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Critical Review of BIM implementation for Construction Industry with respect to adoption, challenges and benefits

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Abstract:
Purpose – This paper aims to present a critical review of building information modeling (BIM) in construction industry with respect to adoption, challenges and benefits.
Design/methodology/approach – The paper outlines the general status of BIM adoption through literature review which uncovers the specific benefits, challenges and risks to BIM implementation.
Findings – The role of different stakeholders is very important in implementation of BIM in construction industry.
Practical implications – The paper concludes that implementation of BIM on projects is a successful solution to overcome these challenges. Despite being adopted globally, BIM capabilities need attention in terms of their effectiveness and hierarchy of implementation in order to overcome the challenges of overall construction project cost overrun and time delays.
Originality/value – This paper explores the overview the status of BIM in construction industry with respect to adoption, challenges and benefits by considering maximum countries studies in the world. This paper has focused on the recent studies in between 2015 to 2022.

Index Terms **- BIM, Adoption, Challenges, Benefits, Implementation, Construction Industry**

I. INTRODUCTION

Building Information Modeling (BIM) is a worldwide evolving phenomenon that may greatly affect the growth of the construction industry. [1] The construction industry is called as an extremely uneven and project-based industry that functions in an undefined and fast altering environment. [2] BIM is considered "a revolutionary technology" that has transformed the process of designing and constructing buildings. [3] India is going through major urbanization and economic development. [5] As a revolutionary technology, BIM was introduced to improve the industry's overall performance. [6] It is a three-dimensional digital representation of a building with its characteristics and components. [7] It provides an integrated platform by which information can be shared and used across a building's lifetime to assist in its operations and management. [8] It has been suggested that construction projects will be more effective and productive with ICT applications. [9] Unfortunately the adoption rate of this new technology has been slower than anticipated, despite the large amount of research which has been dedicated to BIM's development. [10] Thus, it is important to understand the challenges that arise from this implement. [11] Moreover, BIM implementation requires the development of reliable tools for information exchange between different software tools while enabling efficient and direct coordination and monitoring processes between project participants and team members. [12] Past research suggests that implementation of BIM on projects is a successful solution to overcome these challenges. Despite being adopted globally, BIM capabilities need attention in terms of their effectiveness and hierarchy of implementation in order to overcome the challenges of overall construction project cost overrun and time delays. [13].

II. LITERATURE REVIEW

Rogers J. et al. (2015) have explored on the overview and adoption of BIM through Malaysian Engineering Consulting Services (ECS) firms' perspective. The lack of well-trained personnel, guidance and governmental supports are the main barriers in BIM adoption. The study has suggested for much better alignment between the educational sector and accreditation bodies or practice communities in order that the next generation of students are appropriately equipped for the future. Market demands, competitiveness advantage and growing awareness in BIM are the main drivers to adopt BIM within two years. Overall, the perceptions, barriers and strategic intent of the ECS sector did not significantly differ from that of the parent AEC industry. Currently, BIM is already providing a competitive advantage in the niche markets of sophisticated developers. Whether this becomes generalizable to the wider industry depends on BIM proving demonstrable benefit for clients, the clients sufficiently valuing the benefits for the supply chain to justify adoption [1]

Lindblad H. et al. (2015) have given focus in investigating the types of changes that should be proposed to the work practices and processes in relation to BIM implementation. This paper studied the BIM initiation project at a large Swedish public infrastructure client. Research argues that changes to work practices and processes following this implementation can generate increased productivity if it is supported by technological and organizational aspect. This study has argued that the public client organization currently implementing BIM is not certain on how work practices and processes will change as a result of the implementation. Instead, the focus has been to establish an organization that supports the use of BIM by ensuring the quality of the technological and organizational side of BIM [2]

Kerosuo H. et al. (2015) studied the challenges, problems and potential expansions of BIM as a tool in the design, construction and operation of buildings. For this purpose the interfaces between different parties are examined in Finnish construction projects. The methodological approach of the study is cultural historical activity theory, according to which a new artifact becomes a mediating instrument when the participatory subjects reconfigure the entire activity. The implementation of BIM is now spreading from the design activity to other phases of the construction projects, but its use is still limited in the projects' other three interfaces. The collaborative forms of BIM use are also under development in the design of buildings. But the use of BIM is still limited in the other three interphases of construction projects. The adaption of BIM is emerging slowly because the development of specific BIM technologies and a set of supplementary tools are required at each interphase of construction activity. [3]

Rodgers C. et al. (2015) found lower awareness levels of BIM amongst SMEs in Australia. The study observed negative biased perception with reference to requirements and the challenges in implementation among SMEs. This study revealed a significant association between awareness of the benefits of BIM and all aspects of practices. Further Studies can be carried out to investigate on customizing an affordable BIM for simple and small-scale projects. [4]

Ahuja R. et al. (2016) have developed a framework to investigate the reasons of poor adoption of BIM among architectural firms in India. The study proclaims the factors influencing BIM adoption. The study confirmed the support of BIM professionals and senior management as one of the important variables affecting BIM adoption. This study reported benefits of BIM adoption in improved work quality, enhanced effectiveness on job, increased productivity, efficient coordination of construction activities, and trust in technology. [5]

Li H. et al. (2017) have examined the major obstacles of BIM application in the Chinese construction industry. The study has identified 12 barriers impeding BIM. As per this study, client/owner group alone is incapable of promoting the technique without government assistance. The study has put efforts to develop practicable mechanism facilitating the implementation of this revolutionary technology in the Chinese construction industry in future. [6]

Hamada H. et al. (2016) have evaluated the barriers and benefits of BIM in the Iraqi construction firms. Minimizing of the cost of project was the most ranked BIM benefit whereas lack of skilled personnel occupied was the most ranked barriers. The study is foundation for more research and development in adoption of BIM technique in Iraqi construction firms. The study recommended that government of Iraq and concern agencies should play a role in the adoption of BIM technique. [7]

Gerrish T. et al. (2016) Without focused efforts to make developments in BIM more widely known, the comments made 20 years ago, and repeated often will continue to be made. Developing and applying new tools to assist in these functions in some small test cases where many factors are controlled is what the industry excels at, but falls short of widespread exploitation of these improvements. Making this work known, and applying it to less controlled case studies is where new problems are identified and solutions to those problems can inform the creation of more useful tools, that have much greater impact on the performance of buildings. [8]

Bui N. et al. (2016) have presented an overview of BIM research in developing countries. The scope of the research kept limited to technology transfer, seeking to import technology, standards, and collaboration approaches from developed countries to the context of developing countries. Technological and managerial aspects in enhancing BIM implementation can be focused as per this study in further work. This article has recommended how professional communities and industry clusters promoting BIM practice can be cultivated in developing countries. [9]

Walasek D. et al. (2017) have identified and addressed the various barriers impeding implementation. The Return on Investment analysis in this study showed that design fees is most likely increase for companies working with BIM. As per this study the owner should be encouraged to implement it. The study has observed that when project owners understand the benefits of BIM-based facility management they will ensure that BIM is implemented to its fullest potential from the earliest phases of the project. [10]

Vass S. et al. (2017) have suggested that the IT business value model is useful for understanding the interactions between the public client and the actors in the Swedish AEC industry and for understanding the challenges that arise when a large public client implements an IT-supported change process. They have studied the middle and long-term effects of implementations of IT-supported change processes by public clients. They have also studied combining procurement strategies and BIM development for the development of construction project management theory and practice. [11]

Haron N. et al. (2017) have highlighted the barriers because of which Malaysia lagging behind in BIM implementation. The study has focused on cost factor which appears as major obstacle and need to overcome to BIM implementation. The governmental agencies and private developers need to play bigger roles to uphold the role of BIM technology in Malaysia. [12]

Ahuja R. et al. (2017) in their study have examined several existing functions of BIM to develop fifteen BIM capabilities which are responsible for success of the project. The ISM model obtained and the findings have elaborated in detail in this study.

BIM solutions make sustainable design practices easier by enabling architects and engineers to more accurately visualize, simulate, and analyze building performance earlier in the design process. Implementing energy analysis and material take-off tools, more efficient and predictable structural designs can be achieved with a focus on waste and embodied energy minimization. This paper has bought out the logical and conclusive hierarchical relationship for the BIM capabilities. The implication of these findings includes better deployment of BIM for AEC industry in India. [13]

Le N. et al. (2018) in their research have identified key mediating forces that influence the current state of BIM implementation in Vietnamese AEC industry. The research found that BIM team works as a tool (change agent) facilitating BIM implementation but there is a contradiction between BIM team's roles and organizational structure. Proper model can be prepared for organizing BIM team in the existing system's operation [14]

S. Arunkumar et al. (2018) in their research gave a list of major positive and negative factors influencing the implementation of BIM. The results showed that there are lots of benefits in implementing BIM. The results also show that there are a lot of barriers quoted by professionals which prevent them in implementing BIM. To overcome these barriers, the senior management can provide necessary support and encourage the employees to overcome their fear factor and train them successfully. The cost of procurement and cost of training are quoted as major barriers but the savings in cost by proper implementation of BIM can be more compared to the initial investment cost. [15]

Sardroud J. et al. (2018) have introduced five fundamental issues including managerial, cultural, financial, legal, and security in this paper. Many problems can be resolved over time by providing more real world examples. Project stakeholders can invest on BIM with low risk. The support and guidance of governments and use of BIM in specific projects can increase the speed of BIM implementation. Implementation of secure software is also required. [16]

Olawumi T. et al. (2018) in this study investigated the barriers and challenges faced by the industry in its attempt for full implementation of BIM and sustainability practices at the design stage of the construction project. The Delphi technique and other statistical tools such as Kendall's coefficient of concordance, inter-rater agreement (IRA), Spearman's rho correlation; and Mann-Whitney analysis among others were used for the analysis of data. The study also highlighted the current level of BIM and sustainability practices in the construction industry as well as the challenges faced its full implementation in the industry. The findings of the study have contributed and strengthened the existing knowledge base in cross-field BIM and sustainability research by providing stakeholders in the built environment- the key issues hindering the full implementation of BIM and sustainability practices in a construction project. The overall findings of this study contributed to and enhance the goal of sustainable smart city initiative. [17]

Ahuja R. et al. (2020) have quoted the drivers and barriers to BIM adoption and categorized using the TOE framework. Providing guidelines to adopt BIM, suggesting some standardization in the process of implementation, spreading awareness, clarifying the BIM-related processes and increasing top management support can bring about clarity among clients and among the stakeholders on their respective responsibilities in a BIM-integrated work-structure. The greater incentives of green ratings can promote BIM. A national BIM education and research agenda can ensure the creation of a well-defined organizational BIM framework. Further studies and leanings from mature BIM markets can also help Indian AEC industry to develop BIM implementation strategies. [18]

Liao L. et al. (2019) in this study have interpreted full BIM implementation in the Singapore construction industry from an organizational change perspective. The findings from this study were well interpreted in the Singapore context, which may differ from the context of other countries. Nevertheless, the theoretical and practical implications drawn from this study are not limited to the building projects in Singapore. The identification of the non-value adding activities and inefficiencies would be valuable for evaluating the change performance in these case projects, which in turn would purposely and efficiently guide the project teams to change towards full BIM implementation. [19]

Noor B. et al. (2018) this study provides valuable information for both researchers and practitioners in the field of BIM research. The state of the research field and hot topics on BIM research were identified for researchers. In addition, this study will allow practitioners to obtain the key findings to enhance their BIM implementation and develop better BIM products. The meta-analysis system can also be used to visualize the research trend in other topics. [20]

Ademci E. et al. (2018) have suggested for canalizing the investments towards software, equipment and training, as in countries such as the US, the UK, Singapore Finland, and France in order to overcome the BIM adoption issues. Also, preparation of the legal infrastructure to establish relevant BIM organizations and mandatory use of BIM must be considered, which is of great importance for sector professionals and policy makers in terms of developing and deciding accurate strategies on the way to the full adoption of BIM for each region and organization. [21]

Özorhon B. et al. (2019) through the case study have identified the key drivers for BIM which has the potential to reveal the real-world challenges and benefits for the construction companies that are at the beginning stages of BIM implementation. Research findings revealed that 80% of the driving factors are project-level factors and companies have various expectations from BIM. This research showed that these expectations can be fulfilled with proper BIM implementation strategies and carefully devised transformation tasks. [22]

Georgiadou M. (2019) presented an assessment of the scope, value and practical implications of BIM implementation. As per this study, BIM embraces whole lifecycle asset management, thus promoting efficiency and productivity, speed of delivery, and increased profitability by reducing errors, rework and overall waste in construction. BIM effectiveness in residential developments

is still in a transitional period, where challenges, such as higher CAPEX in software and training and lack of expertise need to be addressed. There is also lack of client demand and/or projects being too small to require BIM. The paper revealed that government support for the introduction of innovative processes in design and construction is essential so that BIM benefits are realized. Legislation is still the key driver for a change in industry mind-sets towards BIM with direct implications for those responsible for setting regulatory requirements and voluntary standards. Resistance to BIM adoption around the world has generally revolved around a failure to be convinced of the business case, as the projected returns have not outweighed the costs and risks involved. This study suggested the need of identifying the right balance between regulatory and voluntary tools for a range of building typologies and project sizes. [23]

Jamal K. et al. (2019) in their research identified the current level of awareness according to the stages of building project, whereby the findings showed that the construction stage had the most consistency of low awareness level as compared to other project stages. Several driving factors were also determined by the respondents to improve the use of BIM in the industry. This study provided further insight and findings regarding the adoption of BIM, which serves as a critical reference point for local architects to assess the changes and effects that are crucial in determining the progress of BIM in Malaysia. [24]

Jamal K. et al. (2019) in their study focused on the factors that hinders the adoption of BIM and identified as (1) Lack of skilled and experienced workforce, (2) Steep learning curve for especially for those who are unfamiliar with BIM and (3) High cost to obtain and operate the technology. They recommended that continuous supports from the organization's external as well as internal environment are significant to increase the pace of BIM implementation in the Malaysian architecture industry. [25]

Ma X. et al. (2020) summarized BIM implementation strategies from the international research community; ranked their criticality in AEC projects based on the empirical assessments from the Chinese practitioners; and compared the findings with the Nigerian, Singaporean, and Turkish cases. [26]

Suresh S. et al. (2019) presented a detailed study on the Building Information Model in practice on a Smart Motorway Project. The two most important findings in the research were that the contractor should enforce a communication framework within the organization to ensure the use of the right BIM processes to communicate between disciplines. Secondly BIM competencies between the different disciplines should be similar and although training is being provided, more awareness on BIM would enable the organization to raise interest on the BIM level 2 standards and processes. [27]

Hatmoko J. et al. (2019) in their study provided valuable understanding on BIM adoption and implementation in Indonesia construction industry, and explores barriers and opportunities for future which at the moment otherwise may not be available. It is recommended for further research to look at potentials of BIM adoption particularly for medium and small class contractors and consultants. [28]

Elhendawi A. et al. (2019) in their research proposed a model for BIM implementation in KSA to pave the way to facilitate using BIM, which in turn, increases the chances for creative and innovative solutions to the AEC industry issues, increases the quality, profitability and improves projects' performance and efficiency. The key findings of this research are: exploring the main driving forces and the main external pressures pushing the implementation of BIM in the KSA AEC industry, identifying the main internal pushes, and proposed a methodology for BIM implementation in KSA AEC industry. This study observed that failure to adopt the change to BIM would result in loss of competitive advantage and accordingly fewer chances to win new projects. Applying the suggested methodology could help to ensure the success of the BIM implementation, which in turn could improve the AEC industry performance and effectiveness, solve the project's issues, adapt creativity and innovation and create unexpected positive future for the AEC industry. [29]

Bui N. et al. (2019) in their paper described how the bSN community developed open BIM through different institutional actions. The bSN case study highlights the importance of the leadership as well as the motivation of members to contribute their resources for technology development. This paper addressed the research question by providing an understanding of how a construction community advances BIM technology. [30]

Likita A. et al. (2019) revealed some key challenges in BIM and Lean construction implementation towards a more sustainable and productive construction sector. Barriers such as traditional practices, client related issues, technological performance, knowledge and awareness, lack of lifecycle consideration, readiness, resistance to change, cost of implementation, lack of infrastructure, alignment issue, standard and regulation problems, uneven risk sharing, lack of government incentives and etc. were identified. However with studying these barriers at a macro level it was clear that the barriers can occur at different layers of project, organization and industry. Therefore, adequate attention is needed for BIM, Lean construction and sustainable principles implementation, through appropriate strategies observed accordingly at each layer. [31]

Eadie R. et al. (2020) suggested that long learning curves and lack of skilled personnel could be overcome with this improved education and training. The difference in the ranking of the barriers to BIM for highways Level 2 and 3 proves that Government Pressure is really impactful in getting the benefits of BIM implemented. If clients are not fully aware of the benefits of BIM, then they are less likely to adopt it on a scheme. They have analyzed the drivers and barriers to BIM for the UK highways sector and suggests ways of overcoming the barriers to BIM through two key areas; training and continued government pressure. The success of government pressure in the past can be used as a template for other countries implementation of BIM. [32]

Babatunde S. et al. (2020) in their study identified 23 drivers to BIM adoptions in AEC firms. The top six total ranked drivers to BIM adoptions include desire for innovation to remain competitive; time savings; improving communication to operatives; accurate construction sequencing and clash detection; streamlining design activities and improving design quality; and client/

competitive pressure. The study found that government pressure is one of the primary drivers to BIM adoption in Nigeria. Therefore, this study further recommends massive awareness of BIM by professional bodies, government agencies and non-governmental organizations. Similarly, appropriate government policies that support BIM adoption should be in place in developing countries. [33]

Sinoh S. et al. (2020) revealed the importance of building effective networks of communication among team members of an AEC firm for successful BIM implementation at the firm level. On the other hand, building networks of communication between the different firms involved in a building project may aid in BIM diffusion at the industry level. Future research could explore the drafting of such a curriculum. Thus, future research may explore how to harmonize the dynamics of firm-to-firm interaction in the context of BIM implementation. [34]

Villena F. et al. (2020) studied the innovative capacity of the companies by using BIM. To carry out this study at the project level, the types of innovation boosted by phases of the project life cycle (design, construction and operation) have been distinguished. During the design phase, it is possible to promote social-environmental innovation and technological innovation. During the construction phase, it is possible to promote organizational innovation and process-product innovation. Finally, during the operation phase, using BIM for the facility management activities affects the organizational-process-product innovation for the update of inventory and proper functioning of the asset in service. In summary, this paper intends to give a holistic vision of encouraging innovation using BIM in the construction industry. Professionals are offered a new vision to establish novel ways of doing things to improve their daily work. This study aims helping project managers propose appropriate strategies to implement innovation using BIM in construction projects whether vertical or horizontal. [35]

Doan D. et al. (2020) examined the perspectives of the key construction practitioners towards BIM adoption in the New Zealand construction industry. BIM definition, understanding, benefits, challenges/barriers, solutions for BIM adoption, along with mandating BIM in New Zealand were critically analyzed to provide a full picture of the existing situation of BIM adoption. The findings indicated that the government inputs into BIM implementation could be a significant solution to the SMEs, contractors, and those who do not have much experience in BIM adoption. This research is the first stage of a larger project examining the relationship between BIM adoption and Green Star certification uptake in New Zealand. It is clear from the results that sustainability improvement is one of the potential benefits of BIM adoption in New Zealand. [36]

Durdyev S. et al. (2021) this study aimed at investigating the key drivers for and barriers to the adoption of BIM in the Cambodian construction industry. Implementation of the study findings could support greater uptake of the technology and the leveraging of its key benefits to improving project success and the growth of the Cambodian construction industry, as well as those of other developing economies that share similar socio-cultural, economic, and regulatory environments. [37]

Pidgeon A. et al. (2021) shown that although there are clear opportunities for the benefits to be achieved via the adoption of BIM across the entire lifecycle of a project, there is a gap between the theory and realized benefits at the application stage by industry. Finally, an assurance feedback loop is added to the framework to further ensure that the objectives, the impacts and the outputs are sufficiently clear and proportionate. Further, KPI's development is proposed with a review of staff suitability (skills and qualifications) to improve BIM adoption and gain benefits measured both qualitatively and quantitatively. [38]

Belay S. et al. (2021) outlined the potential benefits and associated barriers of BIM adoption in projects from the international research community; and ranked their criticality based on different empirical techniques in the Ethiopian public construction sector. The findings of this study, for the first time provide empirical evidences of the potential benefits and barriers of BIM adoption in the context of the Ethiopian public construction sector. This paper also provides practical insights and key recommendations to tackle the aforementioned barriers and enhance the current BIM uptake in public infrastructure projects. Further studies can be explored on BIM case studies and comparative evaluation of BIM strategies with regard to organizational basis and types of projects. [39]

Van N. et al. (2021) have studied a total of 39 factors influencing BIM adoption in construction project implementation. This study contributes to the topic of factors affecting BIM adoption in construction projects. The majority of researches in this area so far were conducted based on perceptions of BIM users only. It is recommended that future directions should consider awareness of construction project stakeholders to identify and assess the importance levels of factors influencing BIM adoption in the construction industry. It is essential for further studies into the determinant factors in the implementation of different types of construction projects and respondents remain of central interest. [40].

III. CONCLUSIONS

This paper has presented a critical review of building information modeling (BIM) in construction industry with respect to adoption, challenges and benefits. The paper outlines the general status of BIM adoption through literature review which uncovers the specific benefits, challenges and risks to BIM implementation. The role of different stakeholders is found very important in implementation of BIM in construction industry. The paper concludes that implementation of BIM on projects is a successful solution to overcome these challenges. Despite being adopted globally, BIM capabilities need attention in terms of their effectiveness and hierarchy of implementation in order to overcome the challenges of overall construction project cost overrun and time delays. This paper explores the overview the status of BIM in construction industry with respect to adoption, challenges and benefits by considering maximum countries studies in the world. This paper has focused on the recent studies in between 2015 to 2022.

Abbreviations and Acronyms

BIM = Building Information Modeling
ECS = Engineering Consulting Services

AEC = Architecture, Engineering and Construction

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