart city projects.
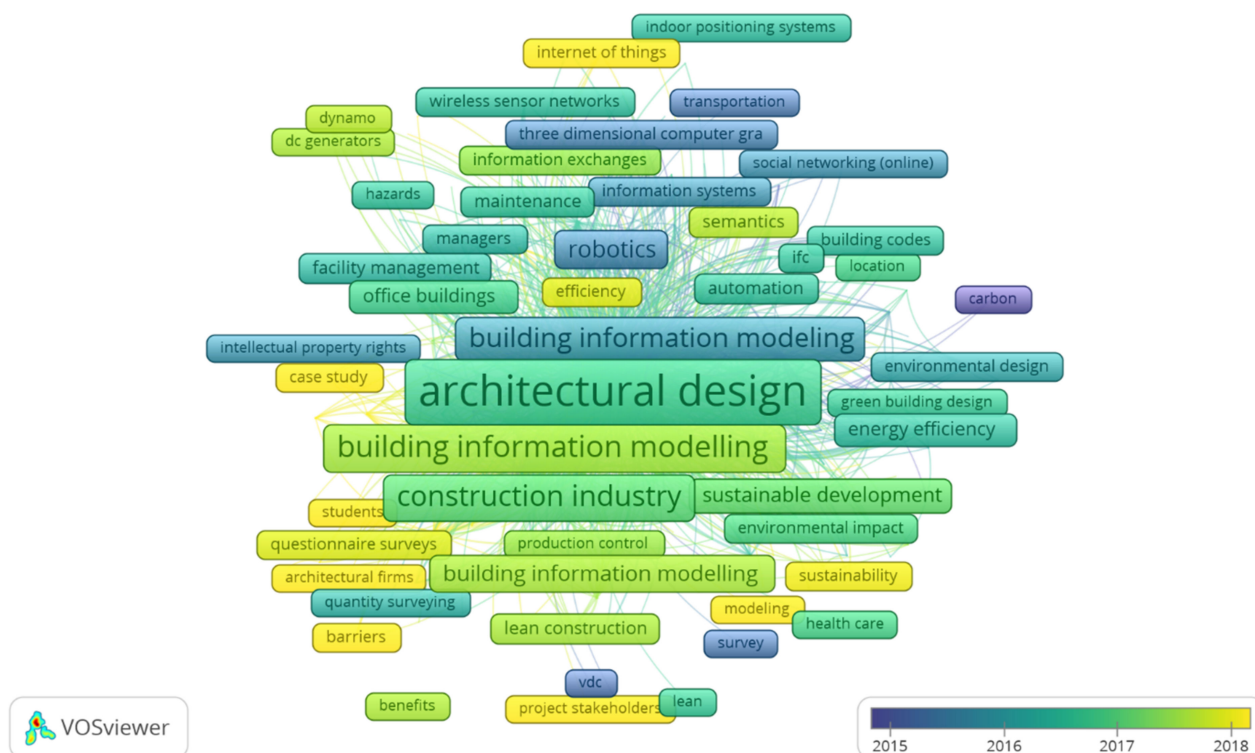
Figure 11. Current research direction.

Table 4. Current research keywords.

	Freq	TLS
Barriers	13	79
Internet of things (IOT)	16	143
Case study	12	87
Energy management	6	50
Sustainability	17	126
Project stakeholders	5	43
Laser applications	7	62
Laser scanner	6	38
Laser scanning	6	55
Interoperability	22	233
Roadmap	5	36
Data mining	5	55
Accident prevention	46	71
Efficiency	16	141
Data acquisition	8	88
Intelligent buildings	14	169
Intelligent computing	9	83
Software testing	7	62
Supply chain management	5	54
Material handling	6	73
Integrated approach	5	57
Interaction devices	6	66
Smart city	7	65
Structural analysis	10	62

7. Future Trends

The future outlook of BIM diffusion in developing countries is identified from the current research trend; they are the areas presently given less attention by researchers. They are still developing and deserve more attention from researchers. Hence, BIM diffusion research projects in developing countries are expected to pay more attention to the implementation of BIM among project stakeholders. Also, the use of BIM as it affects supply chain management is an area that requires more attention. Other areas for future research attention and focuses in relation to BIM include sustainability, smart city, structural analysis, accident prevention, data mining, the roadmap to BIM adoption, laser applications, quality control, design improvement and energy management.

8. Conclusions

This study adopted a user meta-model to map out the BIM research trends and focuses in developing countries (India, Kenya, Malaysia, Chile, Jordan, Brazil, Taiwan Province of China, Mexico, Pakistan, Thailand, Turkey, Egypt, Nigeria, South Africa, Ghana, Tunisia, Morocco, Algeria, Cameroon, Central African Republic, Ivory Coast, Ethiopia, Libya, Malawi, Mozambique, Sudan, Trinidad and Tobago, and Zambia). This was achieved through a quantitative review and a scientometric analysis of 884 literature data retrieved from the Scopus database. The retrieved data were analysed through different visualisations using VOS viewer to gain insights into the BIM research space in developing countries. The study established the influential researchers and mapped the knowledge domains

in the BIM research space in developing countries. It was observed that BIM research in developing countries had increased significantly and progressively over the last 5 years.

Among other findings, the study observed the lack of collaboration among researchers; they are observed to be working in silos. In contrast, achieving BIM adoption and making the required leap requires a concerted and collaborative effort by researchers. Furthermore, the study observed that productivity does not equate to the influence of researchers. The researchers with the most research outputs do not automatically command the greatest or a commensurate number of citations.

Generally, developing countries are still struggling with the adoption of BIM. However, the present situation is encouraging, as there exists evidence of increasing research output among the researchers. Furthermore, the current focus of research is 4IR inclined, and it explores the interaction of BIM with other emerging technologies vis-à-vis the adoption of the case study approach. This is expected to bridge the gap between research and the industry. Hence, industry-oriented results will hopefully be achieved.

Despite this in-depth analysis and number of significant contributions to the body of knowledge, the study has some limitations. This includes the source of data from only the Scopus database (excluding other databases, for instance, Web of Science). Thus, the data coverage might not be all-inclusive, as it might exclude publications not indexed in Scopus. Additionally, the coverage exists up to 2019; thus, there exists an area for further study beyond 2019. This will give an idea of the research efforts during the COVID-19 pandemic and after. Thus this study provides the pre-COVID-19 status and provides a basis for comparison for pre and post COVID-19 status.

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Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

Search Query

Search String	Output
TITLE-ABS-KEY ("*BIM*" OR "*Building information modelling*") AND (LIMIT-TO (AFFILCOUNTRY, "*Taiwan*") OR LIMIT-TO (AFFILCOUNTRY, "*Malaysia*") OR LIMIT-TO (AFFILCOUNTRY, "*India*") OR LIMIT-TO (AFFILCOUNTRY, "*Brazil*") OR LIMIT-TO (AFFILCOUNTRY, "*Turkey*") OR LIMIT-TO (AFFILCOUNTRY, "*Egypt*") OR LIMIT-TO (AFFILCOUNTRY, "*Chile*") OR LIMIT-TO (AFFILCOUNTRY, "*Nigeria*") OR LIMIT-TO (AFFILCOUNTRY, "*Thailand*") OR LIMIT-TO (AFFILCOUNTRY, "*Pakistan*") OR LIMIT-TO (AFFILCOUNTRY, "*South Africa*") OR LIMIT-TO (AFFILCOUNTRY, "*Mexico*") OR LIMIT-TO (AFFILCOUNTRY, "*Ghana*") OR LIMIT-TO (AFFILCOUNTRY, "*Morocco*") OR LIMIT-TO (AFFILCOUNTRY, "*Tunisia*") OR LIMIT-TO (AFFILCOUNTRY, "*Jordan*") OR LIMIT-TO (AFFILCOUNTRY, "*Cameroon*") OR LIMIT-TO (AFFILCOUNTRY, "*Central African Republic*") OR LIMIT-TO (AFFILCOUNTRY, "*Cote d'Ivoire*") OR LIMIT-TO (AFFILCOUNTRY, "*Ethiopia*") OR LIMIT-TO (AFFILCOUNTRY, "*Kenya*") OR LIMIT-TO (AFFILCOUNTRY, "*Libyan Arab Jamahiriya*") OR LIMIT-TO (AFFILCOUNTRY, "*Malawi*") OR LIMIT-TO (AFFILCOUNTRY, "*Mozambique*") OR LIMIT-TO (AFFILCOUNTRY, "*Sudan*") OR LIMIT-TO (AFFILCOUNTRY, "*Trinidad and Tobago*") OR LIMIT-TO (AFFILCOUNTRY, "*Zambia*")) AND (LIMIT-TO (SUBJAREA, "*ENGI*")) AND (LIMIT-TO (PUBYEAR, *2019*) OR LIMIT-TO (PUBYEAR, *2018*) OR LIMIT-TO (PUBYEAR, *2017*) OR LIMIT-TO (PUBYEAR, *2016*) OR LIMIT-TO (PUBYEAR, *2015*) OR LIMIT-TO (PUBYEAR, *2014*) OR LIMIT-TO (PUBYEAR, *2013*) OR LIMIT-TO (PUBYEAR, *2012*) OR LIMIT-TO (PUBYEAR, *2011*) OR LIMIT-TO (PUBYEAR, *2010*) OR LIMIT-TO (PUBYEAR, *2009*) OR LIMIT-TO (PUBYEAR, *2008*) OR LIMIT-TO (PUBYEAR, *2007*) OR LIMIT-TO (PUBYEAR, *2006*) OR LIMIT-TO (PUBYEAR, *2003*) O LIMIT-TO (PUBYEAR, *2002*) OR LIMIT-TO (PUBYEAR, *2001*) OR LIMIT-TO (PUBYEAR, *1995*) OR LIMIT-TO (PUBYEAR, *1989*)	

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