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Potential, Obstacles, and Proposed Solutions in Building Information Modelling

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ABSTRACT

The revolutionary new tool known as Building Information Modelling (BIM) gives civil engineers a centralized digital way to handle all of their design, construction, and facilities management responsibilities. Thoroughly examining the function and influence of BIM in civil engineering is the primary aim of this study. Presented in this research are the advantages, disadvantages, and future prospects of building information modeling (BIM). Findings from prior research on BIM implementation—including cross-sectional, qualitative, and quantitative studies—and methods for resolving these challenges are emphasized in this paper. In addition, it offers a means of acknowledging and elucidating the concrete impacts of the BIM application on construction industry collaboration, financial management, and work progress. To identify real-world situations that could be associated with building information modeling (BIM) project management, we look at the findings of important studies and research.

Keywords: Building Information Modeling Civil Engineering Challenges

1. INTRODUCTION

The advent of Building Information Modelling (BIM) represents a watershed moment in civil engineering. Building information modeling (BIM) is a process that involves creating virtual 3D objects of building projects and components. This allows for a thorough examination of the construction during the planning phase and gives detailed digital models of the projects [1]. In order to aid in decision-making during the facility's lifetime, this representation incorporates not only the geometric or dimensional features and combinations, but also the physical and functional interactions between these elements [2]. The term "building information modeling" (BIM) refers to a method that integrates the many steps involved in creating and maintaining physical structures, such as homes and public buildings [3]. Building information modeling (BIM) incorporates the steps of creating, acquiring, maintaining, sharing, and applying transferable, use-and-shareable data on buildings and structures [4].

When it comes to civil engineering, building information modeling (BIM) is crucial for representing complex systems including traffic flow, water supply lines, and the behavior of buildings. In other words, it's a collection of procedures and resources that may be used to plan how to utilize technology to organize, create, share, and update building design and project information at any point in the building's lifetime. With its increasing growth across the board in terms of software and stakeholders, building information modeling (BIM) has gradually supplanted traditional computer-aided design (CAD) approaches [5]. The inherent benefits of building information modeling (BIM) in areas such as scientific judgment, visualizing accomplishments, etc., process digitalization, information integration, and business cooperation facilitation have driven its use to civil engineering construction [6].

Students' knowledge of building materials, design processes, design creation, and construction technology may be improved by the incorporation of building information modeling (BIM) into civil engineering curricula (Ma & Tao, 2023). Incorporating building information modeling (BIM) into civil engineering courses helps students learn the ins and outs of the sector and develop the skills employers want [7]. In order to improve the overall sustainability and efficiency of civil engineering projects, BIM is known to impact construction practice by using technologies such as the Internet of Things (IoT) and Radio-frequency identification (RFID) [8]. Building information modeling (BIM) in conjunction with virtual reality (VR) systems also provides interactive, first-person views of a building's energy efficiency and other architectural features. Improving the structural

performance, durability, and protection of built projects are some of the benefits of using high-performance concrete materials, which have been designed with the use of building information modeling (BIM) [9].

Civil engineers have used building information modeling (BIM) for seismic engineering to improve building stiffness and safety via better seismic design during construction [10]. It can also detect abnormalities and faults in civil engineering structures, therefore it's useful for assessing the buildings' structural health. As a result, building information modeling (BIM) combined with three-dimensional laser scanning enhances both the creation of finite element models (FEMs) and the three-dimensional evaluation of the condition of concrete structures (Shirtmaker), leading to more accurate and timely structural inspections [11]. Building Information Modelling (BIM) is a technological revolution that gives civil engineers a central digital way to manage their design, construction, and facilities management tasks. It has largely replaced traditional software applications in these areas. Civil engineers' efficiency, efficacy, and professionalism have been substantially enhanced by their incorporation into learning programs, building methods, and structural failure diagnostics. Civil engineering education and practice will likely be greatly influenced by building information modeling (BIM) as the discipline develops further.
This paper aims to thoroughly examine the function and influence of Building Information Modeling (BIM) in civil engineering, drawing attention to its merits, shortcomings, and potential future developments. This study aims to trace the development of building information modeling (BIM), starting with its early applications and continuing up to the present day, when it is widely used and accompanied by cutting-edge technology. Project management, workflow, cost control, and cooperation are some of the concrete outcomes of building information modeling (BIM) application that this research seeks to recognize and explore. This study will review previous quantitative, qualitative, and cross-sectional research on building information modeling (BIM) implementation in an effort to identify the most pressing implementation obstacles and provide solutions. In this study, we want to answer the following research questions: (1) What changes have taken place so far in the use of BIM in the civil engineering and construction industry? Using building information modeling (BIM) technology in building projects offers a number of benefits and drawbacks. Thirdly, how does building information modeling (BIM) influence project management and output? (4) Question 4 of BIM civil engineering New technologies that are essential to BIM's operation? (5) What are some ways to better or overcome the obstacles associated with using BIM in the building industry?

2. LITERATURE REVIEW

BIM has indeed transformed the construction business through an efficient new approach, which aims at improving the management of new construction projects while at the same time addressing tasks of updating a large amount of data during the building’s life cycle [12]. This approach, introduced by Autodesk in 2002, has significantly impacted the way building design, engineering, and construction management are carried out [13]. BIM enables the creation of a digital model of the physical execution of a facility and functional aspects and captures them in the database resulting in a boardwalk of BIM processes during the project implementation.

The evolution of BIM has been notable, with its introduction dating back to the 1970s, although widespread awareness of its potential benefits has only recently gained traction [14]. Lately, the implementation of building information modeling has emerged as a norm in the architectural, engineering, and construction (AEC) business as it provides work solutions to the problems experienced during construction [15]. BIM has assisted in the way of eliminating challenges that have impacted the construction sector for many decades; chiefly, ineffective management of construction projects and no information exchange [16].

A survey on the most recent practices of civil engineering in relation to BIM shows that there is a general adoption of the tool or technology in several constructions globally. For instance, Malaysia has committed itself to the Advanced BIM to mostly building construction projects since it plays a profound role in streamlining the management of projects. [17]. In regions like Pakistan and Saudi Arabia, Subsequently, BIM has been acclaimed for its appreciable advantages in the aspects of VDC practices, offering benefits while also highlighting existing barriers to its full implementation [18], [19]. The Malaysian government is especially active in encouraging BIM adoption for its potential to increase productivity and hit KPIs in construction tasks [17].

It has also come to be clear that BIM has tremendous value in the construction industry, which comes with several advantages. The first and foremost benefit pertains to the better organization of project information. BIM enhances the

communication between the clients and designers, since it involves both the design and detailed modeling, thereby eliminating many of the design problems that are likely to occur at one point or the other during the undertaking of a project[20]. Moreover, the use of BIM helps to establish collaboration with other stakeholders during the early stages of operations, good design, the use of 3D, modeling, assessment of clashes, and enhancement of design and implementation standards [21]. This technology also aids the regularity of lean construction principles and thus improves the positive outlook for project teams and the optimality of the system workflow [22]. Moreover, BIM has been advanced to have impacted the control of the performance of the project and the management of the performance of projects and assets besides enhancing the efficiency of processes in project deliveries [23]. This has been evidenced by the technology squarely placing the concept of design and construction in a more manageable and open realm [24]. Therefore, by helping to facilitate designs to be visually delivered to the owner and construction team and permitting identification of clashes while providing quantified measures, BIM is found to improve project outcomes, reduce costs, and increase the quality of construction [25]. Based on the case studies and experiences it can be noted that the management and the specific application of BIM software in project planning have wonder ability to enhance some aspects of project control, reduction of cost, management risk, and the general developing process [26].

BIM implementation has revolutionized how civil engineering and construction projects are handled by providing end-to-end solutions to most of the challenges encountered in projects. Therefore, the advance of BIM, its current application in the civil engineering field, and the gains of modern construction projects evidence that BIM is a revolutionary technology in improving project productivity, coordination, and execution. As BIM continues to be adopted globally, its impact on the construction sector is expected to grow, leading to further advancements in project delivery and management practices.

However, there are limitations and challenges that might slow the adoption of BIM in civil engineering. procedural one of the primary issues is the limited interoperability and standardization in BIM because of the special features and requirements of the civil engineering activity [27]. In this aspect, there is no consistency in the level of BIM implementation, which hinders the effective integration of the tool within various projects as well as across organizations to foster smooth information exchange and integration.

Another challenge in BIM implementation in civil engineering is the resistance to change and the necessity for a cultural shift within organizations to adopt BIM practices. Some organizational issues, risks, and complexities such as, several firms experience organizational issues, higher risks concerning the use of BIM, and higher challenges in creating building information models; These challenges deter most firms from adopting BIM [28]. Additionally, the challenges in creating BIM models and the lack of predictable knowledge on preventive maintenance of civil engineering structures add to the difficulty of applying BIM in practice [29].

Moreover, one of the key challenges that are associated with the application of BIM is the fact that the initial costs that are associated with the concept are relatively high; for most of the SMEs that operate in the AEC sector, this makes BIM implementation very difficult [30]. Some of the barriers are associated with the financial cost of developing and training employees, including the costs to purchase the BIM software, and facilitating a change from conventional methods of practice to BIM techniques can act as a hindrance to many organizations, particularly those operating with meager resources, this financial barrier can impede the widespread adoption of BIM in civil engineering projects.

The BIM has also been a topic of extensive research, and several studies conducted in the civil engineering areas have presented several advantages of its implementation [31]. Applying BIM as part of the project execution planning has been identified as a positive contribution to the improvement of problem-solving skills among civil engineering and construction management students. Furthermore, the application of BIM in infrastructure projects has been shown to improve project lifecycle management and decision-making processes [32].

An understanding of BIM has also been applied to case studies, where benefits have been highlighted in terms of enhancing construction management in civil engineering projects [33]. Additionally, the application of building component data in formwork planning of BIM influences the design construction processes and the assessment of design solutions, making civil engineering practical engineering approximately for design and construction services by the display of BIM [34].

Furthermore, the combination of BIM with geospatial surveillance technologies has enriched both the quantitative and qualitative calculation models employed in civil engineering, especially concerning stress analysis for structures and systems loaded with specific loads. This integration has enhanced the advancement of understanding structures mainly in engineering and has enabled sound construction management of civil engineering projects [35]. Furthermore, optimized highway alignment applications using BIM and other techniques prove the effectiveness of applying the methods in civil engineering.

In conclusion, while BIM offers numerous advantages in civil engineering, its implementation is not without challenges. These include standardization, interoperability, talk of change, high initial costs, and organizational culture change. However, resorting to case studies and the findings of outstanding studies, it is possible to conclude that the advantages of BIM in civil engineering, including the effective management of occupational risks, individual project life cycle, and construction activities' efficiency, outweigh the challenges mentioned above, efficiency, and sustainability in construction projects.

2.1 Maintaining the Integrity of the Specifications

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3. METHODOLOGY

This study also emphasizes the use of qualitative research since it is appropriate to get a broad perspective and accumulate adequate information that will define BIM in civil engineering. Qualitative research is selected because it can help explore various phenomena and issues within the contexts in which these phenomena exist, providing nuanced insights into BIM implementation and its impact on civil engineering practices.

In as much as collecting data for this research, the primary method that shall be used is research review and synthesis that includes academic journals, cases, and papers from conferences and other related publications. Secondary data source: Journal articles The targeted academic journals will be used to secure editorial Bodily research articles that present factual and reliable information on the impact of BIM technology, management, and implementation in civil engineering. The selection criteria for journals will prioritize high-quality, peer-reviewed articles to ensure the reliability and validity of the findings. Furthermore, several case studies will be reviewed for the purpose of identifying real-world scenarios that may relate to BIM project management. The selection criteria of these case studies will include its relevance, the coverage where the case study is elaborated, and everything innovative, informative, encouraging, and/or problematic that has been observed about the application of BIM, its best practices, problems, and its impact. Other literature sources will be added to the materials published in the CIB journals and case studies since conference papers will provide more recent views and innovations in the development of BIM technology and its application.

Since the study adopts a qualitative research approach, and an extensive literature review mechanism coupled with a thematic analysis, this study strives to proffer a sound framework for understanding the intricacies of BIM and its implications for civil engineering practices.

4. FINDINGS AND DISCUSSION

Some of the common trends and patterns that have been discovered in research literature in the field of BIM in civil engineering include the following. These are the current practices of BIM, the changes it has made to project management, the roles of technology in the practical application of BIM, the costs of implementing BEM, and the skills and training required for BIM.

The use of BIM in civil engineering has expanded greatly due to its visualization of construction projects in a digital format, enabling civil engineers and architects to work efficiently throughout the design and build of projects. Several organizations such as in Malaysia have embarked on affording efforts on BIM adoption in construction projects because of the overall potential of enhancing project productivity and results. However, constraints like the absence of a standard platform for its implementation, resistance to alteration, and high investment, act as barriers for organizations to depend on smart infrastructure.

BIM has brought great change to project management since it has helped to enhance the techniques that are usually applied in managing projects and the overall performance of such projects with high efficiency. It improves interconnectivity with other stakeholders reduces the occurrence of mistakes and misunderstandings and corrects design representation and idealization. BIM allows for the early involvement of stakeholders and alignment with a lean construction work environment meaning that project teams develop high confidence in their work and improve the general workflow.

The integral technological advancements of BIM include i) the Internet of Things (IoT), ii) Radio-Frequency Identification (RFID), and iii) Virtual Reality (VR) interfaces. These technologies increase sustainability, performance optimization, and the ability to understand energy performance features and attributes of a building. Furthermore, 3D laser scanning and Finite Element Method (FEM) models are used in previous studies that highlighted that structural analysis and health assessment will have better accuracy and lesser chance of structure failure.

While the implementation of BIM requires investments in training and organizations it is equally apparent that the costs of implementing this technology are offset by its longer-term benefits of improved outcomes, cost savings, and project quality. BIM promotes enhanced understanding, cost management, risk minimization, and management of resources to deliver successful projects, thereby offering chemical returns on investments.

The use and application of BIM are a specialized area that demands skills and practices in application and management. BIM-integrated teaching and learning initiations are meant to build up student's skills and knowledge as demanded by the

market. Training employees in BIM practices is crucial for overcoming resistance to change and ensuring successful adoption.

The implementation of BIM leads to increase an in interaction and integration between all the members of the project due to an improved graphic model as well as exchanging information. It achieves all these by decentralising the project delivery and establishing roles, responsibilities, and authorities that are coordinated to lessen the probability of disputes between the various stakeholders.

5. COMPARISON WITH PREVIOUS RESEARCH

Prior studies have also revealed the role of BIM in changing civil engineering projects with other benefits in management, project delegation, and project flow of projects [15], [17]. The case studies also identify how BIM operates to enhance various aspects of safety management on Civil Engineering Projects, in aspects such as solving problems and making decisions [31], [32].

6. PRACTICAL IMPLICATIONS OF FINDINGS

The solutions call for more attention to issues that are contingent on the implementation of BIM such as standardization of implementation, change management, and the general high fixed costs that are normally associated with it. The above barriers are, however, tasks that can be undone to facilitate the application of BIM in improving performance, innovation, and sustainability in construction projects.

TABLE I. COMPARATIVE ANALYSIS OF BIM LITERATURE

Theme	[17]	[13]	[14]	[15]	[18]
Adoption and Utilization	Increasing adoption in construction	Enhanced project management	Trends in the AEC industry	Recognized potential benefits	Proactive promotion by the Malaysian govt.
Benefits	Improved project efficiency	Enhanced communication	Integrated project delivery	Optimized efficiency and waste reduction	Better outcomes in project management
Challenges	Interoperability and standardization issues	Initial high costs	Resistance to change	Cultural shifts needed in organizations	Financial and technological constraints
Technological Advancements	Integration with advanced technologies	Digital twins and IoT	Augmented Reality (AR) and Virtual Reality (VR)	AI and Machine Learning (ML) integration	Cloud-based BIM solutions
Future Directions	Strategic training and incremental adoption	Policy and regulatory support	Research on AI integration with BIM	Sustainability and green building practices	Open standards and interoperability

7. PROPOSED SOLUTIONS AND STRATEGIES

The use of BIM in civil engineering cannot be fully executed without the multiple strategies implemented in this case. To understand BIM tools and practices, special attention needs to be given and this is why training and education measures must be taken to minimize the impacts of such difficulties. Conductive training for professionals can make everyone knowledgeable and skilled at their respective stations when another structured training program in accordance with the hierarchy of the organization is followed. Another issue is that continual professional development should be encouraged.

Another probable scenario may also be associated with its gradual implementation also. The concept is to rollout BIM tools and related working models at a gradual level depending on the environment of the applying organisation and its capacity to apply this strategy after this scale of pilot BIM projects. It enables identification of matters that may occur and adjustments to processes during mass transitions to reduce risks thus making it easier. As for the change management aspect, it is also much wiser to build BIM adoption on the progression of WIPs and functions at the organizational level to target these factors.

They should make funds available through grants, subsidies, and subsidies for BIM technologies and training for organizations, lighten the existing burden for organizations for its implementations. It can be an encouragement for organizations that may have some reservations about venturing into new technologies. However, it is crucial to develop policies and procedures regarding the implementation of BIM in construction and eliminate the issue of interoperability in order to form a solid model of implementation.

In conclusion, as there are many problems with the introduction of BIM in civil engineering it can be stated that these problems can be solved by having a proper training program, step-by-step introduction of BIM, and appropriate policies. Therefore, the goal of unlocking the potential of BIM is to do away with technological, cultural, and financial obstructions still preventing BIM from reaching its full potential and contributing toward improving project outcomes and collaboration.

8. FUTURE DIRECTIONS IN BIM

The future of Building Information Modeling (BIM) involves BIM maturity with Artificial Intelligence (AI), Machine Learning (ML), and Internet of Things (IoT) capabilities for improved analysis, BC automation, and near real-time information acquisition.

The adoption of applications such as Augmented Reality (AR) and Virtual Reality (VR) further transforms how stakeholders engage with BIM through immersive virtual tours and training. BIM solutions address the issue of communication by improving access to the model and the ability of team members from different locations to simultaneously edit or update the model.

Additionally, there is a synergy between BIM and sustainability practices; energy-efficient designs and ways to LEED/BREEAM certification are possible. This is because, through embracing the lifecycle approach, the practice of Building Information Modeling emphasizes sustainable management of resources across the building's or infrastructure's lifecycle.

9. POTENTIAL DEVELOPMENTS IN TECHNOLOGY AND PRACTICE

The construction majors mostly adopt proprietary BIM software and tools, and interoperability between various software will increase in the future due to growing support for open standards like Industry Foundation Classes (IFC). This will also lead to the evolution of interfaces where data will be shared and combined between different systems and agents without gaps. Robotics and automation such as drones, booms, and cranes in construction along with integration of BIM models will help in increasing precision and reducing labor costs and risks. The planned apparatus can carry out recurrent and very risky operations, thus maximizing work productivity and shortening the timeframe of a project.

10. FUTURE RESEARCH AREAS

Research on the integration of AI with BIM to develop intelligent systems that can automate complex design processes, predict project outcomes, and enhance decision-making capabilities. Take a closer look at how the concept of applying artificial intelligence in enhancing BIM's predictive measures in relation to resource utilization. Exploring the implications of using BIM specifically to encourage green construction, such as inventions in energy conserving methods, decrease of waste disposal, and proper use of resources. Further discussing the potential opportunities and challenges of implementing BIM toward enhancing CE through the efficient reuse and recycling of construction materials. Looking into the specific uses of BIM systems especially the application of augmented and virtual reality between the human users and the systems. Recognizing how those technologies affect communication, building information modeling, and engaging the stakeholders in construction projects. Exploring the BIM literature with respect to its use in mega-infrastructure projects in infrastructure systems and structures like transportation; bridges and utilities.

In conclusion, the trends of BIM as a concept in civil engineering are analyzed based on the definition of BIM from its evolution and development in related technologies: advanced technologies, cloud-based solutions, and sustainability practices. Future advancements in such areas will be accomplished through sustained investments in research and development, with the end goal of improving project performance and redesigning the construction industry.

11. CONCLUSION

In the field of civil engineering, Building Information Modeling (BIM) has recently evolved as a game-changing technology that has improved efficiency, teamwork, and project management. Due to its comprehensive digital models, which may enhance communication, accuracy, and overall project performance, it has grown in popularity over the years on construction sites throughout the globe. Cost and risk management as well as enhanced cooperation are advantages despite obstacles like standard incompatibilities and the initial investment in building information modeling (BIM).

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