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A REVIEW ON UNEXPLOITED FEATURES OF N-DIMENSIONAL BIM: AN INDIAN CONSTRUCTION SCENARIO

Rhijul Sood[1] and Boeing Laishram[2]

ABSTRACT

Infrastructure sector is a backbone of economic development for most of the countries worldwide. Indian AEC (Architecture, Engineering and Construction) industry is one of the leading sectors in terms of Gross Domestic Product (GDP) and employment. With the increasing demand for infrastructure and continuous development in field of technology, the speed of construction has been improved in various countries. But most of the projects still face the issues of cost and time overruns due to un-exploitation of digital tools and technology. Building Information Modeling (BIM) is one such promising technology that spans several levels of maturity (Level 0, 1, 2, and 3) and dimensions (3D, 4D, 5D, 6D and 7D). Many studies have shown that the construction industry is still lagging behind the rate with which technology should have been adapted, particularly in developing countries including India. This paper, therefore aims to answer systematically about various dimensions and level of maturity and its current status in Indian construction industry and the key factors responsible for un-exploitation of BIM's features due to low maturity. Finally, the paper presented some future research agendas. The study's findings may be of significant value to the practitioners and policy-makers in incorporating mandatory BIM based framework for Indian construction industry and also in other developing nations.

Keywords: *AEC; BIM; Dimensions; India; Level of Maturity.*

1. INTRODUCTION

Infrastructure is generally referred to all physical assets, equipment, and facilities of interconnected systems, as well as the key service providers who deliver linked commodities and services to the general public with the objective of enabling, sustaining, or improving social living circumstances (Weber, et al. 2016). Infrastructure that is of high quality not only attracts new investment and allows existing enterprises to expand for long-term economic growth, but it also improves people's living standards by easing access to crucial health and safety supplies. Projects under construction typically experience a high level of uncertainty at various stages of construction, resulting in an increase in risk in terms of construction cost estimates, handover delays, and poor project quality. Notably, since the outbreak of the pandemic of COVID-19, numerous construction enterprises have attempted to implement innovative techniques to accelerate production recovery and enhance the ability to cope with the crisis. The construction

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industry has moved from a 2D to a 3D environment, and then from a 3D to a design environment using building information modeling (BIM) to boost productivity. BIM is one such technology that spans several levels of maturity (Level 0, 1, 2, and 3) and dimensions (2D, 3D, 4D, 5D, 6D and 7D). BIM is a generic word that refers to the process of digitally producing, representing, and managing buildings and related information using modern 3D computer-aided design software (CAD) (Ikediashi and Uyanga, 2016). BIM helps in applying and maintaining an integral digital representation of all building information for different phases of a project lifecycle (Gu and London, 2010). This is only possible by utilizing various dimensions of BIM. The models created using BIM are used not only to design the building geometry, but also to include information that allows for various types of analysis to be undertaken (structural, schedule, cost estimate, energy analysis) (Kota, et al., 2014). It facilitates in the decision making process of an asset throughout its lifecycle, i.e., from conception till demolition (Won, et al., 2013).

As a result, BIM can be thought of as a collection of software applications with distinct characteristics that are linked together to improve infrastructure design, visualization, operation, and management. BIM has been used to replace traditional computer-aided design and drawing (CADD) for a wide range of infrastructure design and development projects since the early twenty-first century (Lin, et al, 2021). Despite the fact that it is still called "Building Information Modelling", it is increasingly being thought of as a service rather than a software solution or a single product (Isikdag, 2012). The emergence and evolution of the concept of BIM has resulted in the development of a technology platform for exchanging technical information at all stages of construction, as well as enhanced data collection, transmission, and feedback management (Akcamete, et al., 2010). Another benefit of BIM is that data may be prepared once and reused many times, resulting in fewer errors, increased uniformity, clarity, and clear authorship responsibilities (Kelly, et al., 2013). Even though there are many advantages of using BIM in construction but the acceptance and implementation rate is very slow. Each of the BIM dimension has its own characteristics and advantages which are discussed in subsequent sections. Most of the projects worldwide still face the issues of cost and time overruns due to un-exploitation of digital tools and technology. Apart from the United Kingdom (UK) and the United States of America (USA), which have seen increased acceptance and implementation of BIM, the majority of other countries including India are still lagging behind

The current study therefore aims to shed some light on the existing body of knowledge in BIM by studying the research in employing BIM for infrastructure construction industry in India and the key factors responsible for not exploiting the technology in India. In addition, the study aims to provide information on current research trends and identify future research agendas.

The paper is organized as follows in this regard. Firstly, the paper describes the methodology of the systematic review. Secondly, it summarizes the findings of descriptive and content analysis. The study discusses various dimensions and level of maturity of BIM along-with understanding the maturity stage reached in India, what are the unexploited features that still needs to be exploited by Indian construction stakeholders (Clients, Contractors, Engineers, Architects, etc.). In the end, the study summarizes the list of key factors for such trends in India and conclusions are presented with a pathway to future agenda.

2. METHODOLOGY

The current study's research approach was based on a comprehensive review of existing literature. This is due to the fact that systematic review is an important scientific study strategy that can be utilized to assess, synthesize, and communicate the findings and consequences of a large number of research publications on a certain issue (Green, 2005), as has previously been done in various research works. The definition, refining, and evaluation of raw data are all required processes in the data collection process. To retrieve the correct data set for the study, the collected data sets must be articulately stated using the query string. The data must be refined using the relevant parameters, which include, among other things, the year, country, and type of publishing (depending on the study objective). Following that, the data is evaluated to ensure that the information obtained meets all of the search criteria. The process for the review was divided into three stages, as discussed below.

2.1 PLANNING THE REVIEW

The first stage is to define the research problem and then formulate it. This was followed by a SCOPUS database literature search to identify the papers to be included in the review. The database was chosen for its breadth of coverage, as it includes the bulk of peer-reviewed journals in project management and megaprojects (de Araújo, et al, 2017) (Zhou and Mi, 2017). Before beginning a database search, it is critical to identify a list of keywords and other relevant terms connected to the study subject. As a result, the search was conducted using building blocks, which is one of the most commonly utilized search strategies among literature reviewers (Booth, 2008). As a result, the research topic/ problem is divided into discrete phrases that are linked together using Boolean operators such as "AND" and "OR". The terms *"BIM, Building Information Modeling, India*" have been discovered to be relevant to the current study problem. These probable phrases were discovered through a combination of snowballing and trial-and-error searching.

2.2 CONDUCTING THE REVIEW

Following the definition of keywords in the preceding section, the subsequent stage entails searching for and selecting relevant papers, which also comprises of 3 steps. The first step was to conduct a keyword search in SCOPUS. The initial publication date for the research publications was not provided so that a comprehensive collection of papers could be compiled. The list of papers to December 2021 was covered, yielding a total of 485 publications. Only English language publications were retained, and duplicate papers were also eliminated, reducing the list to 126 papers. In the second step, titles and abstracts of publications were critically evaluated based on pre-defined filtering and selection criteria in the databases.

The criteria involved the inclusion and rejection of publications, which included: (a) studies that focused on BIM other than Building Information Modeling, (b) articles that did not focus on the Indian construction sector, were excluded. Following this regressive screening, 61 papers were chosen for further consideration. After exporting the previously filtered articles, a full-text manual analysis was undertaken in the third phase, and a list of 40 papers was determined for the systematic review analysis, as stated in later sections of this paper (refer to Figure 1).

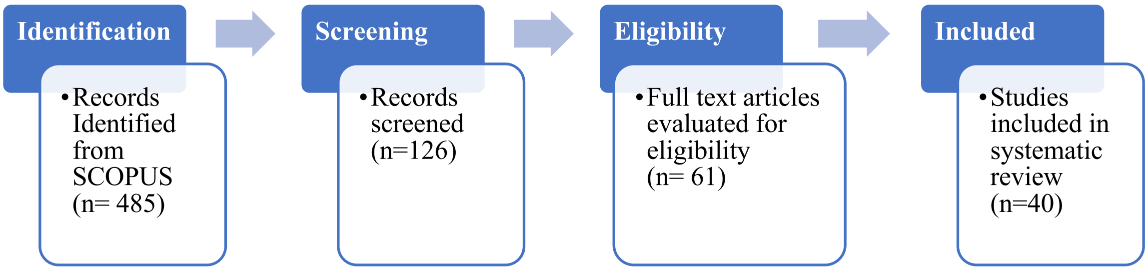

Figure 1: Flow diagram of selection of studies for systematic review of published research

2.3 ANALYZING AND REPORTING REVIEW

At this stage, a descriptive analysis of the papers was carried out in order to provide year-specific and infrastructure sector-specific publications. In the following section, charts and tables are used to illustrate these findings. Inductive content analysis was also performed to categorise the various stages of construction and how BIM is utilised throughout the many lifespan stages of an infrastructure project, as well as distinct levels of maturity. Each document was read several times back and forth in order to extract and group codes, and then categorise them.

3. ANALYSIS AND RESULTS

3.1 DESCRIPTIVE ANALYSIS

As shown in Figure 2, the descriptive analysis includes the publication distributions in various years beginning in 2006. The number of publications was limited in the beginning since digital technology in infrastructure operations and maintenance was still in its infancy considering Indian construction sector. However, as technology advances, the frequency of publications has grown as well. The list of articles is also divided into fields where the majority of the research has been conducted (refer Figure 3). Highways and bridges are regarded as the most vital infrastructure assets, and significant case studies are based on them. As can be observed, following 2016, there was a significant increase of publications, suggesting the usage and more research on BIM technology in Indian construction industry.

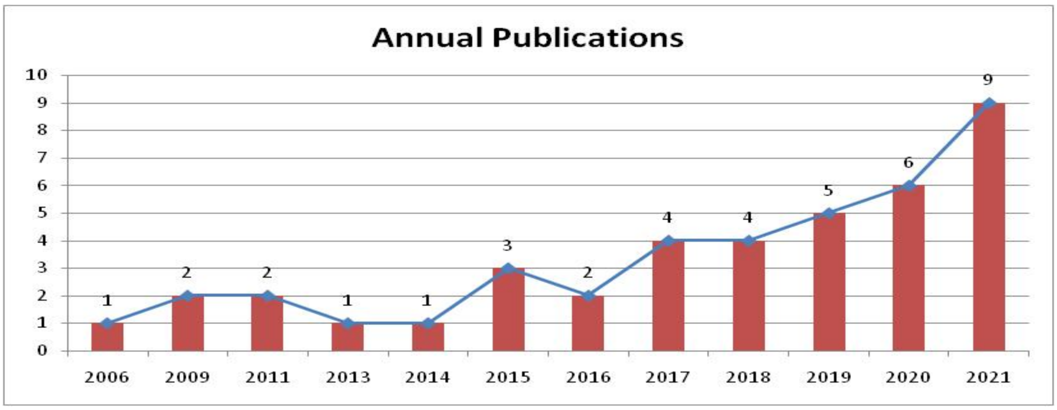

Figure 2: List of annual publications

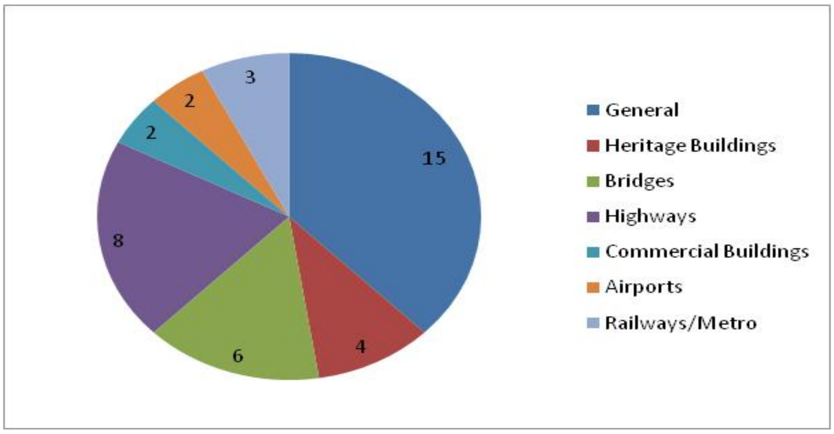

Figure 3: Sector wise distribution of papers

3.2 CONTENT ANALYSIS

The conclusions of the content analysis are presented in this section, which includes the evaluation of all research publications. Section 3.2.1 covers the benefits of various BIM dimensions along with the level of maturity of BIM while Section 3.2.2 highlights the current level of BIM implementation in India along with the key factors that affects high maturity level BIM implementation in the Indian construction industry.

3.2.1 BIM Dimensions

BIM is more than just creating a 3D model of a structure. It also entails adding information about the phases of design, construction, and maintenance. BIM dimensions are defined as the additions of pre-specified used cases to existing models. BIM dimensions includes 3D, 4D, 5D, 6D, and even 7D so as to improve the data connected with the model and allowing for a better understanding of the construction project to be shared. In fact, supplementing data with other information allows the stakeholders to learn how the project will be delivered, how much it will cost, and how it should be maintained. Specific parameters are added to the existing information in BIM, based on project stage needs and project complexity.

3D BIM: Visualization Phase

As we all know, 3D symbolizes the three geographical dimensions (x, y, and z) of a building construction. These dimensions include geometrical and graphical information of the components designed. Even before the project begins, stakeholders can visualize the construction of a building in three dimensions because to geographical capabilities. 3D BIM enables all stakeholders to successfully collaborate for modeling and solving fundamental structural problems. Furthermore, because everything is saved in a centralized area, namely the BIM model, it becomes easier to fix concerns at a later time. Some of the benefits of 3D BIM include improved visualization, streamlined communications, simplified collaborations between multiple teams (civil, mechanical, electrical, and plumbing), clash detection, and reduced instances of rework and revisions due to complete transparency from project's beginning.

4D BIM: Time Phase

4D BIM is the integration of the 'TIME' element to a simple 3D BIM model. Scheduling data aids in determining how much time will be required to complete the project and how the project will grow over time. The data can provide elaboration on the time required for installation or construction, the time required to complete the project, the sequence of installation of various components, and other scheduling information. The advantages of 4D BIM include improved site planning and scheduling efficiency, streamlined coordination among architects, contractors, and on-site teams, improved information sharing regarding project timelines, obtaining accurate project visualizations, and anticipating potential schedule delays.

5D BIM: Quantity and Cost Phase

5D creates a project using a simple 3D geometry and adding the 'COST' element to it. This enables participants to visualize the progress of their actions as well as estimate the overall costs associated with it, resulting in increased accuracy and feasibility of any given project. 5D BIM is useful when budget analysis and cost estimation are necessary right from the start of a project. It helps project promoters and owners to assess the expenditures that will be incurred in the course of the project's activities over time. It offers numerous benefits, including real-time cost visualization with notification of changes in costs, simplified cost analysis and budgetary analysis with predicted and actual spends over time, minimization of budgetary offshoot due to regular cost reporting and budgeting, and the ability to analyze cost and time overruns using earned value analysis.

6D BIM: Sustainability and Energy Analysis Phase

6D BIM aids in the analysis of a building's energy consumption and the generation of energy estimates during the early stages of design. Analyzing energy performance early in the design process allows the designer to choose the best technological solutions for lowering energy consumption, improving quality, and ensuring the project's long-term viability. This method aids in determining the total cost of an asset and how money should be spent to achieve long-term sustainability and cost-effectiveness. 6D BIM is also referred to as integrated BIM since it includes detailed information that can aid facility management and operations in the future. Reduced long-term energy consumption, complete study and impact of a decision on economic and operational aspects over the whole lifecycle (Life cycle analysis), and better operational management of the building or structure after handover are just a few of the benefits.

7D BIM: Operations and Maintenance Phase

7D BIM is a novel concept in which all information about the facility/asset management process is gathered in one location within the model. Building managers and owners use 7D BIM to manage operations and facilities. This dimension is used to keep track of key asset data, such as its status, maintenance/operation manuals, warranty information, technical specs, and so on, for later use. The primary benefits of 7D BIM include improved asset and facility management from design to demolition, simpler and easy replacement of parts and repairs at any time during the life of a structure, and a streamlined maintenance process for contractors and subcontractors.

BIM is utilized in a variety of ways in various nations, depending on the type of project and the level of maturity. BIM maturity levels range from 0 to 3, as indicated in Figure 4. Level 0 BIM shows a lack of collaboration. Working with 2D CAD designs demonstrates Level 0 BIM. Level 1 BIM is demonstrated by using 3D CAD for concept work but 2D for drafting production data and other documents. Level 2 BIM encourages collaboration among all parties involved in building projects. Level 2 makes use of 3D CAD or software models, and information about the design of a built environment is exchanged among the parties involved using a common file format. As a result, it can save time and money, as well as eliminate the need for rework (Lat, et al., 2021) .

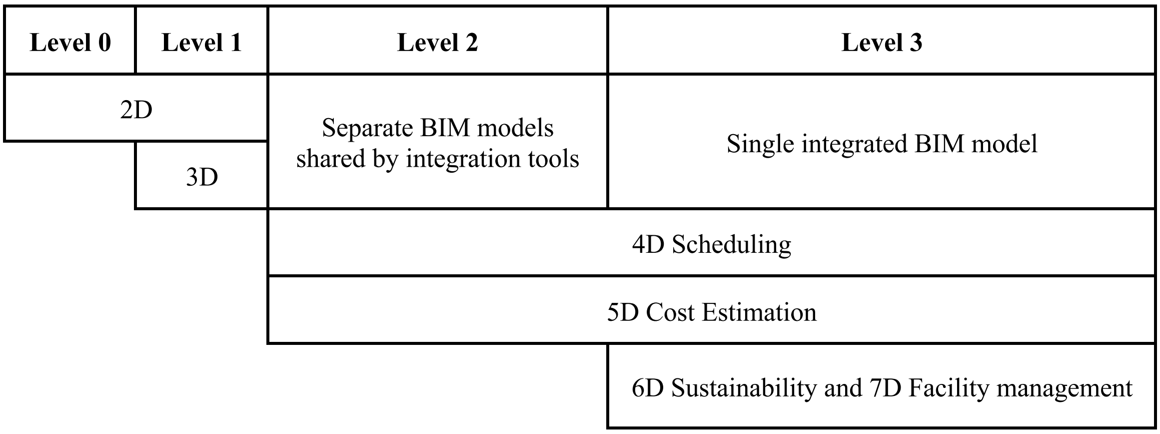

Figure 4: Level of development of BIM maturity

3.2.2 BIM in India

The AEC industry is the largest in the world, and it is the second largest employer in India after agriculture, contributing significantly to the country's GDP (Charlesraj and Dinesh, 2020). India is a developing country that necessitates the construction of all forms of infrastructure. With the COVID-19 problem putting an unprecedented toll on the country's economic activities, significantly increased infrastructure investment is necessary for recovering the country's growth (Wang and Tian, 2020). BIM technology acceptance in the construction sector has lately expanded, with the UK, the USA, and other countries, such as Finland and Norway, displaying a high level of adoption and implementation(Adekunle, et al., 2021). Like UK, USA and all other developed countries the Indian government does not take an initiative to encourage the practice of BIM in the AEC industry (Ahuja, et al., 2020). In India, however, BIM has yet to gain widespread acceptance among building professionals (architects to contractors).

Despite being new to the Indian construction scenario, BIM has shown strong acceptance potential here but implementation rate is very low. India has a booming market for large-scale residential and commercial development. The real estate industry has skilled, trained, and experienced BIM professionals who are using this technology, however in comparison to the worldwide scenario; the proportion of acceptance is not as high. Evidence from literature reveals that developing countries struggle with BIM adoption. Furthermore, the percentage of BIM acceptance differs widely, with India ranking among the lowest, with only 10-18% BIM adoption compared to 71% BIM users in the USA alone (Sawhney, 2014). In India, BIM is most commonly used for visualization, i.e. for 3D modeling and brief client presentations, followed by concept design and asset management (Mohanta and Das, 2022), implying that BIM’s maturity level in the Indian construction sector is at the early stages of Level 2.

The key factors for low level of maturity of BIM in Indian construction industry are studied by many researchers among which the most common includes: lack of defined/contractual guidelines and regulations/BIM standards (Azhar, 2011; Kassem, et al., 2013; Naghshbandi, 2016), lack of BIM Knowledge/Expertise (Gu and London, 2010; Kassem, et al., 2013; Ramilo and Embi, 2014; McArthur, 2015), complexity of BIM tools (Kassem, et al., 2013; Mahalingam, et al., 2015; Ahuja, et al., 2020), resistance for new technology (Azhar, 2011; Naghshbandi, 2016; Sreelakshmi, et al., 2017; T. Patel, et al., 2021), lack of support from owners and other trade partners (Azhar, 2011; Kassem, et al., 2013; Sawhney, 2014; R. P. Patel, et al., 2021), interoperability issues among various BIM Tools (Kassem, et al., 2013; Jagadeesh and Jagadisan, 2019; Ahuja, et al., 2020; Mehedi and Shochchho, 2021; R. P. Patel, et al., 2021), high cost of Implementation (Azhar, 2011; Kassem, et al., 2013; Ramilo and Embi, 2014; R. P. Patel, et al., 2021), low awareness of BIM benefits, risks involved in implementing BIM, doubts about Return on investment (ROI) (Sreelakshmi, et al., 2017; Isac and Anoop, 2019; Ahuja, et al., 2020; Charlesraj and Dinesh, 2020), mindset of construction stakeholders, lack of demand from the client side and insufficient government support (Ramilo and Embi, 2014; Charlesraj and Dinesh, 2020; T. Patel, et al., 2021). These factors can be broadly categorized among several groups such as technical, cost related, managerial, organization culture and others.

4. DISCUSSION

The preceding sections mostly demonstrated the application of BIM in the Indian AEC industry. It also highlights the un-exploited dimensions, levels of maturity of BIM in the Indian sector, as well as the challenges that construction owners and other various stakeholders face while using BIM. Some research gaps have been found in order to help this industry handle the two main difficulties of cost and time overruns by correctly integrating digital technologies such as BIM in all phases of an asset's lifecycle procedures. The COVID-19 event should be viewed as an opportunity rather than a threat by stakeholders seeking to maximise the use of BIM software, particularly the higher dimensions specified in the paper. Overall, the study contributes to a complete and systematic analysis of the demand for BIM in the construction sector, as well as the need for further research on integration with lean management tools and practises.

5. FUTURE RESEARCH AGENDAS

The observations from the current shows some future research areas in the current domain of maturity of BIM and need to enhance the implementation of BIM in Indian construction sector. The analysis of research methods shows that the majority of study in this domain is done on basis of surveys and lacks real world cases on BIM application (Becerik-Gerber, et al., 2012).

Secondly, there is lack of study on the way how COVID-19 has brought the change in the working of AEC industry people. The impact of this pandemic was worldwide and construction being one of the labor- intensive industry with slow technology adapter was impacted the most.

Thirdly, there have been discussions about new dimensions of BIM such as 8D, 9D and 10D which corresponds to safety management, lean management and construction industrialization respectively. These dimensions are still at the initial stage of development and not been mentioned or researched upon yet. But, there have been mention about the integration of lean tools with BIM but the study is very rare (Sood and Laishram, 2021).

Hence, the current study would be helpful to develop new frameworks and methodologies that take a multidisciplinary approach, such as integrating social science theories to analyze the interdependencies of institutions and factors affecting higher level BIM implementation in India. Such studies can help policy-makers understand the key effective institutional structures or strategies to strengthen the Indian construction industry (Favari and Cantoni, 2020).

6. CONCLUSION

According to the current study, the infrastructure construction sector is continually evolving, delivering worldwide economic development as well as continuous improvement through the use of technology at various stages of an infrastructure asset's life cycle. However, digital technology such as BIM is still not extensively adopted in the Indian AEC business. There are numerous fundamental issues associated with the employment of technology and are discussed briefly. However, a comprehensive analysis of the research contribution is required to provide an overview of the issues faced by stakeholders in the efficient use of BIM. In this context, the purpose of this study was to comprehensively investigate existing research on BIM, its different dimensions, and its level of maturity in the Indian setting. The literature search was performed in SCOPUS database. The study adopted a three-step methodology including title analysis, abstract analysis, and full text analysis for filtering and finalising 40 articles for final review. The articles were organised by year of publications and infrastructure sectors.

There has been very less study in understanding the implementation of higher dimension/ maturity level of BIM in India due to less case studies. The COVID-19 outbreak has served as a catalyst for informing stakeholders about the significance of using more technology-based tools and approaches, as well as allowing researchers to gain insight into its impact, particularly the potential gains. By building and examining frameworks through Indian construction case studies, the research paves the way for future research into the usage of lean approaches that have applications in effective BIM utilisation.

Overall, the review provides a comprehensive and systematic review of various dimensions and maturity level of BIM, implementation of BIM in Indian construction scenario as well as the key factors which are responsible for such low implementation. The results obtained contributes to the study of knowledge of BIM in India. Nevertheless, some limitations are present in the review but the practitioners and policy makers in field of Digital construction in India can prepare a future road map for Indian construction based on this study.

7. REFERENCES

Adekunle, S.A., Ejohwomu, O. and Aigbavboa, C.O., 2021. Building information modelling diffusion research in developing countries: A user meta-model approach. *Buildings*, 11(7), pp. 1-20.

Ahuja, R., Sawhney, A., Jain, M., Arif, M., and Rakshit, S., 2020. Factors influencing BIM adoption in emerging markets - The case of India. *International Journal of Construction Management*, 20(1), pp. 65-76.

Akcamete, A., Akinci, B. and Garrett, J.H., 2010. Potential utilization of building information models for planning maintenance activities. *The 17th International Workshop on Intelligent Computing in Engineering* (EG-ICE 2010), pp. 151-157.

de Araújo, M.C.B., Alencar, L.H. and de Miranda Mota, C.M., 2017. Project procurement management: A structured literature review. *International Journal of Project Management*, 35(3), pp. 353-377.

Azhar, S., 2011. Building information modelling (BIM): Trends, benefits, risks, and challenges for the AEC industry. *Leadership and Management in Engineering*, 11(3), pp. 241-252.

Becerik-Gerber, B., Jazizadeh, F., Li, N., and Calis, G., 2012. Application areas and data requirements for BIM-enabled facilities management. *Journal of Construction Engineering and Management,* 138(3), pp. 431-442.

Booth, A., 2008. Unpacking your literature search toolbox: On search styles and tactics. *Health Information and Libraries Journal,* 25(4), pp. 313-317.

Charlesraj, V.P.C. and Dinesh, T., 2020. Status of 4D BIM implementation in Indian construction. Proceedings of *the 37th International Symposium on Automation and Robotics in Construction, ISARC 2020: From Demonstration to Practical Use - To New Stage of Construction Robot,* (October), pp. 199-206.

Favari E. and Cantoni F., (eds.) 2020. *Megaproject Management a Multidisciplinary Approach to Embrace Complexity and Sustainability*. Springer Nature.

Green, S. 2005. Systematic reviews and meta-analysis. *Singapore Medical Journal*, 46(6), pp. 270-274.

Gu, N. and London, K., 2010. Understanding and facilitating BIM adoption in the AEC industry. *Automation in Construction*, 19(8), pp. 988-999.

Ikediashi, D. and Uyanga, J., 2016. Adoption of BIM technologies for facilities management roles in Nigeria: An Empirical Investigation. In *ICCREM 2016: BIM Application and Off-Site Construction*, Reston, VA: American Society of Civil Engineers. pp. 23–32.

Isac, I.A. and Anoop, C.K., 2019. Analysis of building information modelling and scope of BIM in India. *International Journal of Engineering Research and Technology (IJERT)*, 8(11), pp. 72-76.

Isikdag, U., 2012. Design patterns for BIM-based service-oriented architectures. *Automation in Construction,* 25, pp. 59-71.

Jagadeesh, G.M. and Jagadisan, S., 2019. Investigation of BIM Adoption in India. *International Journal of Engineering Research and Technology (IJERT)*, 8(11), pp. 252-258.

Kassem, M., Succar, B. and Dawood, N., 2013. A proposed approach to comparing the BIM maturity of countries| NOVA. The University of Newcastle's Digital Repository. Proceedings of *the CIB W78 2013: The 30th International Conference,* pp. 9-12.

Kelly, G., Serginson, M., Lockley, S., Dawood, N., and Kassem, M., 2013., BIM for facility management: A review and a case study investigating the value and challenges. *The 13th International Conference on Construction Applications of Virtual Reality,* 30-31 October 2013, London, UK, pp. 30-31.

Kota, S., Haberl, J.S., Clayton, M.J., and Yan, W., 2014. Building Information Modelling (BIM)-based daylighting simulation and analysis. *Energy and Buildings,* 81, pp. 391-403.

Lat, D.C., Noor, S.M., Rahman, N.S.A., and Razali, R. 2021. Construction industry towards IR 4.0 - A review. *AIP Conference Proceedings*, 2339(May), p. 020084.

Lin, C.L., Chen, J.K.C. and Ho, H.H., 2021. BIM for smart hospital management during COVID-19 using MCDM. *Sustainability*, 13(11), pp. 6181.

Mahalingam, A., Yadav, A.K. and Varaprasad, J., 2015. Investigating the role of lean practices in enabling BIM adoption: Evidence from two Indian cases. *Journal of Construction Engineering and Management,* 141(7), p. 05015006.

McArthur, J.J., 2015. A building information management (BIM) framework and supporting case study for existing building operations, maintenance and sustainability. *Procedia Engineering,* 118(May), pp. 1104-1111.

Mehedi, M.T. and Shochchho, A.H., 2021. Exploring facility management (7D) with BIM considering quality and performance assessment models. *E3S Web of Conferences*, 304, p. 02007.

Mohanta, A. and Das, S., 2022. Causal analysis of slow BIM adoption in Eastern India with a special focus on green building sector. *Journal of the Institution of Engineers (India): Series A*, 103(1), pp. 319-337.

Naghshbandi, S.N., 2016. BIM for facility management: Challenges and research gaps. *Civil Engineering Journal*, 2(12), pp. 679-684.

Patel, R.P., Thomas, J.R., Curt, K.M., Fitzsimmons, C.M., Batista, P.J., Bates, S.E., Gottesman, M.M. and Robey, R.W., 2021. Dual inhibition of histone deacetylases and the mechanistic target of rapamycin promotes apoptosis in cell line models of uveal melanoma. *Investigative Ophthalmology and Visual Science*, 62(12). p. 16.

Patel, T., Bapat, H., Patel, D., and van der Walt, J.D., 2021. Identification of critical success factors (CSFs) of BIM software selection: A combined approach of FCM and fuzzy DEMATEL. *Buildings,* 11(7). p. 311.

Ramilo, R. and Embi, M.R.B., 2014. Critical analysis of key determinants and barriers to digital innovation adoption among architectural organizations. *Frontiers of Architectural Research,* 3(4), pp. 431-451.

Sawhney, A., 2014. State of BIM Adoption and Outlook in India. *RICS Research*, (May), pp. 1-30.

Sood, R. and Laishram, B., 2021. Infrastructure Asset Management by Integrating BIM and Lean Tools. in *ILCC*, pp. 43-52.

Sreelakshmi, S., Kantilal, B.S., Roshan, M. and Gopinath S., 2017. A study on the barriers to the implementation of building information modelling. *International Journal of Civil Engineering and Technology*, 8(5), pp. 42-50.

Wang, Z. and Tian, H., 2020. Research on obstacles of BIM application in commercial building operation and maintenance stage based on analytic hierarchy process. *IOP Conference Series: Earth and Environmental Science,* 567(1), pp. 1-8.

Weber, B., Staub-Bisang, M. and Alfen, H.W., 2016. Infrastructure as an asset class: Investment strategy, sustainability, project finance and PPP. *Infrastructure as an Asset Class: Investment Strategy, Sustainability, Project Finance and PPP*, pp. 1-392.

Won, J., Lee, G., Dossick, C. and Messner, J., 2013. Where to focus for successful adoption of building information modelling within organization. *Journal of Construction Engineering and Management,* 139(11), p. 04013014.

Zhou, Z. and Mi, C. 2017. Social responsibility research within the context of megaproject management: Trends, gaps and opportunities. *International Journal of Project Management,* 35(7), pp. 1378-1390.