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An Analysis of Different Aspects in Implementation of Building Information Modeling (BIM)

Shashank Saurabh[1], Kumari Nirmala[2]

[1]*Assistant Professor, Department of Civil Engineering, Motihari College of Engineering, Motihari*
[2] *Design Engineer,Civil Section, MECON Limited, Ranchi*

***Abstract*—Building Information Modeling (BIM) has garnered significant attention in recent years due to its potential to revolutionize the construction industry. This paper presents a comprehensive study of existing research on the implementation of BIM, examining various aspects explored by different scholars and practitioners, and also delves into the organizational, technical, and regulatory hurdles faced during BIM implementation. By reviewing key literature, the paper aims to identify the primary benefits, challenges, and methodologies associated with BIM adoption in the architecture, engineering, and construction (AEC) sectors. The study provides a holistic understanding of the factors influencing successful BIM integration, offering insights that can guide future research and practical applications in the field.**

***Keywords*— BIM implementation, project collaboration, design precision, optimization, time management, technological barriers, organizational challenges, sustainable construction, BIM adoption strategies.**

I. Introduction

Building Information Modelling (BIM) has emerged as one of the most transformative technologies in the architecture, engineering, and construction (AEC) industries. It provides a comprehensive digital representation of a building's physical and functional characteristics, enabling enhanced collaboration and coordination across all stages of a building's lifecycle. However, BIM's roots trace back several decades, with its conceptual evolution being shaped by advancements in technology and the growing complexity of construction projects.

The concept of BIM, although not named as such, was first introduced in the 1970s. At that time, the construction industry was beginning to explore computer-aided design (CAD) technologies, which primarily focused on digitizing architectural blueprints. While CAD greatly improved the efficiency and accuracy of design, it did not address the need for a more integrated approach that could link the design with construction processes and building management. This gap led to the exploration of "building models" in the mid-1980s, which formed the basis for the development of BIM.

One of the earliest academic references to building models was made by Simon Ruffle in 1985 [2], and his work was later published in 1986. Ruffle's exploration of how digital models could transform traditional construction practices laid the foundation for future innovations. Around the same time, Robert Aish [3], an expert in construction software, was developing the RUCAPS (Really Universal Computer Aided Production System) software at GMW Computers Ltd. RUCAPS was among the first software systems to introduce the idea of using 3D models for project management and design coordination, notably applied in large-scale projects like London's Heathrow Airport. The success of RUCAPS demonstrated the potential for digital models to improve the efficiency of complex construction projects by integrating design, planning, and execution into a unified platform.

Despite these early developments, the formal term "Building Information Model" did not appear until 1992, when G.A. van Nederveen and F.P. Tolman [4] introduced it in their paper. This milestone shifted the understanding of BIM from simply being a digital design tool to a comprehensive framework for managing the entire lifecycle of a building. Since then, BIM has grown to be a vital tool in the architecture, engineering, and construction (AEC) industries, transforming how projects are designed, executed, and managed. At its core, BIM integrates all phases of a building's lifecycle—from conception to demolition—into a digital representation, offering a shared knowledge resource for all stakeholders involved. This holistic approach enhances decision-making, reduces errors, and improves collaboration, making BIM a cornerstone of modern construction practices.

Like other industries, the construction sector benefits immensely from Information and Communication Technology (ICT) solutions that improve project delivery. ICT applications, including BIM, are increasingly seen as essential for enhancing the effectiveness and productivity of construction projects [5]. BIM, in particular, offers numerous advantages, such as improved scheduling, better design processes, and more efficient facility management. For project stakeholders—including owners, designers, contractors, and management teams—BIM enables greater collaboration, visualization, and control over the construction process, fostering better decision-making and coordination across teams [6]. As a result, BIM technology has received significant attention from both researchers and practitioners as a means to streamline construction workflows and address many of the industry's persistent challenges.

However, the implementation of BIM faces several obstacles, especially in developing countries. In these regions, the construction industry is often characterized by labour-intensive methods, limited technological innovation, and significant knowledge gaps. Wells [7] reported that construction output per person in low-income countries is only about one-ninth of that in high-income nations. Additionally, construction in these regions tends to be material-intensive, and projects are frequently delayed, suffer from poor working conditions, low quality, and high accident rates. These issues highlight the need for more efficient practices, which BIM and other ICT solutions could help address.

In this context, the adoption of BIM in developing countries holds great potential to improve the efficiency of construction projects. BIM can optimize the use of resources, improve working conditions, and enhance overall project quality. Furthermore, as construction is a key driver of economic growth in many developing regions, more efficient practices supported by ICT and BIM could play a significant role in national development goals [8-9]. For these reasons, increasing the use of ICT, including BIM, is seen as a promising avenue to tackle the challenges faced by construction industries in these regions.

The benefits of BIM are increasingly recognized, but its implementation in developing countries remains underexplored. While BIM holds promise for addressing the challenges faced by construction sectors in these regions, such as inefficiencies and safety issues, the adoption of this technology is still limited. This paper aims to assess the current state of BIM implementation and identify areas where further research is needed to accelerate adoption. By answering these questions, researchers and practitioners can gain insights into how BIM can be leveraged to drive the development of construction industries in these regions, ultimately contributing to national growth and development goals.

II. Literature Survey

Building Information Modelling (BIM) has evolved significantly over the years, and many researchers have delved into its multifaceted applications, advantages, and obstacles across various contexts. This review offers a detailed, chronological overview of the major developments in recent years, focusing on the adoption of BIM in different regions and sectors, its integration with project management techniques, and its potential to drive improvements in sustainability and efficiency in the construction industry. By highlighting the key studies, this review also brings forward the ongoing challenges that BIM faces, such as training, standardization, and the reluctance of stakeholders to adopt new practices.

BIM: Now and Beyond

Azhar, Khalfan, and Maqsood's 2012 study provides a pioneering review of BIM, spotlighting its transformative potential for the construction industry [6]. Their research indicates that BIM was seen as a tool capable of enhancing collaboration, accuracy, and overall risk management in construction projects. However, while BIM was gaining popularity in 2012, widespread implementation was hindered by several obstacles, including insufficient technological infrastructure, the lack of universal standards, and a degree of resistance from industry stakeholders. These barriers were not insurmountable, but they slowed down the adoption process. The authors suggested that if BIM could be fully integrated into the industry's processes, it would significantly enhance the efficiency and quality of project delivery across the entire lifecycle of construction projects, from design to completion. This study laid the foundation for much of the future research into BIM and its role in transforming the way the construction industry operates.

BIM Implementation Throughout the UK Construction Lifecycle

In their 2013 study, Eadie et al. explored how BIM had been adopted throughout the construction lifecycle in the UK, with a particular emphasis on the impact of government mandates [10]. One such mandate, introduced in 2016, required the use of BIM on all public sector projects, serving as a major driver of BIM adoption. Their analysis revealed that the use of BIM significantly improved the management of different project stages, including design, construction management, and even post-construction phases, such as maintenance. However, the study also highlighted several challenges associated with BIM integration, such as the need for ongoing training, the development of standardized practices, and the resistance encountered from industry professionals who were more comfortable with traditional methods. These barriers were seen as slowing down BIM's full integration into the UK construction industry. To address this, the authors argued that continuous training and strong institutional support were necessary for realizing BIM's full potential, particularly as more sectors and professionals became engaged with the technology.

Career Advancement of Civil Engineers Through BIM

In 2014, Udhayakumar and Karthikeyan delved into the growing importance of BIM proficiency for civil engineers seeking to advance their careers [11]. As BIM gained traction across the construction industry, engineers who were skilled in using BIM were increasingly better positioned for leadership roles in both design and project management. The authors argued that as BIM became a central tool in construction, engineers who mastered it would find greater career opportunities and an edge in competitive job markets. However, the study noted a significant gap in educational programs, as many civil engineering courses were not incorporating sufficient BIM training into their curricula. This gap left many graduates underprepared for the demands of a BIM-driven industry, creating a disconnect between the skills required in the workforce and those being taught in universities. The authors called for a revamp of academic programs to ensure that new engineers entering the field are well-versed in BIM, thus aligning education with the evolving needs of the industry.

BIM and Project Management: A Stakeholders' Perspective

Travaglini et al. (2014) approached BIM from the perspective of various project management stakeholders, examining how its adoption affected different roles within the construction process [12]. Their research underscored the diverse ways in which architects, engineers, and contractors interacted with BIM, with each group having distinct expectations and requirements. For instance, architects might use BIM primarily to improve design accuracy and visualization, while engineers might focus more on the integration of technical details and structural elements. Contractors, on the other hand, often viewed BIM as a tool for enhancing construction planning and execution. This variation in expectations sometimes led to communication challenges and mismatched goals during project implementation. The authors emphasized that strong leadership from project managers was crucial to ensure that all stakeholders were aligned in their use of BIM. They also suggested that targeted training and clearer communication could help bridge the gap between different stakeholder expectations, ultimately leading to more cohesive and efficient BIM adoption across projects.

Applications of Bridge Information Modelling

In 2014, Marzouk, Hisham, and Al-Gahtani expanded the application of BIM principles to bridge construction, coining the term Bridge Information Modelling (BrIM) [13]. Their study focused on how BrIM could be used to improve collaboration, design, and lifecycle management in bridge construction projects. The authors demonstrated that BrIM allowed for enhanced communication among stakeholders, reducing the likelihood of design errors and construction delays. Moreover, BrIM provided more accurate and detailed models for the complex structural and material requirements of bridges, which differ significantly from the needs of traditional building construction. However, the study also acknowledged several challenges unique to BrIM. The structural complexities of bridges required specialized software and workflows, distinct from those typically used in standard BIM applications for buildings. Despite these challenges, the authors argued that BrIM held great potential for improving the efficiency and quality of bridge projects, particularly in terms of reducing errors and improving long-term maintenance.

BIM-enabled Life-cycle Information Management

Xu, Ma, and Ding (2014) explored how BIM could be leveraged for lifecycle information management, which involves managing a project's data across its entire lifespan—from initial design through to long-term operation and maintenance [14]. Their research highlighted that one of BIM's most significant advantages is its ability to integrate and store data from all phases of a project in a centralized, accessible format. This integration enables better decision-making throughout the lifecycle of a project, reducing operational costs and improving efficiency. The authors proposed a framework for utilizing BIM's capabilities in lifecycle management, which included ensuring that data is continuously updated and made available to all relevant stakeholders at each stage of the project. By doing so, facility managers and other stakeholders could use BIM to streamline maintenance operations, monitor building performance, and make informed decisions about renovations or upgrades, thus enhancing the long-term success of a project.

A Comparative Review of BIM in Building and Infrastructure

Shou and colleagues (2015) provided a comprehensive comparison of BIM implementation in both building and infrastructure sectors [15]. Their study found that while BIM had been more widely adopted in the building construction sector, its use in infrastructure projects, such as highways, bridges, and railways, lagged behind. The authors attributed this discrepancy to several factors, including the increased complexity and scale of infrastructure projects, which often require more sophisticated and specialized BIM tools. Furthermore, infrastructure projects tend to generate vast amounts of data, which requires advanced data management systems to handle efficiently. Shou et al. argued that the infrastructure sector could benefit from developing more tailored BIM tools to meet its unique needs, as well as investing in improved data management systems to handle the large volumes of information that these projects produce. By doing so, they suggested, BIM could become just as transformative in infrastructure as it has been in building construction.

Assessing Embodied Energy and Greenhouse Gas Emissions Using BIM

Krantz et al. (2015) explored the role of BIM in assessing the environmental impacts of construction projects, particularly focusing on embodied energy and greenhouse gas emissions [16]. Embodied energy refers to the total energy consumed in the production and construction processes of a building, while greenhouse gas emissions are a key contributor to climate change. The authors demonstrated that BIM's ability to provide detailed data on materials and processes could be used to perform accurate assessments of these environmental factors. By integrating this data into project planning, stakeholders could make more informed decisions about material selection, energy use, and sustainability practices, ultimately minimizing the environmental footprint of their projects. The study also highlighted BIM's potential to support the construction industry's shift towards greener, more sustainable practices by enabling better lifecycle assessments and optimizing energy usage throughout the construction process.

The Issues and Considerations Associated with BIM Integration

Bataw, Kirkham, and Lou (2016) identified and analyzed the various challenges associated with integrating BIM into construction workflows [17]. These challenges spanned technical, organizational, and managerial domains. On the technical side, the lack of standardized protocols was a significant barrier to successful BIM adoption. Without universally accepted standards, companies often struggled to implement BIM consistently across different projects. Organizational challenges included steep learning curves for many stakeholders, as BIM requires a deep understanding of both the software and the workflows associated with it. Additionally, resistance from traditional industry stakeholders, who were often hesitant to adopt new technologies, slowed down BIM integration. The authors suggested that creating industry-wide standards, coupled with structured training programs, could help address these challenges. Furthermore, they emphasized the need for BIM to be better aligned with existing project management methodologies, as this would facilitate a smoother transition to BIM-based workflows and make it easier for organizations to adopt the technology on a broader scale.

BIM-Based Energy-Saving Design

In their 2016 study, Xia and Ma explored the potential of BIM to optimize building designs for energy efficiency, emphasizing how the technology could be leveraged to support sustainability goals [18]. They demonstrated that BIM offers advanced simulation capabilities that allow architects and engineers to assess a building's energy consumption during the design phase. By creating detailed models of different building configurations, stakeholders can evaluate how factors such as building orientation, material selection, and insulation impact overall energy performance.

The study highlighted that BIM's ability to analyze energy use in real-time makes it a powerful tool for reducing operational energy consumption. For example, designers can simulate how various environmental factors—like sunlight exposure, wind patterns, or seasonal temperature changes—affect energy needs, enabling them to optimize building designs accordingly. Xia and Ma's research underscored BIM's role in advancing green building practices, particularly in urban settings where energy efficiency is becoming increasingly critical. The authors concluded that as the construction industry continues to prioritize sustainability, BIM's potential to deliver energy-saving solutions would become a key driver of its adoption in architectural and engineering projects.

A Project Management Framework for Enhanced Productivity Using BIM

Liao, Teo, and Low (2017) proposed a project management framework that integrates BIM to improve productivity in construction projects [19]. Their research showed that the traditional project management processes could benefit significantly from BIM's ability to streamline communication, enhance scheduling accuracy, and reduce errors. One of the key advantages of BIM, as noted in their study, is its capability to facilitate real-time collaboration among stakeholders, including architects, engineers, contractors, and clients. This improved collaboration helps to reduce misunderstandings and conflicts, leading to smoother project execution.

The authors also emphasized that BIM's ability to visualize project timelines and workflows in three dimensions made it easier to identify potential bottlenecks and inefficiencies early in the project. By integrating BIM into project management protocols, construction firms could improve both their short-term productivity and long-term project outcomes. However, the study acknowledged that integrating BIM with existing project management tools required a well-structured framework and training for project managers. The authors suggested that organizations would need to invest in training and education to maximize BIM's potential, particularly for managers tasked with overseeing complex construction projects. Overall, the study demonstrated that the integration of BIM into project management practices could yield substantial productivity gains by reducing delays, improving coordination, and minimizing rework.

BIM in Hydropower Engineering

Zhang et al. (2017) explored the application of BIM in the context of hydropower engineering projects, where the technology has shown promise as a collaboration platform [20]. The authors demonstrated that BIM can be used to manage Engineering, Procurement, and Construction (EPC) processes in large-scale infrastructure projects, such as hydropower plants. These projects are typically complex, involving a wide range of stakeholders who must work together to deliver the project on time and within budget. BIM’s ability to centralize information and facilitate collaboration across these different groups makes it an invaluable tool for managing hydropower projects.

Their research revealed that BIM could improve coordination between stakeholders by providing a shared, visual model of the entire project, helping teams identify potential issues before they arise. In hydropower projects, where precision and coordination are critical, BIM's ability to reduce errors and streamline workflows was particularly advantageous. Moreover, the authors highlighted that BIM could be used to optimize resource allocation, enhance safety protocols, and ensure that construction milestones were met more efficiently. Overall, Zhang et al. concluded that BIM had the potential to significantly enhance project outcomes in the hydropower sector, reducing risks and improving overall project efficiency.

Stakeholder Competency in Evaluating Environmental Impacts Using BIM

Murphy and Nahod (2017) investigated how BIM could be used to evaluate the environmental impacts of large-scale infrastructure projects, emphasizing the importance of stakeholder competency in utilizing BIM for sustainability assessments [21]. Their study underscored BIM’s ability to provide detailed data on materials, energy consumption, and emissions, which allows project teams to make more informed decisions regarding a project's environmental footprint. By leveraging BIM’s comprehensive data integration, stakeholders could assess the environmental impacts of construction activities in real-time, adjusting materials and processes to minimize energy use and reduce greenhouse gas emissions.

The authors highlighted that while BIM offered the technical capability to perform these evaluations, the successful use of BIM for environmental assessments depended heavily on stakeholder competency. Engineers, architects, and project managers all needed to be proficient in interpreting and applying the data generated by BIM to optimize project sustainability. To this end, the study called for more robust training programs that focus specifically on environmental sustainability within BIM platforms. Murphy and Nahod concluded that improving stakeholder competency in using BIM for environmental assessments would be essential for promoting greener construction practices and ensuring that the industry moves towards more sustainable, low-impact project outcomes.

III. Challenges & Gape Analysis

While the body of research on Building Information Modelling (BIM) has expanded significantly in recent years, several gaps remain in the literature that require further exploration. The key areas where current research is either insufficient, lacks depth, or presents opportunities for further investigation are discussed in this section.

Lack of Standardization and Global Best Practices

Current research highlights the challenges associated with the lack of standardization in BIM adoption, particularly across different regions and industries. Although there is recognition of the need for consistent protocols and guidelines, little has been done to develop a universal framework that can be applied globally. The absence of such a framework limits interoperability between systems and creates inefficiencies in cross-border collaborations. Future research should focus on establishing international standards and best practices that ensure seamless integration and communication across different platforms, industries, and regions.

Insufficient Focus on Training and Education

While the importance of training and education in BIM is often discussed, there is a noticeable gap in empirical research that evaluates the effectiveness of current training programs. Many civil engineering and construction management programs still do not adequately prepare professionals for the advanced use of BIM tools. Additionally, the literature lacks detailed studies on the competencies needed for different roles within BIM-enabled projects, particularly for engineers and project managers. Research should be directed toward developing more comprehensive educational frameworks that integrate BIM training into professional and academic curriculums, ensuring that the future workforce is equipped to meet industry demands.

Limited Exploration of BIM in Infrastructure Projects

While BIM has been widely adopted in building construction, its application in infrastructure projects—such as highways, railways, and large-scale utilities—lags behind. Research on how BIM can be tailored to meet the specific challenges of large-scale infrastructure projects is limited. Infrastructure projects often involve more complex coordination and longer lifecycles compared to buildings, requiring specialized tools and approaches. There is a need for more in-depth studies that explore how BIM can be adapted for these types of projects, addressing unique issues such as large-scale data management, stakeholder coordination, and technical complexities.

Inadequate Integration with Sustainability Goals

Research has explored the potential for BIM to support sustainability efforts by evaluating energy consumption and environmental impacts, but much of this remains theoretical. There is a lack of comprehensive case studies that measure the long-term environmental benefits of BIM-enabled projects. Furthermore, while BIM's capabilities in green building practices are recognized, few studies focus on the regulatory or policy frameworks necessary to promote widespread adoption for sustainability purposes. Future research could explore how BIM can be better integrated with sustainability regulations and incentives, providing clearer guidelines for implementing environmentally responsible practices in both building and infrastructure projects.

Regional Disparities in BIM Adoption

BIM adoption rates vary significantly between regions, with some countries demonstrating rapid progress, while others lag due to cultural, economic, or regulatory barriers. While research acknowledges these disparities, there is limited exploration of the socio-economic factors driving or hindering BIM adoption in different contexts. Studies often focus on specific regions without drawing broader conclusions that can inform global BIM implementation strategies. More comparative studies are needed to understand how regional policies, economic conditions, and industry practices impact BIM adoption and how less advanced regions can catch up.

Limited Understanding of Stakeholder Dynamics in BIM Projects

Although the collaborative nature of BIM is well-documented, research has not sufficiently explored the human dynamics involved in BIM-enabled projects. Most studies focus on technical aspects, such as software and data management, rather than on how stakeholders interact, communicate, or resolve conflicts within a BIM framework. Given the importance of coordination among architects, engineers, contractors, and other stakeholders, more research is needed on the social and managerial aspects of BIM adoption. Understanding how these dynamics influence project outcomes could lead to more effective collaboration and stakeholder engagement strategies in BIM projects.

Insufficient Focus on Lifecycle Management and Facility Operation

While BIM is recognized for its benefits during the design and construction phases, there is less emphasis on its application in the operation and maintenance stages of a project. Research on how BIM can be used for long-term facility management and cost optimization is limited. Most studies focus on the early stages of project development, overlooking how BIM can support asset management, operation efficiency, and sustainability in the later phases. Future research should investigate how BIM can be integrated with emerging technologies such as IoT and AI to enhance facility management and ensure long-term operational success.

IV. Conclusion

In conclusion, the evolving landscape of Building Information Modelling (BIM) presents both opportunities and challenges that warrant further investigation. While significant advancements have been made in understanding BIM's applications and benefits, critical gaps remain that hinder its full integration and utilization across the construction industry. Areas such as standardization, training, and education require more focused research to develop comprehensive frameworks that can guide practitioners in effectively implementing BIM. Moreover, the specific challenges associated with infrastructure projects, regional disparities in adoption, and the integration of sustainability goals into BIM practices highlight the complexity of the current landscape. Addressing these gaps is essential for promoting more effective collaboration among stakeholders and enhancing the overall efficiency and sustainability of construction projects. Future research should aim to bridge these gaps by exploring innovative strategies and technologies that leverage BIM's full potential, ultimately leading to improved project outcomes and a more sustainable built environment.

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