An Overview of BIM as a Material Management Tool in the Construction Industry

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Abstract

The construction industry's acceptance of innovative technological tools such as Building Information Modelling (BIM) is rapidly increasing globally. Based on scholars' findings, BIM has shown substantial capability in the building project's whole lifecycle. The construction stage entails a series of managerial tasks. Material management is one of the crucial notable managerial tasks performed during the construction phase of a project. For decades building materials management has solely relied on manual managing and recording. These usually resulted in increased construction costs and waste of materials. These challenges have raised great concern for the construction manager (CM). The CM is now looking for an innovative way of managing building materials. This study aims to check the capacity of BIM as a material management tool based on the available results. Secondary data sources were thoroughly evaluated, and trends and visualization network mapping were carried out. The findings of this study disclose that the BIM-based material management model can help minimize rebar waste and effectively manage material handling and supply during construction. This study will create more awareness of BIM capability. These will alert the construction managers and BIM experts to consider BIM adoption in managing building materials. Also, add to the knowledge on building material management based on an innovative technology approach. Subsequently, it will increase the adoption and wider use of BIM in the construction stage.

Keywords

BIM, Material Management, On-site, Construction Manager, Innovative.

1. Introduction

The construction industry is regarded as one of the largest global project-based sectors. It primarily expected the completion of projects within budget and on schedule. Understanding the proper handling and management of materials becomes an essential on-site task. Odubiyi et al. (2021) noted that achieving a construction project's success requires effective materials management. Proper materials management during construction can reduce the project delay time. Moreover, several studies have identified the lack of appropriate material and resource management as part of the critical challenges construction projects suffer (Kasim et al., 2021; Mall, 2019; Na et al., 2021; Odubiyi et al., 2021; Wu, 2020).

Material management is a process that coordinates sourcing, planning, purchasing, storing, analysing requirements, minimising waste, transporting, and regulating resources, and improving profitability by reducing material costs (Patel & Vyas, 2011). Although, Manual recording and management of building materials have been the only option in the construction industry for decades. These often resulted in higher building costs and resource waste. Abou-Ibrahim et al. (2019) opined that 50% - 60% are the costs associated with costs incurred from improper on-site material management. These could result in an 80% delay in several construction projects (Caldas et al., 2015). With the current evolution of innovative technologies in the construction industry globally. The industry is now rapidly trying to adopt an innovative model that could enhance the management of materials needed/used during building production (Beorkrem, 2015; Čuš-Babič et al., 2014). One of the adopted models is Building Information Modelling (BIM).

Nevertheless, the adoption and integration of BIM in the conception/design and construction stage of building projects have gained significant attention, mostly in developed countries (Ullah et al., 2019; Wang & Wang, 2015). Its adoption at the post-construction stage is still at the infant stage (Toyin & Mewomo, 2022). Nevertheless, BIM

adoption to manage the coordination of the material flow process has not received significant attention. Researchers such as (Chen et al., 2020; Čuš-Babič et al., 2014; Mostafa & Zhineng, 2018; Wu, 2021), etc. have tried to contribute substantially to this context. However, there are limited or no comprehensive available records that triangulate the finding of several scholars on the use of BIM for material management. Therefore, this study seeks to juxtapose the available findings of researchers and experts in this study area by conducting an extensive review of published documents supported by trends and visualisation network mapping. With a focus on BIM use for material management during construction invented.

2. Study Methodology.

It is essential to define precise boundaries in a literature review to restrict the study (Toyin & Mewomo, 2023). The articles considered for this study were sourced from Google Scholar, Scopus, and Web of Science (WOS). The adopted sourced search engines and database was considered because they are one of the largest scientific databases and search engine; They possess a high degree of quality control and cover a wide range of research disciplines (Mewomo et al., 2021; Ullah et al., 2019). Google Scholar was used to locate links to related materials in their repository domain. This study follows three distinct steps, as depicted in Figure 1. The first step entails data sourcing. In the retrieval of relevant articles for this study, the following keywords and phrases were repeated in the selected databases and search engines: "BIM" OR "Building Information Model*" AND "Material Manage*" within "Article Title/ Abstract/ Keywords." The use of '*" in the search keywords allows a broader range of locating articles with different spelling strings of a suffix, such as model*: - Model, Modeling, Modelling, etc. The retrieved documents were restricted to journal articles, conference proceedings, and book chapters written in English (Toyin & Mewomo, 2021). Google Scholar search generated 21 documents, Scopus generated 20 documents, and WOS generated six documents. Thus, an initial total of 47 documents. The 47 documents were then imported into an excel spreadsheet as a CSV file for screening and filtration. Hence, 26 duplicates were deleted, left with 21.

Further abstract screening was conducted, eliminating an additional document on rail infrastructure. Thus, finally, n=20 articles. Step 2 involves an extensive overview and visualization of the retrieved articles to deal with the aims and objectives of this study. Overview in research could be seen as a flow process where researchers bring together several contributions of scholars in tandem with the study context. Finally, Step 3 covers the conclusions and suggestions for further study.

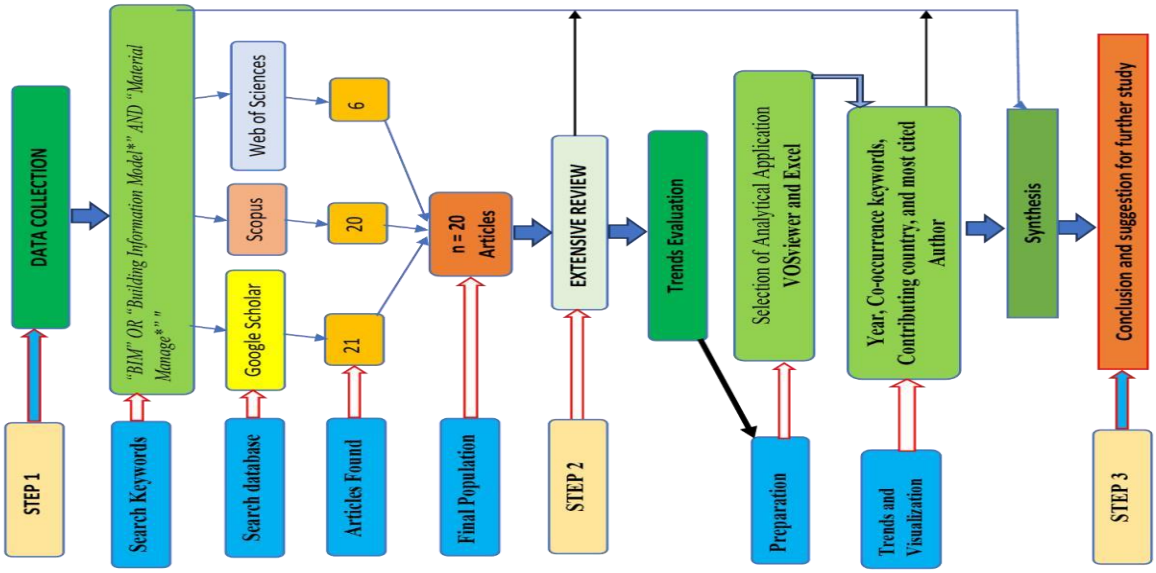

Fig. 1. Study flows sequential flow chat.

Fig. 2. Data location.

3. Extensive Overview discussion

3. 1 Material management using BIM-Model

There would be no comprehensive discussion of material management in the construction industry if the essential components of material management were not mentioned. According to (Gulghane & Khandve, 2015; Kulkarni et al., 2017), Materials management can be categorised into five processes. These are majorly found on construction sites: "Planning, Procurement, Logistics, Handling, and Stock and waste control" processes. Materials planning includes quantifying, ordering, and scheduling (Albert et al., 2018). Figure 3 explains the five processes in a schematic chat.

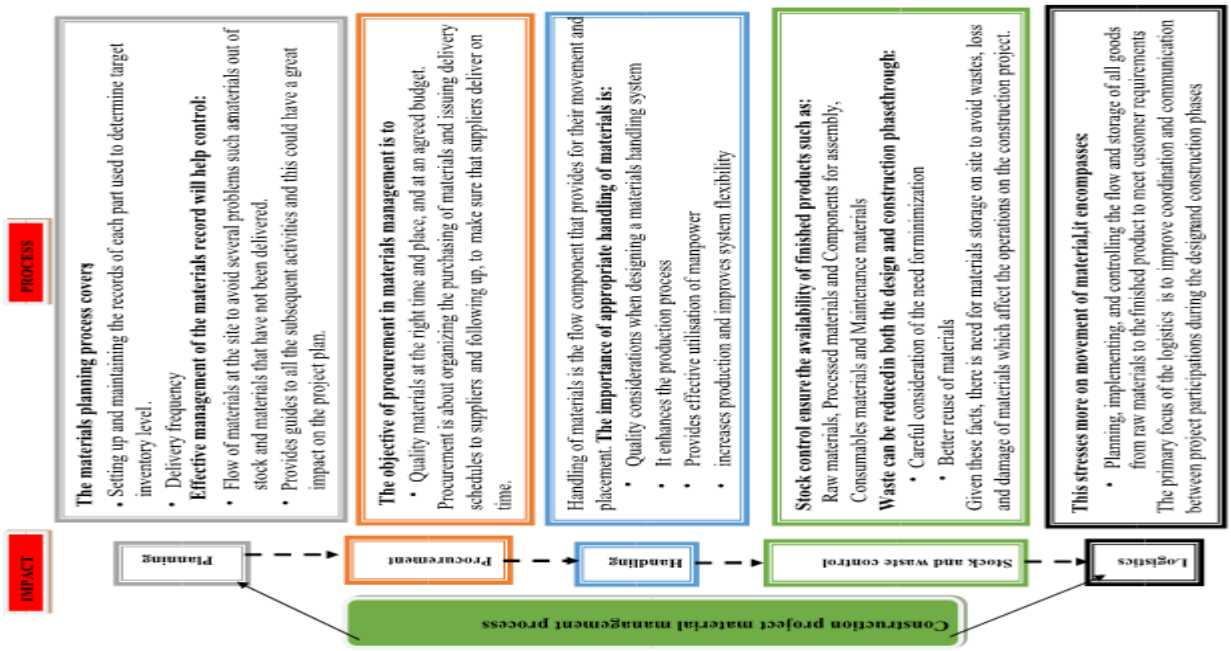

Fig. 3. Construction material management process.

Nevertheless, the management of building materials is an incorporated procedure that contains the integration of technology, organizations, people, and procedures. It is used to acquire effectively, quantify, expedite, identify, inspect, store, receive, transport, and conserve the equipment, materials, and related information throughout the lifecycle of a capital project (Caldas et al., 2015). However, the primary aim is to guarantee that the correct quantity and quality of equipment and materials are acquired efficiently, purchased at a realistic cost, and available when needed. Nevertheless, adopting innovative managerial models such as BIM for material management will contribute to more successful project results (Wei et al., 2017). BIM could improve quality and productivity, reduce costs, and enable a better working environment (Ma, 2018). Moreover, this could be achieved through using reliable, innovative material management techniques in construction projects—Table 1 documents the authors' main objective for conducting their research and the contributing findings.

Table 1. Author's contribution to material management using BIM.

Purpose	Contribution
(Porwal & Hewage, 2012)	
The author proposed a model to analyze reinforced concrete structures using the waste-optimization technique integrated with BIM.	Minimize rebar waste during the design stage and supports cost-effective decision-making during the design process
(Čuš-Babič et al., 2014)	
The author proposed a BIM theoretical model for information mapping concerning material management. They used a construction company's operational environment as a case study.	The researcher presented an approach that supports the mapping model and documents the benefits accruable by the industry.
(Wang & Wang, 2015)	
Application of the BIM-based Model to resolve problems emanating from green building materials management (GBMM) with the combination of life cycle assessment theory.	The management of the materials was framed on BIM-Model. It improves the management level of GBM in the construction project.
(Feng & Lin, 2017)	
Proposed a framework for the BIM Model to manage MEP materials in construction projects.	The model enhances information transmission and efficiency of the MEP professional and achieves the purpose of cost control
(Wei et al., 2017)	
Investigate using a BIM-based Model for calculating auxiliary materials needed for building construction.	The proposed model significantly enhances auxiliary materials management and the supervision of material distribution.
(Ma, 2018)	

Purpose	Contribution
Studies the management of green building materials and develops a BIM-based material management evaluation model.	The authors submit that the BIM-based model and supply chain systems could deliver supply chain information fast, accurately, and safely
(Mostafa & Zhineng, 2018)	
Study the integration of the BIM-Based model in green building materials management.	The scholar triangulates the need to improve China's current means of managing green building materials with BIM adoption.
(Mall, 2019)	
Investigate the application of BIM to reduce material waste	Design a model for BIM waste reduction.
(Wu, 2020)	
Compare the use of BIM for material management with the conventional method.	Used sampling survey and sand table simulation technology to conduct the investigation.
(Beorkrem, 2015)	
Assess the suitability of BIM for Material management and fabrication.	Implement BIM-model to embrace the management of materials and fabrication.
(Yu et al., 2016)	
Investigated the use of a BIM-based model for managing the supply of site materials	They developed a dynamic BIM-based model for managing the supply of site materials.
(Hu et al., 2021)	
The author investigated the application of BIM technology to manage a stadium project.	Use of a BIM-based model for managing material during stadium construction.

3.2 BIM integration as a material management tool.

Porwal and Hewage (2012) designed an innovative methodology in the Canadian Architecture, Engineers, and Construction (AEC) industry, to minimize rebar waste during the project design stage. Through analyses of BIM models with a quick optimization technique. This technique allows project stakeholders to use BIM models to "simulate relevant project design requirements" and compare results faster to effect necessary design adjustments to reduce rebar waste. Čuš-Babič et al. (2014) Investigate the issues related to the integration of information flow in the construction industry supply chain. The authors focused on a case study using a BIM-based Model for material management. Their findings proposed how to bridge gaps among the information systems used for on-site construction material management processes. The scholars submit that integrating the BIM-based model in construction can minimize issues resulting from improper material management and information gaps. The study of (Wang & Wang, 2015) investigated the combination of BIM and Radio Frequency Identification (RFID) technology to improve the management level of green building materials. The findings reveal that implementing these techniques improved the management level of green building materials compared with non-BIM and RFID-based projects. Fig. 2 shows the design framework for material management. The researchers see RFID as a "non-contact automatic identification technology, which is usually used for data collection." At the same time, BIM serves as an information exchange model that saves scanned data and information collected by RFID in the design process to visualize green building components, materials, and construction projects.

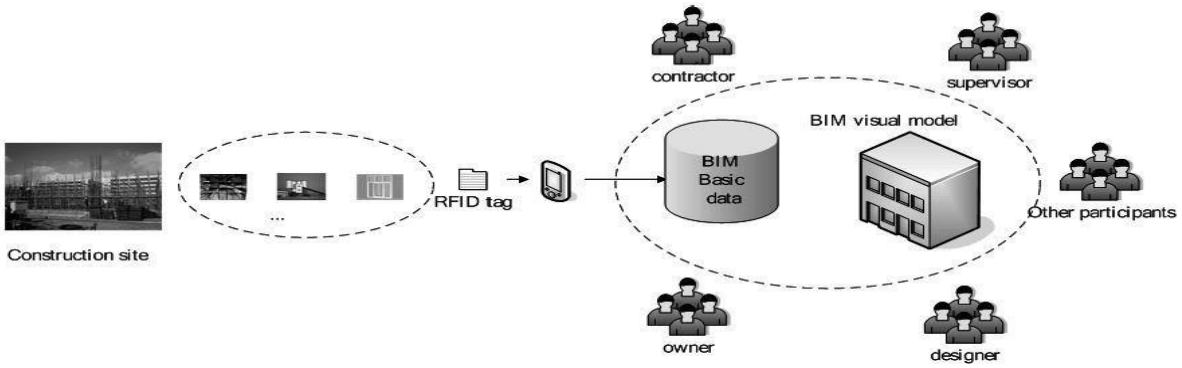

Fig. 4. BIM and RFID material implementation system framework. (Wang and Wang, 2015).

The study of Feng and Lin (2017) focused on how to use the BIM model to smoothen the management of MEP materials, focusing on a case study of fire-fighting systems. Dynamo modules were formed to smoothen the process of developing the BIM model for the case study. The findings of Mall (2019) identified the causes of material waste on construction sites and the problem faced by its management. The adoption of BIM for material management was demonstrated to eliminate most problems. The author designed a BIM-based model to arrest those problems. The model's outcome summarized it could reduce clashes that could lead to material waste during construction, coordinate design to reduce waste on-site, and reduce redesign and rework, which could lead to material waste. Wu (2020) uses the method of "sampling survey and sand table simulation technology to compare the prefabricated building material management based on BIM technology with the conventional method" it focuses on the production and construction stages. The result reveals that adopting BIM in managing building materials has an advantage over the traditional method.

Beorkrem (2015) noted the need for BIM in managing building materials due to the unique nature of the design material. It was noted that BIM could be utilized as a design and production tool that integrates ethical and inventive decision-making within parametric design environments. Thus, it can help improve its management during the construction phase. Figure 5 shows the BIM model's line used for building materials management.

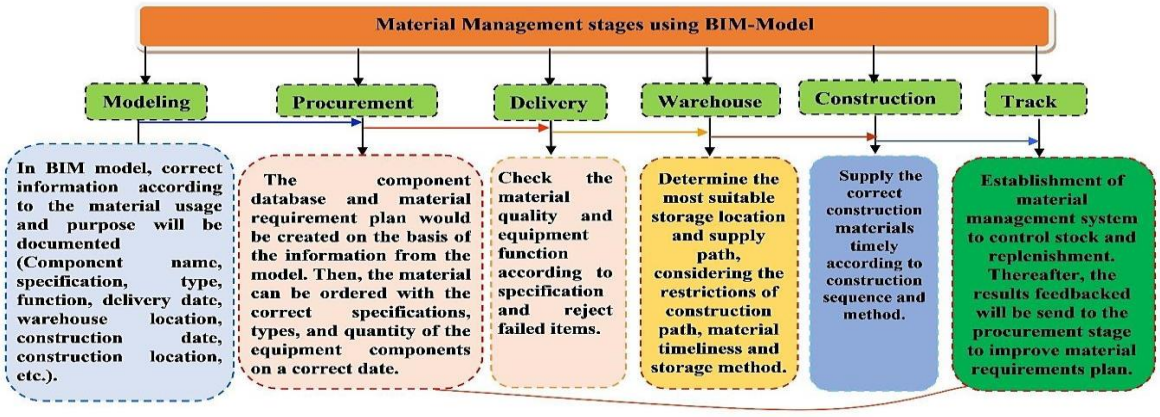

Fig. 5. Use of BIM-model to manage building materials.

Wei et al. (2017) proposed a BIM-based model for effectively managing auxiliary materials needed for building construction. The authors found that the developed model is more effective and consistent in managing and calculating the number of auxiliary materials needed for the project compared to the previous management process. These significantly reduced auxiliary materials waste and strengthened supervision in material distribution. The study of Ma (2018) focused on using a theoretical basis for applying a BIM-based model in the green building materials management system. A logical structure for managing green building materials was developed based on BIM. According to the authors, BIM may increase information cooperation and database sharing. Project parties can optimise and supplement the information in a timely way, decreasing information loss and management expenses. Mostafa and Zhineng (2018) researched in China, where there has been a report on the imperfect status of the China green building material management (GBMM) system. Therefore, the authors proposed using BIM technology to improve the management of the GBMM system. RFID was also incorporated for monitoring and tracking the management of construction materials.

To automate the input of information in the BIM model. The study by Yu et al. (2016) proposed a BIM-based model for managing materials supplied to the site. The authors validated the model by subjecting it to a real-life case study. The BIM-based model demonstrated its capability in managing dynamic site material through 4D modelling, optimal scheme generation method, and acquisition method of site information. Hu et al. (2021) researched the construction of a stadium; the author introduced the application of BIM-based technology in the management of stadium projects. The BIM-based model was used to monitor and manage the A-Z of the project. The application of the BIM-based model enables easy means of controlling the system progress, tracking the materials system, and safety monitoring system.

4. Trends and Visualization Evaluation

4.1 Publication per year.

Out of the over 900,000 BIM-related publications searchable in Google Scholar and over 24,000 are indexed in Scopus, and over 15,000 in WOS (Web of Sciences). Only 20 articles could be located at the time of this study

(August_9_2022) that address the use of BIM for material management. This shows that concentration in this study area is significantly low. The following can be deduced in Figure 6: The spread of the publications; in 2012, the first released article was published by (Porwal & Hewage, 2012); in the year 2020, four articles were published, which account for 20% of the total publications in this study area.

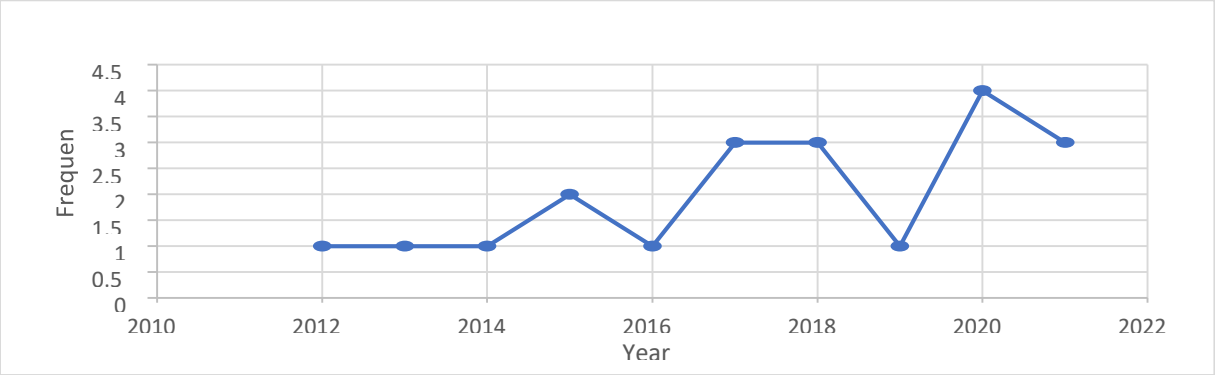

Fig. 6. Trend of publication.

4.2 Publication per year.

Keywords are phrases, nouns, and terms that comprise the essential elements of an article/publication and demonstrate the progression of study themes through time (Xiang et al., 2017). The Scopus database contains two types of keywords: (i) author keywords, which authors submit, and (ii) index keywords, which are recognized by journals. A network of co-occurring keywords was constructed with both types of keywords from the 20 bibliometrics data. Cooccurrence may also include keywords connected to the same issue but do not have the same meaning; the proximity of keywords is related to the degree of co-occurrence (Xiang et al., 2017). Initially, 215 keywords were identified. To identify the one that has occurred more than once. Inclusion criteria were set to two. Wherein 37 keywords meet this threshold. Thus, proceed to map out its overlay visualization. Overlay visualization is used to picture the occurrence trends of keywords over a period. Figure 7 shows the trends of the keywords over time. Earlier, the focus was more on waste management and material management. Then it moved to information requirements and interactive devices. However, recently the focus started from architectural design, green building materials, and BIM technology to material handling, building materials, information management, and construction management. For easy tracking of the occurrence trend, the ledged in Figure 7 shows the colour used to represent the trend move. Purple represents the initial focus, and yellow regions show the recent focus.

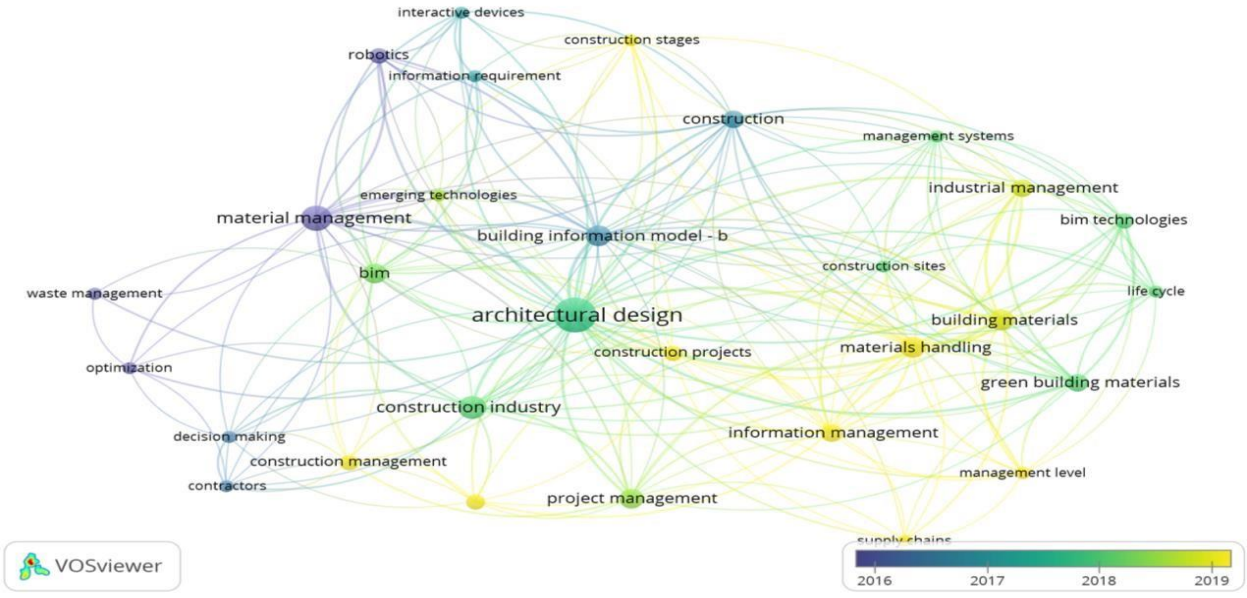

Fig. 7. Keyword trend visualization.

4.3 Publication per year.

This section outlines the most contributing countries in this study area and the most cited country at the time of this study. Seven countries have contributed to this study area. The following can be found in Figure 8: China is presently

seen as the most contributing country with nine documents which account for 45% of the 20 published articles, followed by Canada. Based on the most cited county, Canada topped with 133 citations, while Slovenia followed with 59 citations, down to Germany and Taiwan having two citations each. Looking at figure 9. These unleashed the leading countries with BIM adoption as recently published (UNITED-BIM, 2022). The result of the most contributing countries in this study validated the list, having China, the United States, and Germany on the list.

Create Map

Verify selected countries

Selected	Country	Documents	Citations	Total link strength
☑	canada	4	133	0
☑	china	9	33	0
☑	egypt	1	54	0
☑	germany	1	2	0
☑	slovenia	1	59	0
☑	taiwan	2	2	0
☑	united states	2	56	0

Fig. 8. Most contributing country.

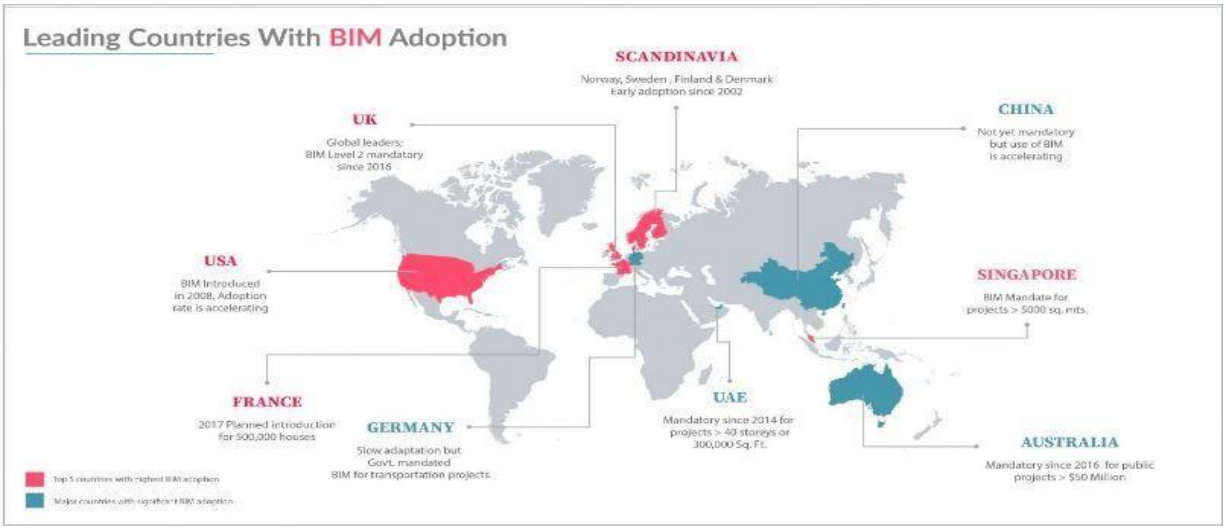

Fig. 9. Most BIM-adopted countries.

4.4 Most Cited authors.

Most cited authors' mapping is used to express various authors' significant impact and contribution to a particular study area with their publication(s). Initially, fifty authors were identified in the documents. A minimum of 50 citations was used to identify the most cited authors from the surplus of authors. Thus, eight authors meet this requirement, as seen in Figure 10. Porwal A. and Hewage K. N. had 70 citations each. This author co-authored an article titled: "Building information modelling-based analysis to minimize the waste rate of structural reinforcement."

Create Map

Verify selected authors

Selected	Author	Documents	Citations	Total link strength
☑	el-rayes k.	1	54	0
☑	hewage k.n.	1	70	0
☑	nekrep-perc m.	1	59	0
☑	podbreznik p.	1	59	0
☑	porwal a.	1	70	0
☑	rebolj d.	1	59	0
☑	said h.	1	54	0
☑	čuš-babič n.	1	59	0

Fig. 10. Most contributing author.

5. Conclusions and Suggestions for future studies.

5.1 Conclusion.

This paper presents the result of the extensive review and the visualization trend check on the status of BIM adoption for on-site building material management within the construction industry. The review findings extracted from the selected articles reveal that the implementation of the BIM model for the management of building materials during the construction phase has gained considerable attention in the following areas: “Rebar waste control, MEP material management, application of BIM technology for the management of green building materials, use of BIM to control material waste, and development of several BIM-model to assist in the management of building materials.” The visualization trend checks reveal the limited contributing authors, counties, and focus trends over the years. This shows less advancement in the adoption of BIM for material management globally. Having just seven contributing countries in this study shows that their adoption of material management is still relatively low compared to the design and procurement stage. Nevertheless, BIM is a promising and emerging innovative technology capable of solely managing building materials and can house the incorporation of other related technologies.

5.2 Suggestions for Future Studies.

There is still much research that must be conducted in the context of BIM-based technology use for the management of construction materials. Moreover, its suitability for the management of materials has been established. Therefore, researchers may:

- Validate or modify the existing BIM-Based model through a real-life case study and document the various challenges faced during the validation of the model
- Develop a BIM-based model that will incorporate the management of material and supply chains.
- Document the possible barriers hindering BIM-Based material management model implementation.

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