BUILDING INFORMATION MODELING: A COMPREHENSIVE OVERVIEW OF CONCEPTS AND APPLICATIONS

ABSTRACT

With the advances in new technologies, there has been an increasing interest in the application of Building Information Modelling (BIM). BIM is a process that involves creating and managing digital representations of physical and functional characteristics of a building or infrastructure. Understanding the concept of BIM involves recognizing it as a digital approach to designing, constructing, and managing buildings and infrastructure. This paper presents a comprehensive overview of BIM, exploring its fundamental concepts, evolution, and diverse applications. It begins with an examination of the core concept underlying what actually is BIM, including its data-centric approach and collaborative framework. The review then delves into the various applications of BIM across different stages of a building project, from conceptual design to construction and facility management. Understanding the concept of BIM involves grasping its fundamental principles, components and how it revolutionizes the AEC industry. By synthesizing current research and industry practices, this review aims to provide a holistic understanding of BIM's role in advancing modern construction practices and its potential for future development.

Keywords: BIM, digital model, construction management, decision-making

1. INTRODUCTION

With the advances in new technologies, there has been an increasing interest in the application of Building Information Modelling (BIM). BIM is a process that involves creating and managing digital representations of physical and functional characteristics of a building or infrastructure. BIM is increasingly becoming a predominant technology as it progressively involves more individuals in the AEC industry. It entails utilizing 3D virtual models of buildings to gather and manage building data from project inception through construction to building operation. Employing BIM initiates with creating a detailed 3D digital model of the building, representing a more sophisticated use of computer technology in designing, constructing, and operating building projects [1]. Unlike traditional methods of producing and sharing information through drawings, BIM generates a complete digital representation and functional description of a constructed facility. It preserves and disseminates all data using detailed digital models known as building information models. BIM stands for gathering of every piece of information of a construction project at one platform that too in a digital format thus building first the structure in the virtual world. This information can be assessed by anyone interested for any purpose e.g. to explore and evaluate the different design aspects or to optimize the use of space etc. The BIM technology has been demonstrated through the following figure 1. It is used to automatically calculate accurate quantity take-offs, identify clash detection, project sequencing, etc. Investigating BIM's potential as a tool for preserving local cultural values could help address challenges related to inadequate heritage conservation and inconsistent historical documentation management [2].

The specific impacts of BIM on work processes remain unclear, although most industry professionals agree that BIM comprises information-rich 3D models. Throughout all disciplines and stages of a building's lifecycle, project participants transfer information using BIM. BIM is viewed not as the end goal itself, but as a tool to help achieve project objectives [3].

In other words, it is a process supported by numerous tools and technologies for standardized organization of construction works. Working in a collaborative environment refers to BIM. BIM involves collaboration among all stakeholders and is facilitated by a cohesive digital framework. This framework includes a centrally coordinated model accessible to project team members for contributing or accessing information at any time. The aim of this study is to achieve a comprehensive understanding of BIM, encompassing its purpose, key uses, and its role in enhancing collaboration among stakeholders.

Fig. Error! No text of specified style in document. **Building Information Modelling**

1.1 What is BIM Actually

Even after many years since the inception of BIM, the industry struggles to define BIM with a single, definitive definition. This challenge persists because the significance of BIM evolves and varies depending on the specific project or purpose for which it is employed. There are also diverse opinions on how BIM should be implemented in the design, construction, and maintenance of buildings [4].

BIM means different things to different professionals. Some perceive BIM as a type of software, to others it is a platform for gathering information and effective multi-disciplinary collaboration. Some say it is a revolutionary approach allowing digital information management and providing accurate information at the right time [5-6].

Despite a number of definitions and descriptions about BIM, it is widely acknowledged that it is a combination of technology and process. The technology part in BIM is used to create an accurate virtual model of the facility to help project stakeholders to simulate construction processes in the real world while the process part helps to integrate the role of all participants to improve collaboration. Collaboration is the fundamental aim of the BIM process. According to "US National Building Information Model Standard (NBIMS) Project Committee" BIM has been defined as:

"Building Information Modeling (BIM) is a digital representation of physical and functional characteristics of a facility. A BIM is a shared knowledge resource for information about a facility forming a reliable basis for decisions during its life-cycle; defined as existing from earliest conception to demolition."[7].

There are various acronyms associated with this concept. The fundamental idea is to consolidate building infrastructure and construction information in one central location, enabling its use by team members across different project stages. Today, BIM is an area of significant interest, offering transformative solutions to challenges in the AEC industry. It represents a modern digital approach to creating and managing 3D building models during development, providing professionals with new insights and tools to efficiently plan, design, construct, and manage buildings and infrastructure. According to [8], BIM is recognized as one of the most promising advancements in the AEC industries, offering digitally accurate virtual models.

1.2 BIM Model

The result of the BIM process is the building information model, often referred to as the BIM model. This integrated entity comprises information from multiple disciplines including architecture, structural engineering, electrical systems, construction management, and others, providing a comprehensive view of the entire building. This model can be used not only for planning, design, construction of a building but also for smooth operation and maintenance throughout the life cycle of the facility. BIM Model attracts information shared by various persons associated in the construction project and is updated by them from time to time at various stages of the project [9]. It is a systematic approach to generate, store, exchange and disseminate building-related information throughout the various stages of the construction project. BIM is not a single model, rather a collection of several different models and databases linked together. Every stakeholder is the owner for his/her model and discipline, who is responsible to make changes or can provide the control to make any alterations. Advanced modeling tools enable the project stakeholders to visualize and simulate the structure to predict the behavior, performance and appearance of the building before the actual construction starts.

2. FUNCTIONS OF BIM

BIM models are digital files that contain semantic information about building components, facilitating decision-making in construction projects through exchange and collaboration. Through object oriented concept of model, BIM is able to hold semantics about a building in a digital format including things like location, dimensions and properties of building components. People working across various locations, using different tools, and at different times can collaborate to achieve a shared outcome. It also permits enhanced analysis of state of affairs through simulation. BIM is not software or tool to buy; rather it is a process for visualization of building components in the early design process. When utilized effectively, BIM can save time, reduce costs, and streamline the construction process. It consolidates all building component information into a single accessible location, enabling anyone involved in the project to utilize it for various purposes (Figure 2). The data stored in BIM supports diverse applications such as generating structural models, estimating quantities, scheduling in 4D, conducting energy analyses, and simulating building performance. The construction industry is beginning to realize the advantages of BIM, with architects, designers, project managers, and contractors using it to enhance their workflows. Numerous case studies demonstrate that BIM can minimize rework [6] and enhance cost predictability. Changes made in the model automatically propagate throughout the project, reducing coordination errors. In other words BIM offers the opportunity to accomplish long sought goals of industry to minimize cost overruns, better time management, enhance productivity and quality and reduce project delays. As such it can be referred as a repository for shared information about a construction project to help the design team for making reliable decisions during all the stages of the project [10]. Hence, BIM is an idea for a progression of procedures that facilitate the procedure and practice of virtual design and development through the entire life cycle of a project. The appropriate use of BIM can lead the engineers to a revolutionary road in the construction industry.

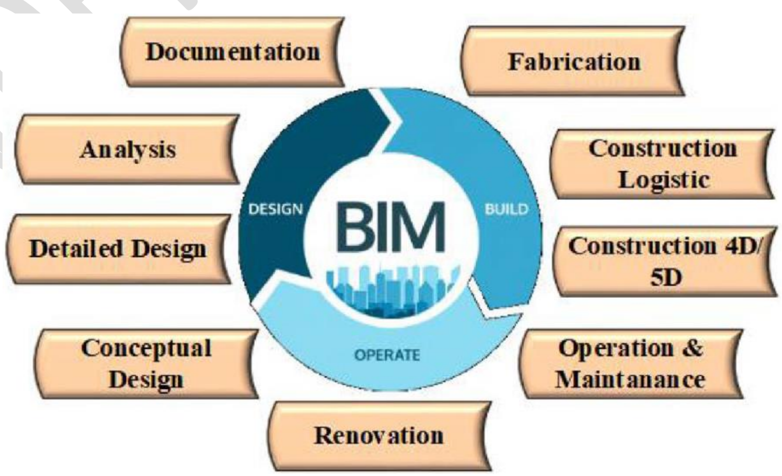

Fig. 2 Functions of BIM

2.1 PURPOSE OF BIM

Generally people are familiar with the use of software for creating 3D models of construction facilities, for energy assessment, cost estimation and for many more applications. However many fail to realize the main purpose of BIM. It is not actually understood by many that implementation of BIM in any project does not require any change in design criteria or standards, rather it is an advanced technology intended to restructure the approach professionals and processes handle the project. Purpose of BIM is bringing all the construction project professionals on a common platform [11]. Data management is incorporated considering the entire extent of modern potential BIM usage, from the initial design to the end of a building's lifecycle. During occupancy, assist the owners'/facility managers in charge of maintenance and operations with greater insight offering the owners an as-built model. For a variety of functional areas like construction, life-cycle management and design tools in BIM software packages have been created given the complexities involved with stakeholder and project requirements. Many firms, instead of attempting a total BIM deployment, identify specific areas on their specific requirements and strategic goals; they wish to concentrate their efforts. Different phases of activity sequences and construction work, facilitating the study and the most accurate project time scheduling is provided by BIM. The project's agreed completion time is secured by this method [12]. To complete the project, this helps the contractor develop the proper financial plan that BIM's capacity to provide automatic quantity take-off and cost estimation ensures predictable project implementation costs throughout the design stage.

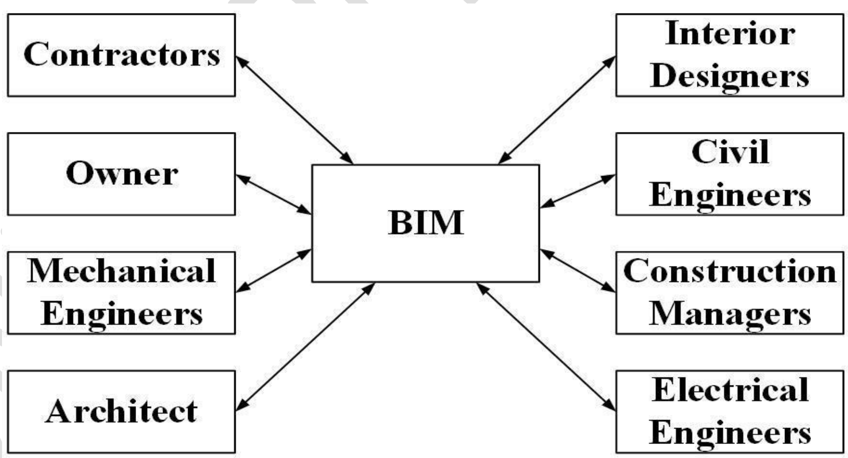

Fig. 3 Different Purposes of BIM

Access to all the needed information about every stage of the project to different professionals and stakeholders is provided through a common platform (Figure 3). They can navigate through 3D BIM models to experiment and optimize certain design ideas. Any change by a professional would be communicated to all the participants. A large amount of investment, knowledge for use and experience has been required for an organization with any BIM function adopted based on this fact the examination is provided. To focus on some BIM tasks than others, some general contractors may be more prone to strategic BIM implementation. It's not an add-on technique and for the sake of it, it's not about making a 3D model. Uncertainty characterized the construction projects as complex from start to end and it is a unique process. These should be transferred, shared, managed, minimized, and accepted. However, they should not be disregarded because risk and uncertainty are inescapable in such projects. Risk management and its concept aren't new. In industry and construction projects, risk management is feasible through BIM according to various researches [13].

Improved information use should be the focus of measures to reduce reworks, which refers to BIM deployment [14]. Even though the BIM adoption trend in the business appears to be on the rise, prospective adopters should be mindful of potential obstacles (particularly among larger enterprises). Intensive software training needs, significant upfront expenditures and a lack of assistance from executives who favour more traditional ways are all barriers to BIM deployment and utilisation of the most advanced BIM technologies. Some businesses are wary of risking a return on investment that is low or negative for maximum effectiveness; significant (monetary and temporal) resources must be invested in an in-house BIM deployment. In the project, another barrier to BIM implementation is software interoperability amongst involved agencies. A universal file format is lacking for the several programs developed to facilitate BIM. In the same programme they have invested, with models produced by another party or those currently in use, one stakeholder's software may be ineffective.

3. PRINCIPLES OF BIM

Construction professionals can benefit from BIM in both theories and practice with an understanding of the ideas underpinning allowing them to have client and colleagues discussions that are well-informed, addressing the fundamentals of BIM, its contemporary application in practice and how things might change in the future. BIM is utilized for exchanging, creating and collating shared structured and intelligent information and data across a project. To understand the principles behind it and how work methods will need to adjust to accommodate it as its use develops, more construction professionals will be needed. The heart of BIM is well-structured data, which will enable massive efficiency in the construction industry, that across the entire project team and standardised, there is a full collaboration. To aid in the comprehension of BIM is the intention of Practice and the Principle of BIM.

- ❖ Emphasizes the data and model interoperability and relevance of integrated practice and collaboration.
- ❖ To understanding the aims and objectives of the BIM, provide the project team with a road map, its rules, and how it may be gathering, provides the information that a typical Protocol Document might include

- ❖ The legal problems that surround the deployment of BIM on a project are thoroughly examined.

Throughout the building's life cycle, BIM models can be thought of as a repository of information that has been generated and managed, as well as the quality of that information and high quantity were characterized. The construction, operation, better design and maintenance a certain building are facilitated through easy access to information [15]. To track the deterioration and damage to these structures to plan maintenance and/or restoration efforts, there is now an urgent need. The existing buildings are attracting growing interest and are managed by the BIM methodology [16]. When it comes to the planning of repair and remodelling projects, this method is crucial in the digital transfer of information about the properties of such structures.

4 BIM CLASSIFICATION

Building Information Modeling (BIM) is a multifaceted approach to building design, construction and management. Its classification can vary depending on the perspective and context in which it is used. BIM can be classified in multiple ways: as software tools used for modeling and documentation, as a platform that supports data integration and collaboration and as a methodology that enhances multidisciplinary teamwork. Each classification highlights different aspects of BIM’s role in modern architecture, engineering and construction practices.

1) BIM as Software

BIM Software refers to the specific tools used to create, manage, and analyze BIM models. These tools are specialized for different disciplines within the construction industry and support various aspects of the BIM process.

Architectural BIM Software: Focuses on the design and documentation of building architecture.

-Examples: Autodesk Revit, ArchiCAD, Vectorworks Architect.

-Structural BIM Software: Specializes in the structural design and analysis of buildings. Examples: Tekla Structures, Bentley STAAD.Pro, RAM Structural System.

MEP BIM Software: Used for modeling and analyzing mechanical, electrical, and plumbing systems. Examples: Autodesk Revit MEP, Trimble SysQue, IES VE.

-Integrated BIM Platforms: Offer solutions that integrate various disciplines and aspects of the project lifecycle. Examples: Bentley OpenBuildings Designer, Allplan, Autodesk BIM 360.

2) BIM as a Platform

BIM Platforms are comprehensive solutions that provide a collaborative environment for managing and sharing BIM models across different project stages and disciplines. These platforms facilitate integration, coordination and data management throughout the project lifecycle. This includes:

Data Integration and Management: BIM platforms often provide a centralized hub where data from various disciplines can be integrated. For example, Autodesk BIM 360 is a cloud-based platform that allows for collaboration across different project stages and disciplines, offering tools for project management, coordination, and real-time updates.

Interoperability: Platforms facilitate interoperability between different BIM software tools, ensuring that data can be shared and used across different applications. This is crucial for collaborative work where different teams might use different software but need to work with a common data set.

Collaboration Tools: Modern BIM platforms include collaboration tools that allow for seamless communication and data sharing among team members. Examples include Trimble Connect and BIMcollab, which provide cloud-based collaboration environments to manage model exchanges, issues, and changes.

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3) BIM for Effective Multidisciplinary Collaboration

Effective Multidisciplinary Collaboration highlights BIM's role in integrating various disciplines (architecture, structural engineering, MEP) to work together seamlessly. This approach leverages BIM to enhance project coordination, reduce errors and improve overall efficiency. This classification emphasizes the collaborative nature of BIM rather than the tools themselves:

Integrated Project Delivery (IPD): BIM supports IPD by facilitating a shared vision and common data environment (Azhar, 2011, Succar, 2009, Bryde *et al*., 2013) where all stakeholders—architects, engineers, contractors, and owners—can work together from the earliest stages of design through to construction and facility management.

Clash Detection and Resolution: BIM models allow for the early detection of clashes between different systems (e.g., structural elements interfering with mechanical systems). Tools like Navisworks are used for clash detection, which helps resolve issues before they become costly problems on site.

Enhanced Communication: BIM models provide a clear, visual representation of a project, which helps in communicating design intent and construction processes to all team members and stakeholders, leading to better understanding and fewer misunderstandings (Liu *et al*., 2017).

Examples of Multidisciplinary Collaboration

One World Trade Center: The design and construction of this iconic skyscraper involved extensive use of BIM for coordinating various disciplines, including architecture, structural engineering, and MEP systems. The use of BIM helped to integrate different components and resolve conflicts effectively (Lewis and Holt, 2011).

The Edge, Amsterdam: Known for its advanced use of BIM, this office building utilized BIM for not only design and construction but also for managing building operations and sustainability. The collaboration between various disciplines was facilitated through the BIM process, leading to a highly efficient and innovative building (Jalia *et al.* 2019).

4. NEEDS AND KEY BIM USES

Throughout the phases of design, construction, and operations, BIM is employed for data creation and management. Figure 4 illustrates the BIM process, outlining how planning, designing, building and operating are integral components. BIM integrates multidisciplinary data to generate detailed digital representations that can be continuously updated on an accessible cloud platform. From the beginning of built environments design and creation, saving money and time while also ensuring that the completed growth meets everyone's expectations, BIM is an increasingly crucial tool for architects, allowing collaboration with clients, collaborators and other stakeholders. The outputs are all consistent because they all come from the same model, which is the benefit of BIM. If a door is shown in 3D view then the same will be reflected in the plan.

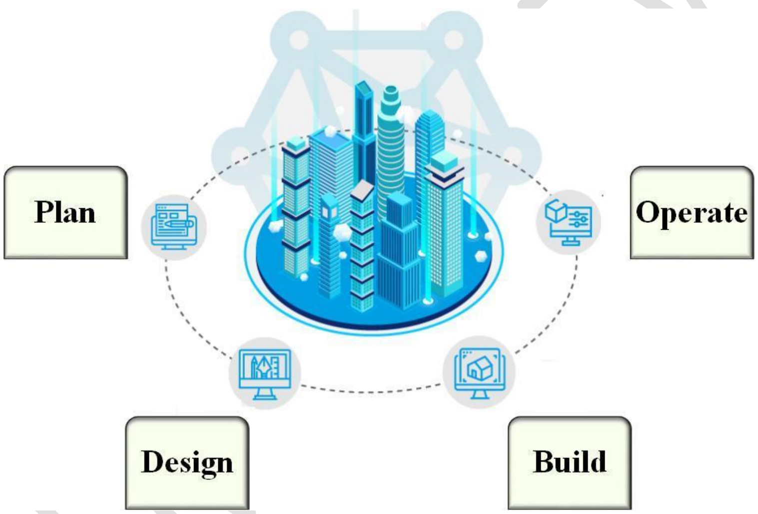

Fig. 4 Process of BIM

Until recently before the advent of BIM, for every single change made, it needs to check manually and update each drawing which is a laborious and error prone task [17]. Now the output is more reliable and error free as all output is generated from the same BIM model. At an earlier stage, design developed in detail, results in higher-quality design.

BIM encompasses the quantification, geometry, spatial, geographic information, properties, and lighting of building components. BIM spans the entire building lifecycle, encompassing construction processes and facility operation. Design models serve as the basis for contractors to develop construction models, providing detailed information on assembly techniques and construction methods. These models simulate and analyze construction schedules and generate quantity data for cost estimation purposes. The benefits of operating within a BIM environment are evident from design through maintenance phases of the project lifecycle. The BIM methodology aims to integrate processes and engage engineering practitioners through the use of structured and intelligent 3D virtual models on collaborative platforms [18].

Across all project participants, BIM makes it significantly simpler to coordinate a design. To create the finished building, most projects involve working together and many different organisations. From the same set of BIM models, everyone is working, to work together, BIM makes it much easier. The world's population will reach 9.7 billion people by 2050 according to the UN [19]. To meet global demand for smarter and more resilient spaces, the global AEC sector is increasingly turning to more efficient methods of design and construction. With BIM, design and construction teams not only operate more efficiently but also capture valuable data to benefit operations and maintenance tasks throughout the process. This is the reason across the world, the BIM mandates are increasing.

During the development of design, it is considerably easier to add 3D views and VR for building users [20]. The maintenance team can check that all the maintainable equipment is easily accessible and for interactive signage, the commercialisation team might take a virtual round of the model to reach an agreement. Ultimately, as clients' systems become increasingly digital, critical data from the BIM design can seamlessly integrate into the client's operational systems. This integration enables clients to derive enhanced value from BIM data throughout the building's entire life cycle. Other countries worldwide closely following BIM Level 2 are at the heart of the UK government. Through information exchange requirements, product requirements are encountered by BIM use. The way to use BIM efficiently and in this manner the projects are carried out is changed and that should refrain from altering the project. To specify which project data needs to be shared, the level of detail is inextricably tied to the concept of BIM use.

To fulfil some particular goals, BIM use is a means of implementing BIM over the lifecycle of a facility. Through information interchange, BIM is frequently characterised in terms of meeting product needs. The level of depth of the information idea to explain which project information must be transmitted is the notion of BIM use. A new definition of detail information level is utilized to describe BIM uses by the most effective strategy to achieve criteria by [21]. The appropriate amount of information detail is established, employing the idea of real abstraction, it must first assess the needs that must be met using BIM. In deconstruction, BIM uses changed practices and vice versa [22].

5. CONCLUSIONS

BIM is transforming the way buildings and infrastructure are designed, constructed and managed by leveraging digital technologies to improve efficiency, collaboration and decision-making across the entire lifecycle of a project. In essence, BIM transforms traditional building design and construction processes by leveraging digital technologies to create a comprehensive and coordinated approach to building project management and lifecycle maintenance. It enhances efficiency, reduces costs and improves the quality and sustainability of buildings and the overall quality of building projects from conception to operation. BIM addresses diverse needs in the AEC industry by providing a comprehensive digital approach to building design, construction and management. Its key uses span across all stages of a project lifecycle, offering benefits in collaboration, efficiency, cost control, sustainability and regulatory compliance. Understanding the concept of BIM involves grasping its fundamental principles, components and how it revolutionizes the AEC industry. By synthesizing current research and industry practices, this review aims to provide a holistic understanding of BIM's role in advancing modern construction practices and its potential for future development.

Disclaimer (Artificial intelligence)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

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