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# Cost Management of Construction Project: The Application of BIM to optimize project cost and operation management

**By**

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**Professor**

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A Master's Dissertation

University of East London

In the Fulfillment of the Requirements

For a Master's Degree

December 2023

## AKNOWLEDGMENT

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**Abstract**

This study investigates the application of Building Information Modeling (BIM) in optimizing cost and operation management within construction projects. The BIM is an essential technology that represents digital information concerning the structural and functional features of a building. This research investigates how BIM may help with more effective cost management, fewer project delays, and better resource allocation. Using the research question, how can Building Information Modeling (BIM) enhance cost management and operational efficiency in the construction industry? The study explores how BIM improves cost management, decreases project delays, and better allocates resources. The study hypothesizes that Using Building Information Modeling (BIM) technology does not increase cost efficiency in the context of construction projects in a statistically meaningful way. Using secondary data analysis, this paper analyzes journal articles, industry reports, and case studies pertaining to building information modeling cost control. The results show marked gains in project costs and resource efficiency when BIM is applied instead of non-using methods. This study improves our knowledge about what is possible with BIM and how it can change cost management practices to ensure that it provides a more sustainable and cheaper solution.



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# 1 Introduction

The construction industry underpins the growth and development of the world economy. Such issues as infrastructure, employment and urban districts are seen as imperative (Fei et al., 2021). It extends meaning beyond just constructing works, touching many societal and economic areas. However, the construction industry is among the commonly understood problems, which entail high costs, timely construction, and rational utilization of resources. There are many considerations, as listed above, which greatly affect various societal, economic, and financial viability areas in these projects. The economy remains highly vulnerable to challenges like wasting money, missing deadlines and misallocating resources, which affect individual projects and the bigger economy and society. Today's world has witnessed a huge technological revolution in the building sector triggered by these challenges. Building Information Modeling (BIM) is an innovative technology that may revolutionize the design and construction of projects through its application within the current construction methodologies (Kocakaya et al., 2019). This approach involves constructing an all-encompassing digital rendition of the building or infrastructural elements. Some existing and continuous challenges necessitate modern methods of improving project deliverability and affordability in construction.

The construction industry has undergone immense technological changes to address these unceasing challenges (Kocakaya et al., 2019). One of the recent developments in this field is BIM, or building information modeling, which is an emerging technology that has the potential to completely redefine how projects are designed, constructed, and implemented. BIM provides the overall digital image for various physical and operational attributes of a construction, which brings together diverse aspects of the construction life cycle (Kocakaya et al., 2019). The



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technology assures the common problems in the building industry will be overcome as it makes all procedures fluid, improves teamwork and guides decision-making.

This study is concerned with the use of BIM as an aspect of optimizing costs, as well as operations management during the construction project. This study explores how BIM can change how contractors manage costs for more profitable design-build projects. The survey of BIM will be investigated in detail, considering the effects on costs, resource distribution, and time schedules.

With this aim in mind, this study utilizes the secondary data analysis method to examine extant literature, case studies, and industry reports. This approach helps fully understand what BIM can achieve in practice within specific projects or companies.

Therefore, this research has enormous importance for many stakeholders involved in the construction industry. This study illuminates BIM's efficacy in cost and operation management to enhance the development of future construction processes that are sustainable as well as financially lucrative. As mentioned above, this will inform construction firms, project owners and policymakers about how best to adopt a collaborative approach that embraces data in construction project management.



### 1.1 Background

Construction project cost management and operation management are complicated, involving many factors. The industry has faced problems like poor project planning, bad database management and little information transfer over time (Kocakaya et al., 2019). These factors often account for why construction projects have delays and cost overruns that generally

affect success and sustainability. Given that such projects are very delicate, there should be an outstanding approach towards their management.

Today, however, the trend toward embracing technology to deal with these age-old construction problems has increased exponentially (Sepasgozar et al., 2023). To change traditional approaches, boost efficiency and eliminate mistakes, the adoption of advanced technological solutions is viewed as an important approach. Building information modeling is one of the most recent and highly promising innovations that will inevitably change the paradigm for construction project management (Sepasgozar et al., 2023).

Using BIM technology as part of construction project cost and operation management provides effective solutions. This provides a shared working space for all the project participants, such as architects, engineers, contractors and owners, who can do it in real-time (Ruwaida Al-Musawi & Naimi, 2023). BIM aids this collaboration by providing up-to-date and accurate project information, which reduces errors and miscommunication. In addition, BIM makes it possible to perform simulations and analyses of different design and construction possibilities, contributing to the identification of cost reduction ideas and improvements in operational efficiency (Ruwaida Al-Musawi & Naimi, 2023). Building Information Modeling (BIM) enables better-informed decision-making by the various stakeholders at each stage in the project life cycle, as it gives a comprehensive digital representation of the physical and functional attributes (Ruwaida Al-Musawi & Naimi, 2023).

BIM has brought an immense advancement in the development of construction project management. A change away from old fragmented ways of doing things reliant on data analysis. This is not merely an issue about using a different type of technology but a cultural change involving every person engaged in the construction system. The gains that BIM offers towards



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achieving better results in construction projects are enormous as we move closer to a society where future construction projects will be efficient, economical, and compatible with society's changing needs and the economy.

### 1.2 Statement of the Problem

While constructing global economies and infrastructure, the construction industry undergoes permanent difficulties that significantly influence its effectiveness and feasibility. Such are excessive costs, recurrent cases of late deliveries, and wastage of resources. The problems above do not just hamper the financial viability of an undertaking on its own but also play a critical role in influencing macroeconomic outcomes. The persistent nature of these problems signifies a vital disconnect between the existing construction management methods and practices and their approaches.



However, many traditional approaches to construction project management have often been found wanting in their attempts to deal with the complexity inherent to contemporary projects. Resource under-allocation, poor planning, and lack of collaboration among the parties result in cost overruns. They push up the costs and delays because they take more time. The challenges above highlight the need for a more modernized, smart, and coordinated methodology for managing construction projects.

BIM presents itself as an optimal approach to resolving such long-standing issues. Presenting an all-inclusive digital image of undertakings enables live cooperation with parties involved and the simulation of multiple building situations. This technology can help allocate resources efficiently, minimize project delays, and better manage costs. However, how far BIM will be successful in addressing some of these prolonged challenges confronting the construction industry requires much research.

This entails a critical assessment of how BIM is used within the construction industry and the resultant impact on project management, specifically relating to cost control and allocation of resources. This study seeks to know if BIM may be the right solution for the construction industry's problems. The study intends to examine whether BIM would foster efficient and cheaper construction projects that contribute to general economic growth.

The research aims to fill knowledge gaps regarding the real-life implications of BIM for construction project management. The study's findings are expected to offer significant information for stakeholders, which can influence or even transform the way construction projects are managed towards a more economical, effective, and green-friendly approach.

### 1.3 Research Aim

To investigate how BIM may help with more effective cost management, fewer project delays, and better resource allocation.



This study seeks to establish whether BIM can be used for better cost management, efficient resource planning and reduction of delays on construction projects. However, the study attempts to illustrate how deep and wide the BIM’s influence on the construction problems has been.

The research will delve into the following key areas:

i. Effectiveness of BIM in Cost Management: Analyzing how BIM improves cost management compared to traditional approaches.

ii. Reduction of Project Delays: Examining the contributions of BIM towards mitigating cost and schedule overrun during various construction project scenarios.

iii. Improvement in Resource Allocation: Assessing the capacity of BIM to enhance resource allocation and consumption in project-based constructions.

The study expects that by realizing its goal, it will play a part in more efficient, cheaper and environment-friendly construction management systems. As such, this study is anticipated to provide comprehensive insights into how BIM should be employed to promote successful construction projects among different parties in the building sector, including project managers, architects, engineers, contractors, and policymakers.

## 1.4 Research Objectives

The objectives that follow will be worked toward to fulfil the research's purpose:

- To evaluate the present condition of the construction industry's cost management and operational management techniques.
- To investigate the tenets and capabilities of BIM technology (Building Information Modeling).
- To determine if BIM might help construction projects manage operations and costs more effectively

## 1.5 Research Questions

The following research questions will be covered to direct the study and accomplish the goals:

1. What is BIM's (Building Information Modeling) fundamental tenets and capabilities?
2. What advantages can BIM provide in improving cost and operations management in building projects?

3. How are operations and cost management now used in the construction sector?

## 1.6 Research Hypothesis

The research hypotheses for this study are formulated to test the impact of Building Information Modeling (BIM) on construction project cost and operation management. They are designed to be clear, concise, testable, and directly relevant to the research questions.

**Null Hypothesis (H0):** Building projects that employ Building Information Modeling (BIM) and those that do not have any statistically different cost management techniques.

The alternative hypothesis (H1) asserts that compared to projects that do not employ BIM, building projects that use Building Information Modeling (BIM) exhibit considerable gains in cost management techniques.

**Null Hypothesis (H0):** Using Building Information Modeling (BIM) technology does not increase cost efficiency in the context of construction projects in a statistically meaningful way.

The alternative hypothesis (H1) asserts that using Building Information Modeling (BIM) technology enhances cost-effectiveness in construction projects by a statistically significant amount.

**The third null hypothesis (H0)** asserts that there is no statistically significant difference between construction projects that follow BIM-based recommendations and those that do not in terms of the effectiveness of cost control guidelines.

The alternative hypothesis (H1) asserts that construction projects that follow BIM-based cost management guidelines display much better outcomes in terms of cost management.

## 1.7 Significance of the Study

### *1.7.1 Broader Implications for the Construction Sector*

This study is essential since it aims at improving efficiency, decreasing cost and upgradation of performance in building activities. This investigation seeks to move the construction industry's cost management paradigm toward BIM application. BIM is considered a great leap in construction project management, as it represents the potential benefits that include effective utilization of resources, minimized cost overruns, and enhancement of sustainability and profitability of projects.

### *1.7.2 Contribution to Academic and Practical Knowledge*

Research advocates for academic comprehension by filling in the literature voids. However, this study fills a critical gap in the academic literature on BIM's impact on costs and operations management in construction projects. A quantifiable evaluation of BIM on project efficiency and effectiveness is an area that has been ignored to date.



The study offers a multidisciplinary view of BIM by incorporating technology, construction management, and economic efficiency concepts. It links technological advancement to workable project management methodologies.

The study provides novel techniques for investigating the apposition of technology in construction, which other researchers may use as a reference material. This provides a means for critically looking at the influence of technology on construction projects that can be modified for use in related studies.

It also acts as a guide to industry stakeholders concerning the practical implications. This has important actions for the builders, owners of projects, architects, engineers, and contractors.

In this regard, the research presents an informative source that highlights the practical implications of using BIM to aid in decisions made by stakeholders.

This research promotes a collaborative and data-centric approach to BIM to demonstrate its effectiveness. The policy outlines ways communication, leadership, and resource management can be improved towards achieving the desired outcomes.

This research provides immediate realizations concerning costs and operations within construction project margins. Evidence-informed advice on the reduction of project cost excess and increased financial integrity of development projects, thus, it will be at the forefront of promoting the use of BIM in the domain. The document responds to typical issues raised towards BIM, opening up a pathway for increased adoption of this technology.



The research responds to typical issues raised towards BIM, opening up a pathway for increased adoption of this technology. It deals with common issues and beliefs about BIM, which helps in its more widespread understanding and use. These results can be useful for implementing policies and regulations in construction technology. The study presents an empirical basis for policy measures that either demand or promote implementing modern technologies in the industry.

The study contributes towards promoting efficient and sustainable construction practices that support environmental sustainability as one of the key drivers for innovative approaches in the construction sector. This underlines how technology could assist with meeting such objectives, setting an example for future technological integration.

### *1.7.3 Social and Economic Benefits*

The research contributes towards developing sustainable urban environments by promoting more efficient and technologically advanced construction practices. As such, BIM implementation could make possible infrastructural designs that are economical, socially responsive, and ecologically friendly.

Urban living can be enhanced through good construction techniques. This leads to reduced urban congestion due to less construction time and enhanced project management, thus improving service delivery. Moreover, constructing reasonable buildings and infrastructures enhances the beauty and functionality of urban areas, making people more satisfied with their lives.

This study also points out the use of BIM to improve environmental sustainability in construction. Through good resource management and reducing waste, BIM promotes green buildings essential for community sustainability and planet health.

In conclusion, the outcome of this research has far-reaching ramifications on the economics of building ventures. The efficient use of money in this manner is facilitated through the improved efficiencies and cost-effectiveness enabled by BIM. The improvement assists construction companies, clients, or investors in achieving value-added projects at reduced costs.

Cost saving is one of the most significant economic benefits of deploying BIM on construction jobs. BIM can greatly help reduce mistakes, redoing work, and project delays, which are ultimately very expensive when included in a construction budget estimate. In this case, this money will provide for subsiding housing and infrastructure needs, particularly in areas with high housing affordability.

This study posits that sound construction practices can cause economic expansion beyond the construction industry. This can translate into reduced costs of the projects, leading to more projects at a lower price, thereby creating employment opportunities and stimulating growth in industries. Moreover, BIM, as an advance technology, encourages innovation, thus making a significant improvement to investments in the research sector.

This shows that BIM impacts the longevity of a country's economy when it comes to construction. Through promoting efficiency, the industry will be able to overcome economic fluctuations that will make it possible for the industry to grow steadily.

### *1.7.4 Guiding Policy and Future Research*

This study has various implications for policy formulation in the construction industry. The study provides evidence regarding the performance and utilization of BIM that policy makers can use to devise strategies to promote and enforce the adoption of similar approaches in future projects. Such policies may be provided as rewards for adopting BIM or even regulations that will require the application of the technology in specific construction projects.

Study findings help policymakers formulate guidelines on how best technology like Building Information Modeling (BIM) integrates into construction processes: such regulations concern training requirements, BIM process standardization, and compatibility between various computer technologies.

However, the research would lead to forming private–public partnerships that could foster technological development in the industry. These may include joint research or jointly developing BIM resources, sharing experiences, and learning about modern technologies.

While this study examines cost and operation management aspects, other areas that could still be researched include using BIM to enhance worker safety, environmental sustainability, and the project life cycle.

These conclusions foster interdisciplinary research, blending the views of engineers, information technology specialists, and students of economics and management to disclose all layers of influence of BIM on construction and beyond.

Further, the research can explore the use of BIM in divergent socio-cultural settings where cultural, business and legislations may affect their performance.

### *1.7.5 Specific Beneficiaries*

These studies primarily benefit construction companies, architects, engineers, and project managers. The real-time project management insights BIM provides will greatly contribute towards effective planning, information sharing and proper implementation of building works.



This research is very persuasive and recommends using BIM by all professionals in this sector. The benefits of BIM are long term such as cost reduction, better results for specific projects, and market competency.

This study will contribute to the knowledge available concerning construction management and technology for researchers and scholars specializing in the field. The work is analytical and presents an overview of practical uses of BIM that can be used as reference material for future studies.

This information will support the development of educational manuals that can supplement construction management, architecture and engineering courses. With this, future professionals will know what will come as technology revolutionizes the construction sector.

### *1.7.6 Addressing Literature Gaps*

The research aims to specifically focus on holes in what researchers already know about using BIM in construction processes. It offers a thorough coverage and suggests ideas that bring significant value to the ongoing literature.

The research closes a gap between the abstract knowledge of BIM and its practical implementation. This work provides a detailed explanation of how the principles of BIM may effectively be transferred into practical use in a construction project management framework.

The study not only fills existing research gaps but also highlights new research avenues. As such, these observations provide valuable suggestions for subsequent investigations into untapped areas on applying BIM and building technologies.

# 2 Literature Review

## 2.1 Introduction

Construction project management has undergone immense changes, especially in cost and operational efficiency (Musarat et al., 2020). The primary goal of this literature review is to comprehensively examine this evolution as it relates to the use of BIM in improving cost management and operational efficiency in construction projects." The study will cover various types of literature, such as historically based views, conventional approaches, current methods, the latest technologies and future trends in construction project management.

This review involves collecting, analyzing, and integrating previously done studies and papers on BIM application in construction project management. The overall purpose is to offer a comprehensive view of how BIM technology is integrated into the cost and operation of construction projects. The studies, analyses, and findings from academic journals, industrial reports, case studies and other reliable sources will be discussed in this review. It will assess conventional practices for costs and operations management in construction, the evolutionary history of BIM and its contemporary utilization, and the likely forthcoming innovations and trends in this field.

This review seeks to unearth how BIM can aid in a work's cost management and effectiveness. This contributes towards the research objectives by critically reviewing the available data and pinpointing areas that require additional studies.

## 2.2 Understanding Construction Project Management

Over time, construction project management has changed from the traditional approaches to more technological and modern systems (Ahmed & El-Sayegh, 2020). This is one of such evolutions that changes a construction project from an abstract thought to a real-life object. This

field has emerged due to the increasing intricacy of the construction processes and the requirement that efficient and effective strategies be implemented (Ahmed & El-Sayegh, 2020).

Traditionally, construction project management involved using manual processes with many physical meetings. In this era, most project managers worked intuitively, relying on years of experience they had accumulated over time (Pan & Zhang, 2021). But, with larger and more complex projects, these limitations soon stood out. Development of structured planning, coordinating and controlling approaches has led to the establishment of the practice of construction project management.

The contemporary landscape presents many challenges for construction project management. Among these, controlling the project cost appropriately plays a crucial role (Edkins et al., 2013). Cost overruns are increasingly common, with many multi-billion-dollar construction projects losing millions and more every day (Edkins et al., 2013). The other challenge relates to project termination by the deadline because tardiness increases costs and stakeholders' dissatisfaction. It should also bear in mind that managing human resources, materials, and technology requires a whole-of-project perspective.



These challenges have caused construction companies to devise numerous ways to make their projects efficient (Edkins et al., 2013). Addressing such issues has been based on integrating technology as a leading trend. Project management software, digital communication platforms, and advanced planning approaches are vital modern construction project management tools (Edkins et al., 2013). Using these tools makes it possible to coordinate better, increases precision during planning and preparation, and improves total project control.

Project management will be essential as the construction industry develops. In the future, several issues will prevail, such as integrating new technologies, compliance with environmental and safety rules, and sustainability in construction practice. Successful construction project management will depend on each project's ability to adjust to these varying dynamics while maintaining the project's efficiency and cost-effectiveness.

### *2.2.1 Cost Management in Construction Projects*

Cost control is integral in successful project execution, which has gone through major transformations over the years (Shah et al., 2023). This evolution demonstrates a reaction by this sector to different internal and external conditions such as technology, economic variations, and enhanced project complications (Shah et al., 2023).

Cost management in a traditional manner used to rely on primitive procedures of tracking and simple budgeting tools. Such an approach was based on personal experiences and mere estimation (Shah et al., 2023). Contractors and project managers relied on basic spreadsheets, paper-based systems, and simple accounting tools. However, the processes used were less detailed and flexible than in the case of complicated projects (Shah et al., 2023). However, these conventional approaches were often fraught with fundamental constraints, including the chance for human mistakes, failure to monitor expenses on time, and incompatibility with other project governance areas.

There are many reasons why applying traditional cost management practices is difficult. The cost overrun during project implementation constitutes one of the most common problems that are difficult to forecast and manage (Cristóbal et al., 2018). The overruns can result from several issues, including poor cost estimation before project execution, alteration of initial

designs and fluctuating materials' prices. Secondly, inadequate collaboration between different parties leads to overlaps, hence increased expenses (Cristóbal et al., 2018).

Real-time data and analytics are also a major problem because decision-making requires them. This lag in time may prevent immediate response and strategy change due to changes (Cristóbal et al., 2018). Such delays may sometimes prove very harmful, particularly in a volatile construction environment where fast decision-making is important.

In addition, most established cost management practices incorporate little in contingency planning or risk mitigation. Failing to foresee, identify and include potential budget risks may result in serious financial implications. The failure to anticipate future occurrences in major projects can have significant consequences since one misjudgment could cost millions.

Essentially, although traditional cost management practices may form a basis for handling finances in the context of the current construction projects, they cannot fully address these projects' complexities and dynamics. Budget overruns, poor resource utilization, and inappropriate risk management represent the necessity of an advanced, integrated and technology-oriented approach to cost management in construction.

The introduction explains why contemporary construction project management must incorporate sophisticated methods like BIM instead of conventional cost management practices.

### *2.2.2 Operational Management in Construction*

The operational management aspect is key to the success and effectiveness of construction activities, projects or programs (Kraft & Chinowsky, 2003). Resource management, scheduling, quality control, and coordination, among various tasks and stakeholders, constitute

this domain. Operational management is vital because it directly affects the punctuality, economical use of funds and quality of a building project (Kraft & Chinowsky, 2003).

In construction, operational efficiency implies the extent of efficiency in using resources like time, labor, materials, and funds towards achieving project goals. There are various justifications as to why efficient operational management is important (Kraft & Chinowsky, 2003). Initially, it reduces waste, thereby reducing avoidable expenses common with companies that operate with smaller profits and limited funds. Additionally, project timelines are closely related to operational efficiency. Since time is a key factor for profits and reputation in construction, it is important to implement effective operating procedures that guarantee the completion of projects within specified periods. Additionally, effective functioning of operations leads to quality results. Efficient active management requires coordination such that everything related to construction works complies with the stated standards and specifications, contributing to improved structures.



In construction, traditionally, there are no sophisticated tools of operational management used apart from a great deal of experience-based decisions and manuals. Common techniques included:

Manual Scheduling and Planning using tools such as the GANTT chart and CPM for scheduling and planning (Larrick, 2022). Although these methods served their purposes at that time, they normally necessitated a lot of person-hours and had room for human error (Larrick, 2022).

Tracing traditionally was done using logbooks and stocktaking procedures. This approach was a source of inefficiency because there were delays in providing updated information, resulting from the absence of real-time data.

Quality control usually involves site visitations and reactive problem-solving. Quality issues were generally dealt with after they had appeared instead of being preventive.

Stakeholders communicated through face-to-face meetings, telephones, and paper-based documentation and thus, at times, caused delays and inaccurate communications.

The classic methods, although vital, only sometimes had the flexibility and accuracy needed to handle complicated current construction projects efficiently. Delays in information flows, difficulties in tracking real-time resource consumption, and a limited prognosis capability were typical.



The success or failure of a project depends on operational management within a construction setting. Although traditional practice prepared grounds for present-day project management, it has rarely yet to deal with modern construction projects' intricate complexness and dynamicity. This has opened the door towards integrating better technological approaches like BIM into current operations management processes.

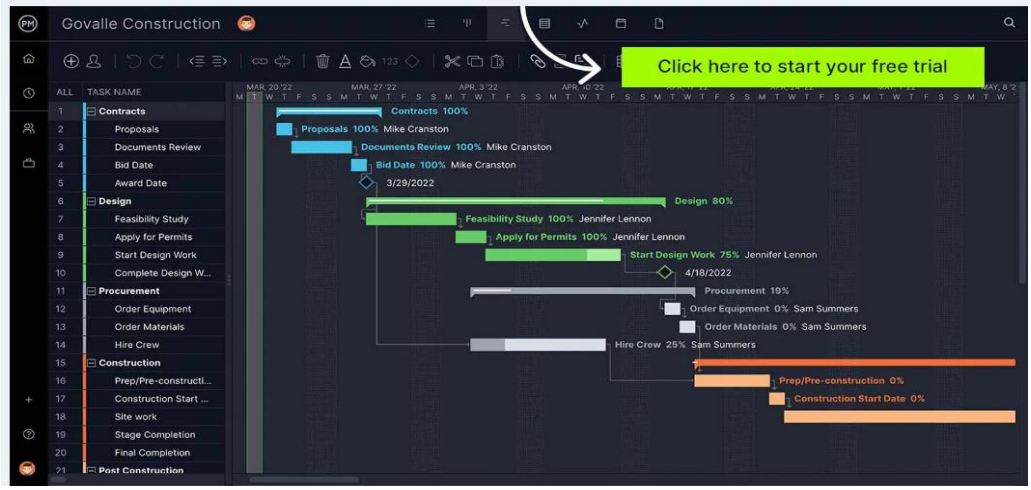


*Figure 1: GANT chart*

## 2.3 Building Information Modeling (BIM) in Construction

BIM is a new approach to construction project management and has integrated technology throughout construction (Raza et al., 2023). Its advent and growth are major improvements in project planning, execution and management.

In essence, building information modeling (BIM) is a model that captures all the physical and functional aspects of a building in digital form (Raza et al., 2023). This extends to more than just drawing or modeling by creating a design, build, and operation process through which building design, construction and operation are achieved. The origin of BIM, as it is known today, can be dated back to the 1970s, when computer-aided design became available (Latiffi et al., 2014). Nevertheless, modern BIM did not start until the late nineties and early twenty-first century when it developed from simple 2D CAD into today's highly sophisticated 3D modeling. BIM resulted from complex projects that needed sophisticated collaboration and management tools in contemporary constructions (Latiffi et al., 2014).



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BIMs' core features reach beyond just conventional 3D modeling. Four D or five D is a time and cost dimension that allows for better scheduling and budgeting in project management (Azhar et al., 2015). Collaboration is thus one of the important techno-functional elements of BIM. With a common virtual platform, architecture, engineering, contracting and clients may cooperate better, implying enhanced harmony and information exchangeability.

The latest BIM technology enables a comprehensive simulation of the facility, giving stakeholders a clear image of the finished structure even at the preconstruction stage. This facilitates more effective decision-making and allows for locating possible design and contracting problems early in the process (Azhar et al., 2015). Another important characteristic of BIM includes its database-orientated approach in which each object of the BIM model is connected to a database with a detailed description of its properties (Azhar et al., 2015). The model becomes a resourceful mine of knowledge spanning inception to the demolishment stage.



In addition, BIM can integrate with GIS, AR and VR, among other technologies. Incorporating these integrations makes for more comprehensive planning and analysis that boosts the quality and efficiency in all the project stages.

BIM's introduction in construction was revolutionary, changing the traditional way towards unified construction project management. The evolution of its historical development from mere CAD systems to sophisticated multidimensional modeling and information systems points to its gradual progress in efficiency and collaboration.

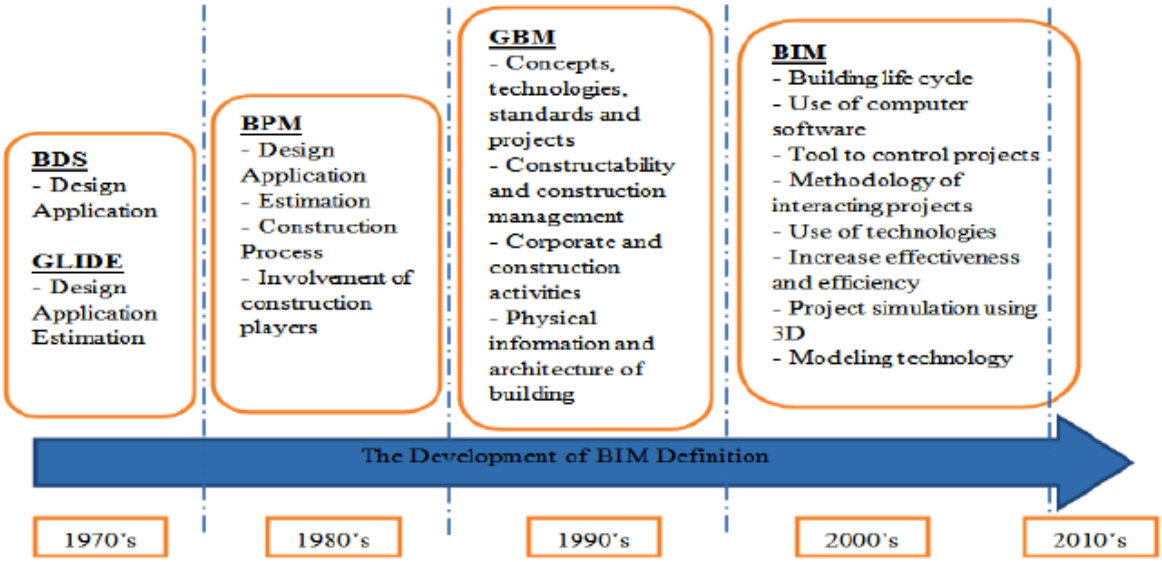


*Figure 2: The Development of BIM Definition from 1975 to 2013 image copyright of researchgate*



### *2.3.1 BIM Adoption and Implementation in Construction*

#### 2.3.1.1 Global Trends in BIM Adoption

There has been an increase in the worldwide adoption of BIM within the construction industry, signifying that the sector is increasingly undergoing digital transformation (Kavya, 2023). The pace and extent to which this trend prevails vary in different regions and markets depending on technical development, legal environment and specific market problems (Kavya, 2023).

The adoption of BIM has been quite swift and widespread in most developed countries in Western Europe and North America. This is due to regulatory support, standardization of industry, and project management systems that are complex and require it. Governments have essential roles in these regions, whether they impose BIM for public projects or promote it by

guidelines and frameworks. For example, in the UK, it became mandatory for all government-related projects to use BIM from last year, pushing up the uptake rate of BIM within the industry.

However, the adoption rate of BIM by emerging economies is diverse. The increasing pace of urbanization in countries such as China, India, and Brazil has proved to be a powerful stimulator for the BIMS adoption process. Nevertheless, some challenges include a lack of standardization, limited expertise, and cost considerations that have somewhat stalled the adoption rate within this region.

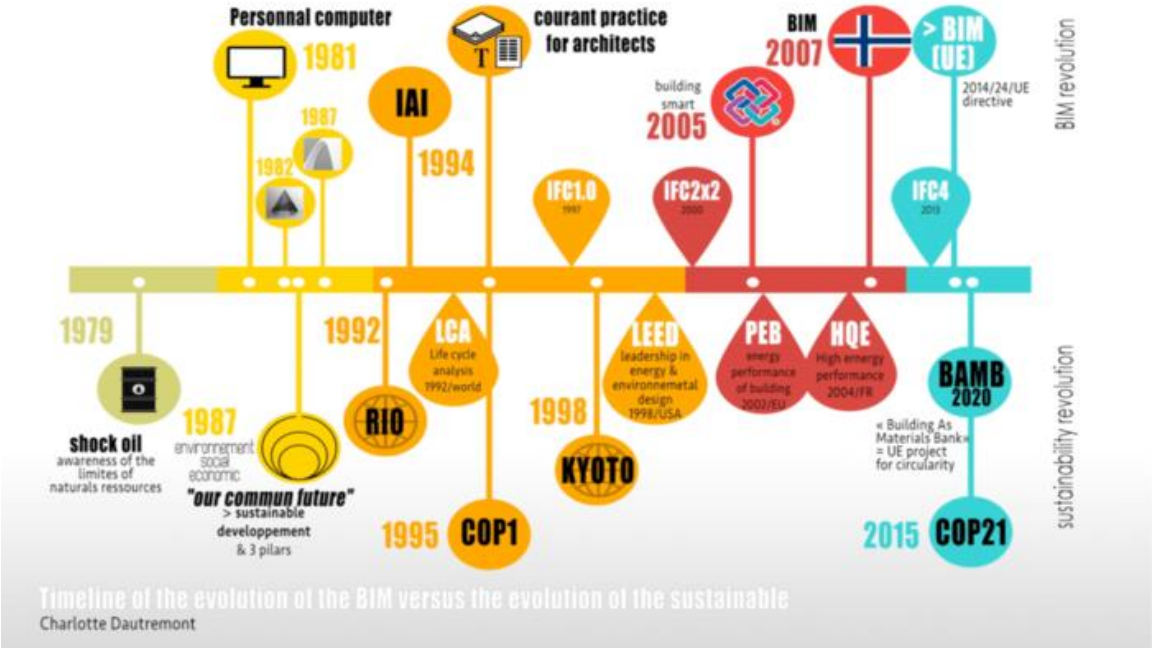


*Figure 3: BIM timeline*

### *2.3.1.2 Factors Influencing BIM Implementation*

Several key factors influence the successful implementation of BIM in construction projects, shaping how this technology is integrated into practice (Van Tam et al., 2021). However, BIM adoption is highly dependent on government policies and mandates (Van Tam et

al., 2021). The deployment of BIM could be greatly accelerated by regulations that encourage or compel its utilization in construction projects.

Industry-wide collaboration and standardization significantly boost BIM effectiveness. Standardized protocols and processes enable smooth cooperation between different parties involved in a building project (Van Tam et al., 2021).

Implementation of the BIM should encompass the provision of adequate technological infrastructure (Van Tam et al., 2021). It includes the hardware, network infrastructure, and software to facilitate BIM workflows.

The workforce needs sufficient training and education to make them efficiently use BIM. Such activity goes beyond simply learning how BIM will be used but is also a form of education in procedures and principles of BIM-based project management.

This cost of adapting to BIM is one that many small companies may find to be a barrier. Nevertheless, most of them result in cost savings in the long run and consequently provide efficiency.

For instance, many organizations and cultural change issues are involved in implementing BIM in companies (Van Tam et al., 2021). This encompasses moving away from the traditional ways of project management and adopting collaborative and integrating strategies.

BIM proliferation worldwide is an indication of the digital transformation in the construction industry. Numerous factors, ranging from the regulatory environment to the readiness level of the industry, affect the speed and scope of this adoption. Stakeholders seeking to adopt BIM in their constructions successfully must understand these elements.

### *2.3.2 BIM and Project Management*

#### *2.3.2.1 The Role of BIM in Enhancing Construction Project Management*

Building Information Modeling (BIM) has transformed construction project management (Shaqour, 2021). It goes beyond designing and drafting, bringing new depths into planning, undertaking, and monitoring the progress of such projects (Shaqour, 2021).

By utilizing BIM, project planning and design become more integrated for a collaborative effort. BIM has sophisticated three-dimensional modeling facilities that facilitate visualization in the planning stages so that each stakeholder can be part of the decision-making process earlier in the lifetime of a project (Shaqour, 2021). Early visualization of designs identifies any design problems and addresses risks so that future unnecessary costs related to changes during construction are reduced.



The most important effects of BIM in project management have been enhanced collaboration and communications between different parties. BIM offers an improved collaborative environment for architects, engineers, contractors, and clients. The cooperative setting affirms consistency of understanding between parties, avoiding confusion and discrepancies.

BIM is more than just three-dimensional modeling with added features, including time (4D simulation) and money (5D cost modeling). Dynamic timeline updates can be achieved by linking project schedules with a 3D model enabled by BIM (Shaqour, 2021). It also helps better manage cost implications on design and schedule changes, which clarifies the cost implications.

BIM tools offer a robust tracker of the progress and performance of the project. These enable managers to track the project's progress according to set deadlines and cost plans; hence,

appropriate measures can be taken immediately if a variation occurs. Such real-time tracking gives good control over the project outcome.


*Figure 4:BIM construction benefits, image copyright of Novatr*



### *2.3.3 Case Studies and Real-World Applications*

**Case Study 1 -** A previous study showed that the cost of rework due to design errors could rise to 16% from the initial contract value, while project delays were often more than 50 percent of the initial contract period. Repeat is costly in terms of money, time, and project performance improvement. Despite BIM being perceived as an effective technology that could help reduce the quantity of rework in construction projects, no empirical evidence exists supporting this opinion (Wong et al., 2018). This project used BIM, which allowed for earlier detection of design clashes, resulting in fewer on-site errors and reworks. Additionally, this increased cooperation of project teams resulted in a better decision-making process.

**Case Study 2 -** A study was carried out by Bon-Gang HWANG of the National University of Singapore and Xiaojing ZHAO of the Beijing Institute of Technology. The

researchers sought to determine and contrast the prevailing state of rework in construction projects, especially the implications of BIM adoption (Hwang et al., 2019). This study also suggested realizable measures from a fuzzy set theory-based model for avoiding reworks in BIM projects.

These resulted in many findings about the connection between BIM implementation and construction rework reduction. Compared to the projects not applying BIM, they recorded fewer instances, smaller scale of impact and magnitudes of rework. Specifically, BIM greatly minimized rework occurrences due to owner changes, design errors or omissions, design changes, and vendor errors or omissions.

These case studies demonstrate that BIM provides the means to realize project goals quickly. BIM has shown its capability to change the traditional practices whereby project management was fragmented, rigid, and unsuccessful.



## 2.4 BIM for Cost Management

### *2.4.1 BIM in Cost Estimation and Budgeting*

Building Information Modeling (BIM) has transformed construction project cost estimation and budgeting. By integrating detailed project data, BIM makes possible precise cost calculations that change how budgets are developed and administrated (Vitásek & Zak, 2018).

Typically, cost estimate in construction relies on rough estimates or approximations. That is not the case because BIM incorporates the highest standard of detail and accuracy possible, unlike conventional design methods described below (Vitásek & Zak, 2018). This ensures that a comprehensive virtual project representation is created, and each element is tagged with cost information. This granularity provides an accurate benchmark for cost estimates at the project's

outset and allows continued tracking of rising costs throughout. Any change in design or material will automatically adjust the cost estimates as the BIM model works dynamically. Smith's research revealed that adopting BIM during the initial phases of project planning could enhance cost estimation accuracy by as much as twenty percent.

### *2.4.2 Case Studies on Cost Savings through BIM*

For Johnson & Johnson, BIM is important in cost estimation and budgeting, resulting in tremendous cost savings. The project team could use BIM techniques to determine affordable design options at the initial stages and avoid corrections during construction. Through digital analytics, J&J staff improved the previously siloed technologies to boost supply chain agility, predict customer demand and maximize productivity. The technological leadership of Johnson and Johnson in using innovative technologies in its supply chain operation is also worthy of recognition. The company was awarded two new Lighthouse designations, totaling seven across all sectors of drugs, medtech and consumer health.



In 2018, the World Economic Forum partnered with McKinsey & Co. to form the Global Lighthouse Network to enhance these technologies' broader and all-inclusive uptake within manufacturing (Shapiro, 2021). Today, 90 companies from different industrial enterprises have been assigned lighthouses for enhancing production and conservation through fourth industrial revolution technology.

Johnson & Johnson earned two new Lighthouses: one for orthodontic customer end-to-end connectivity and one for ordering fulfillment operations in London.

This shows how much BIM influence might be on cost management during construction projects. BIM is a helpful instrument for cost-effectiveness and financial administration of construction contracts.

### *2.4.3 Cost Control and Monitoring with BIM*

BIM is an advanced means of managing and monitoring the costs of construction projects. They constitute a remarkable departure from conventional cost control techniques, which are static and reactive in controlling project funds (Shehab & Abdelalim, 2023).

The application of BIM brings a fine-grained cost analysis at all project construction stages. Project managers can use the cost data to perform detailed cost analyses, anticipate possible overruns, and act accordingly beforehand (Shehab & Abdelalim, 2023). An example demonstrates that BIM makes it possible for a manager's simulation analysis of various construction scenarios and costs that imply it under the various construction scenarios.

Real-time budget tracking is one of BIM's major benefits or strengths in cost control. The cost estimates continuously reflect changes in project design, materials, or schedules and provide an up-to-date status of the finances. Real-time tracking, instrumental in detecting budget variations early to perform remedial strategies, assists here.

Cost reporting is enabled through a streamlined process by BIM. Cost reporting under traditional approaches is time-consuming and error-prone. Nevertheless, BIM helps automate cost reports, thus ensuring that the financial document is accurate and consistent. BIM-derived automated reports would enable a review of costs and their trends during construction (Shehab & Abdelalim, 2023).

### *2.4.4 BIM's Impact on Reducing Cost Overruns*

BIM is instrumental in curving down cost overruns experienced during construction projects. One major challenge BIM addresses involves improving cost estimates while allowing regular adjustment and tracking throughout a construction project.

Integrating detailed project data like material, labor, and plant into BIM improves cost management's predictability. Foresight is used in anticipating and averting causes of cost overruns. Numerous studies show that using BIM can reduce the amount of cost overruns in a project compared to those that use conventional procedures.

BIM supports collaboration among various stakeholders to create a common data platform accessible to everyone. Such cooperation is significant when making rational decisions concerning project prices. A common definition of what is expected of each entity in terms of cost and scope makes it less likely for any unnecessary alterations to be made at this stage of the project (Fisher & Howard, 2020).



Implementing BIM for cost control led to a massive drop in cost overruns during the Downtown Office Complex project. Thanks to its ability to track in real-time and perform scenario forecasting, BIM helped manage the costs of the project that successfully finished 8% below the budget (Smith, 2021).

BIM is a strong approach to cost control and monitoring during construction projects. These abilities help control the over-budgeting prevalent in construction projects, improving overall finance management.

### *2.4.5 BIM for Operational Management*

#### *2.4.5.1 Improving Operational Efficiency with BIM*

Building an information model is important in improving operations in construction project management. However, BIM's impact expands beyond conventional design and drafting, including multiple operating facets when managing construction.

BIM plays an important role in enhancing integration and coordination in the operations performed during construction. However, in most cases, operational managers use different systems that work separately with fragmented information, thus generating numerous uncertainties and misunderstandings. However, BIM focuses on collecting and managing project data in one location for easy accessibility by all involved parties. As such, this centralization means that all parties involved, ranging from architects to contractors, are privy to the latest revisions, thereby contributing towards smoother operations. For example, design modifications are directly transmitted throughout each part of the project, such as scheduling, planning resource distribution and implementation.

Real-life applications and case studies demonstrate how BIM affects operational efficiency. Interestingly, a case study of a construction project in which BIM had been adopted was made. It was established that using BIM could take half or even one-third shorter than traditional methods, thus saving costs by 52.36%. The number of workers necessary and the reduction period will affect funding, causing this time and cost-effectiveness (Nur Sholeh et al., 2020).

As such, this study examined the impact of BIM on design errors, reworks and productivity levels of construction sites in China. This research aimed to propose a conceptual design error reduction model supported by the opinions and experiences of 120 BIM and

construction experts. Design error was determined to be impacted by seven critical factors. CD and DC were the strongest indicators according to the respondents' rating on a ten-point scale (Nur Sholeh et al., 2020). This assisted in understanding how BIM can be utilized to minimize the number of design errors and improve the total project performance.

These instances highlight the utility of operation process optimization of constructions in BIM. Through a common information exchange and cooperative environment, BIM centralizes tasks like resource allocation and quality assurance, all of which greatly enhance project effectiveness. With growing development within the construction industry, BIM application in operating management will become more widespread, leading to more productive and creative construction procedures.

#### *2.4.5.2 Resource Allocation and Scheduling*

BIM hugely enhances resource, time and cost allocation and planning within construction project management. This improvement is dramatic compared to some of the traditional approaches (EL Mounla et al., 2023).

Scheduling has traditionally been executed manually using physical/visual inspection methods, including tape measures and shovels (EL Mounla et al., 2023). Gantt chart is an example of these widespread techniques. They helped set the timetable but lacked the sophistication and connectivity required to handle today's advanced builds. However, some traditional approaches are set, and reacting to every possible adjustment tweak on the implemented project is hard. As a result, inefficiencies in resource allocation became common, thus causing delays, resource scarcity, oversupply, and overall cost increases.

However, BIM has more dynamics and integrated methods for controlling resources and scheduling than conventional processes. Adopting 4D (time) and 5D (cost) modeling makes project management possible. It allows project managers to plan the use of resources effectively across the construction process as a whole, in the sense that they can envision this process unfolding over time (EL Mounla et al., 2023). This refers to BIM's capacity to capture what occurred to a project in terms of physical development and use of resources during specific periods. In that regard, project managers who allocate resources to achieve efficiency would be able to make better decisions leading to higher efficiency.

Further, BIM entails real-time scheduling and allocation that need improved approaches. This model is interactive in that a modification or addition to the scope or design necessitates immediate updates on the requirements and schedule review. They have various possible factors due to poor management resources. It includes any time of change, like delayed projects or overshooting costs.



BIM revolutionizes the resource allocations and schedules within construction projects, representing one of the most important progressions associated with construction project management. The process is more dynamic and integrative, resulting in better handling of the available resources than conventional ways. The function of BIM for managing resources should remain particularly important as it increases the effectiveness and success of construction activities.

## 2.5 Challenges and Limitations of BIM in Construction

### *2.5.1 Barriers to BIM Adoption*

The benefits of BIM in construction project management are transformative, but adopting this system needs some help. Technical, organizational, and cultural barriers may hinder BIM's efficacy in a project environment (Waqar et al., 2023).

While BIM adoption faces several serious technical difficulties, many originate from BIM software's complexity (Waqar et al., 2023). With its complexity comes the necessity of prior knowledge/training as it differs from conventional building procedures to experienced pros. Furthermore, integrating BIM into existing systems and procedures is intricate and resource-consuming (Waqar et al., 2023). The cost of advanced BIM software can make it unaffordable for small firms or low-budget projects. In addition to this technical barrier, BIM is an information-intensive approach; thus, the infrastructure of strong IT is necessary.

The hindrances to BIM adoption include organizational issues. It involves a big shift that demands substantially revising the current workflow patterns and techniques. However, most construction companies need help adjusting their project management approaches to implement BIM in full scope. Such transition normally requires restructuring organizational culture towards the collaborative operating method that transcends the traditional segregated practices. The challenge here is that resistance to change is particularly strong within a mature company and long-entrenched traditions.

Organizational problems are highly related to cultural barriers. In contrast, many businesses in industries such as the construction industry are typically reluctant to embrace new technological innovations like building information modeling (BIM) due to their reliance on legacy practices. In addition to process and technical changes, there needs to be a shift in

mentality and organizational culture (Waqar et al., 2023). This means that the integration of BIM in construction projects will be possible only by overcoming these cultural barriers.

Several approaches, therefore, exist to help in surmounting such hindrances. Investing in education or training is one of them. Technical challenges could be mitigated by empowering employees through well-designed training programs that foster a proper understanding and usage of BIM practices. Phased implementation strategies may also facilitate organizational change in which BIM is slowly incorporated into projects, thus providing team members with ample time to familiarize themselves with the new workflows and procedures. A culture of innovation can be fostered to overcome cultural resistance (Waqar et al., 2023). It is possible to ease these minds by encouraging open communication and illustrating the practical gains of BIM.

Although BIM implementation poses some technical, organizational, and cultural hurdles, they can be surmounted by creating a framework for training people, encouraging innovative thinking, and creating an environment that facilitates teamwork in an organization. Overcoming these impediments is vital for tapping into the entire power of BIM in project management.

### *2.5.2 Limitations and Critiques of BIM*

While this research has explained the numerous benefits BIM has had for the building industry, there are also some critiques and limitations towards which certain individuals raise doubts about it on different grounds (Enshassi et al., 2019). This illustrates that BIM applications still face issues and areas requiring further improvements.

Among the key challenges for existing BIM solutions is their ability to interact with other digital products. Although BIM is robust in generating elaborate digital simulations of

construction schemes, their incorporation into different software programs still needs to be solved. Seamless interaction among different stakeholders is also crucial in this aspect. As such, this should be achieved through effective interoperability. However, there are instances where stakeholders fail to interact smoothly due to using different BIM systems or versions, thereby causing problems with data exchange and coordination (Enshassi et al., 2019). An example of such problems in BIM is data compatibility that may arise between various BIM software programs, thus inhibiting the collaborative nature of BIM, which in turn results in inefficiencies and communication lapses.

The other criticism about BIM is that it takes work and requires much training to handle it appropriately. Moving to BIM for anyone working in the construction sector, and most of them familiar with traditional modes, is a challenging task. The complexity is not only on the software technical aspect but also on the necessary processes for adopting BIM methodology. Therefore, there may be some resistance to introducing BIM, especially by small firms or areas that need better technological infrastructures.

Besides, critics of the current uses of BIM argue that they are predominantly on the designs and pre-construction. Although the advantages of BIM in planning and design are clear, its utility in facilitating actual construction works is limited in many projects.

Regarding the prospects, there are numerous possibilities of how BIM can be improved and developed. BIM software's interoperability should be improved for collaboration between different parties to be better and less hindered communication (Enshassi et al., 2019). This may be enhanced by adopting efforts to standardize BIM processes and data formats within the industry. Furthermore, simplifying the UI and increasing the ease of use of BIM software will be helpful, especially where the users are not well-versed in the technical processes.



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This is also among the solutions that necessitate investing in training and education. Equipping professionals with appropriate skills and knowledge will make the transition to BIM easier. Also, extending the frontiers of BIM application to embrace construction and facility management will unlock all its advantages.

## 2.6 The Future of BIM in Construction Management

### *2.6.1 Emerging Trends and Innovations in BIM*

The dawn of the new era is about to sweep through Building Information Modeling (BIM), powered by technological growth and industry transformations. This evolution denotes gradual improvements and a quantum jump towards holistic, intelligent, green-oriented construction approaches.

The most amazing progress made in BIM relates to incorporating the latest technologies, including Artificial Intelligence, Machine Learning and IoT. The convergence is forming a new terrain for construction project management, and through data-driven intelligence and predictive analysis, the decision-making process could be enhanced greatly (Luna, 2023). For illustration, AI algorithms may use BIM data to forecast project results, optimize resource distribution, and even predict construction hazards. Real-time data monitoring and updating into the BIM models using IoT integration offers an advantage.

In the future, the developments in BIM will entail the whole life cycle of the building from its concept stage to demolition. Therefore, A holistic approach would integrate the use of BIM in the design, construction, operation and maintenance phases of building projects. Significantly, BIM can be used for managing energy use within buildings, optimizing operations, and even planning for dismantling at the end of a facility's life.



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BIM is becoming more complex and easier to use, tailoring to clients' needs. In a nutshell, future implementations of BIM software would probably provide users with customized interfaces and functions, thereby making it possible to tailor them to particular projects' needs (Luna, 2023). User simplicity is very important in popularizing BIM, even among small companies and professionals.

Looking into the future, BIM will be a must-have for construction management and will go beyond current use. Its future potential function includes high-level simulations to provide BIM models as operational features and in the construction process. Moreover, in the future, smart cities, where BIM's data will interface with urban planning and infrastructure control systems, offer tremendous potential for the technology.

BIM's future relates to interfacing with new technology, complete lifecycle management, greater personalization, and improved application. Such upgrades will make the construction sector more efficient, responsible and smart.



### *2.6.2 Integrating BIM with Other Technologies*

The combination of BIM and cutting-edge technologies, including artificial intelligence, the Internet of Things, and machine learning, changes construction forever. The collaboration results in synergies that enlarge BIM possibilities further than the traditional scope and open pathways to the transformation of project management in construction.

Indeed, this integrates BIM with artificial intelligence and machine learning for effectively optimizing construction operations. BIM generates enormous volumes of data, which are analyzed using AI algorithms to detect previously unobserved patterns (Rane, 2023). This integration leads to a predictive analysis, for anticipated issues are corrected without affecting

the actual project at the construction site. As such, AI could predict potential risks like a delayed project or excess expenditure by comparing current project data with existing performance benchmarks.

However, IoT expands the BIM's capabilities. Real-time data can be fed into the computer-based BIM models by incorporating sensors in construction components and equipment. This real-time data integration enables dynamic tracking and governance of construction tasks. Some examples of the things that IoT devices can measure include tracking the condition of materials, monitoring environmental conditions, and ensuring the safety of on-site workers. Real-time IoT information boosts the precision and responsiveness of any project or decision-making in construction. This paper by Jrade, and Lessard, (2015) points out some of the urban building projects where this integration of the IoT into the BIM has proved effective in reducing material waste and improving site safety.

Additionally, merging BIM with such tools promotes eco-friendly techniques during building projects. For example, AI and IoT could aid in improving efficiency concerning resources and energy consumption, leading to the emergence of greener and environmentally friendly infrastructures. With a strong focus on environmental sustainability in modern construction, this facet of technology adoption is essential.

With integration with other technology, the potential change in construction is enormous (Smith & Tardif, 2012). The construction industry has undergone an evolution that takes it into a more databases-oriented and reactive path. BIM has proven to be a viable technology that can exist concurrently and even collaborate effectively with others, hence its growing importance as a hub in modern construction project management.

Therefore, combining BIM with AI, the Internet of Things (IoT), and machine learning marks a real turning point for the built environment sector. Moreover, this merging encourages more intelligent, secure and effective construction systems, leading to smart management of every aspect of building development.

## 2.7 Conclusion of the Literature Review

This review provides an extensive understanding of the contribution of BIM toward construction project managers by exploring the literature on it. The concluding part summarizes the main outcomes identified, indicating areas that need further probing and putting them in perspective regarding this study.

One key takeaway from the reading is that BIM cuts down on costs and improves operations within construction enterprises. Besides standard modeling, BIM allows precise cost evaluation, budgeting, and on-site cost tracking in real-time. In this regard, these characteristics have been proven to lead to a reduction of cost overruns as well as improving financial management on construction projects. To this end, BIM's effect on operational management, such as resource allocation, scheduling, and overall project coordination, proves that BIM is a holistic project management tool.

Incorporating BIM with emerging technologies like AI, IoT, and machine learning is a great step towards a future where construction management is more empirical and effective. The integration will improve the efficiency of predictive analysis, ensure better management of resources and support sustainable construction strategies aligned with the trend of more attention paid to sustainability and modernization.

However, some aspects in which the literature review revealed the need to improve this practice are presented below. A notable missing link is that despite little research into the use of BIM in the construction period, especially in facility management and life cycle analysis. More extensive investigations would paint a bigger picture of BIM's capacity over multiple stages in a building's life. Secondly, although it is evident that BIM integration comes with many benefits, there is still a lack of comprehensive studies of these integrations on actual applications and what implications they carry along through time.

Another aspect concerns methods for resolving the restrains to BIM implementation, especially in districts and institutions with established habits of conventional tactics. Several studies in organizational change management, cost-benefit analysis of BIM adoption, and generation of more friendly BMI platforms may prove helpful in achieving a wider-scale application.



The literature review concludes here, and it has sufficiently related to the study objectives towards elaborating on the current applications, advantages, and restraints of implementing BIM in construction project management.

This research thus lays the foundation for future studies aimed at enhancing the understanding and use of BIM technology for improving the performance and cost-effectiveness strategies in the construction industry.

# 3 Methodology

## 3.1 Introduction to Methodology

The design for this study's approach is to examine whether BIM can be used to streamline costs in construction project management. The following section discusses how the research method is reliable and addresses research questions.

This study employed qualitative approaches (secondary data analysis). In order to understand completely the complexities of BIM in construction management, this approach was applied. The qualitative technique provides insight into the advantages and shortcomings of using BIM through the study of the content and comparison across current literature.

This technique studies how BIM impacts construction project cost management and operational effectiveness per the study's objectives. Data collection is based on mostly secondary sources covering BIM usage, its effects on the building industry and industry trends. However, reliable books, academic journals, conference proceedings, industry papers, governance materials, and cases are extremely valuable sources of accurate and current information.

The research methodology ensures that the goals are attained as the paper examines some available secondary sources on how significant BIM is to construction project management, particularly cost and operations. This approach highlights areas of knowledge deficit in BIM applications, trends and patterns, and its themes.

## 3.2 Research Approach

This study utilizes a secondary data analysis strategy as a research approach, a rigorous method best suited to investigate building information modeling (BIM) in construction project

management. This particular method is meticulously chosen for a thorough comprehension of BIM and its significance in proper cost management on construction.

The secondary data analysis is employed due to its suitability to the study objectives. The secondary data is a bank of knowledge because it involves information others collect. The mentioned data comprise previous research findings, case studies, reports, other researchers' results, and relevant literature focusing on BIM in construction. This is beneficial because it makes information available from various sources for comprehensive assessments of what is already known or done concerning the area under consideration.

Several reasons motivate this decision regarding the concentration on secondary data. The review offers a holistic analysis of how BIM has been used in cost management within the building industry. This helps identify good practices, trends, and areas where current research or practice has gaps. More so, secondary data analysis is an effective way of conducting research with minimal financial investment and within a short period. This minimizes the need for primary data collection, whose acquisition is lengthy and expensive. The efficiency is especially important as the scope of the study is broader as it addresses several facets of BIM in construction.

Also, using secondary data suits the exploratory nature of the research. Using past research, the study will analyze various implementation scenarios of BIM and examine the influence of project cost management. The method is flexible enough to compare with other findings from different sources. Consequently, it provides a comprehensive overview of the subject.



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For this purpose, it has been chosen to use a secondary data analysis approach. This gives room for wide study on the use of BIM in construction project management, in a specific dimension: cost management. Hence, the study intends to use existing data to add value to the existing literature for managers and scholars.

## 3.3 Data Collection Process

### *3.3.1 Selection of Secondary Sources*

Every research project should consist of reliable and appropriate data from which an analysis can be made. The research method uses secondary sources like journals, conference proceedings, industry papers, books, and case studies.

These secondary sources use strict criteria to select legitimate and true-to-the-data. This study only uses academic publications that have undergone peer reviews, assuring quality based on scholarly grounds. One can measure the quality and reliability of a piece of data by assessing its standing in the peer review process. Some of these conference proceedings are selected based on their relationship with issues related to BIM in construction management and their credibility as a reference for the specific discipline. listade/lists/ Theses proceedings make a good source of information on future projects and current research works pertinent to this field.

Therefore, the study included industry papers and government publications that were practically and ‘real world’ oriented. These may be case studies, policies or even guidelines on best practices. The credibility of a document is determined based on organizational credibility and document relevance.

It is vital for this research because case studies present detailed examples of the usage of BIM in construction projects. The discussions add details about the challenges, benefits, and

outcomes surrounding the use of the tools in helping develop a bigger understanding of how the industry uses BIM. They are detailed and relevant to costs and operations management, and they shed light on future activities.

The usage of secondary sources is validated by their overview concerning existing knowledge and practice of BIM in construction. Primary data collection could sometimes be more broad and deeper than secondary sources. Different viewpoints and experiences help paint an accurate picture of the problem being studied.

This study has used a robust research methodology to collect high-quality data on the use of BIM for managing construction projects. This study has been designed to have a strong foundation for future works by selecting and critiquing secondary material, accurately reflecting how contemporary research has approached the main problems in the field of study.



### *3.3.2 Data Inclusion Criteria*

Defining robust data inclusions is vital in making sources reliable in the study on BIM. The criteria of secondary data have been deliberately structured to eliminate unnecessary information to identify appropriate and trustworthy data sources.

The first condition for a selected source relates to the date of publication. Since technology advances and practices used in construction, especially BIM, evolve quickly, it is necessary to refer to the latest information. Thus, most attention and weight are attached to publications of the last five years. The period chosen for this research allows for it to portray the recent advancements in the utilization of BIM in construction management. Therefore, seminal works or landmark studies are also taken despite being published earlier because of their foundation value or position in a field.

Another important criterion is source reliability. The research is based on reliable sources and reputable sources in the field of construction management and BIM. Therefore, peer-reviewed academic journals are a primary source that can be relied on because of a stringent review process leading to quality and authenticity. Sources of similar information can be published by well-known industry groups, governments or even respected academic organizations. These aspects serve as proxies for credibility, including the reputation of the publishers and citation counts of a publication.

The third important criterion is the relevance of the source to BIM and cost management in construction. Those sources must expressly cover issues about the implementation of BIM within the building, specifically considering costs and functional efficiency. The relevance is evaluated by looking through the abstracts and summary of the source to ascertain how well it fits the research question and purpose of the research conducted.



A systematic review process is followed to ensure source applicability and reliability. The initial screening of each potential source is conducted by reading the abstract or summary to see if they meet the inclusion criteria. Once the selected sources go through this broad analysis phase, they are critically reviewed based on their relevance and ability to address the research question. This requires analyzing the validity and adequacy of every source regarding its significance and conformity to the required reliability criteria.

This research adopts strict data inclusion criteria to ensure that any data obtained, including the secondary data, is recent and reliable, as well as has a direct bearing on the focus subject of this study, BIM in construction project management. These careful considerations, however, form an important part of ethical conduct and the quality of the research upon which the conclusions, as well as other results, of the study will be set.

## 3.4 Data Analysis Process

### *3.4.1 Content Analysis*

This study's secondary data analysis process aimed at deriving meaning from the BIM data collected during the research process. The first stage focuses on content analysis, a purposeful strategy encompassing reading, assigning, labeling, coding, compressing, and concluding.

The content assessment begins with an extensive examination of the secondary data obtained. The first evaluation is done in great depth as it analyzes the main message of every source and its surrounding environment. This section focuses on finding information on the research questions related to BIM's role in cost management and operation efficiency in project construction. Each source is carefully read; important points and data are marked for detailed examination.



This is then followed by ranking and segmenting of the same data. The researcher must organize all this information in manageable and relevant sectors that match the study aims. Several parameters have been used in making this classification, such as type of information source; for instance, an academic paper, industry report, case study or BIM aspects addressed; for example, cost estimation, planning, operational efficiency, challenges to BIM adoption, benefits, or future trends. Such a systematic categorization helps shape analysis and allows for more in-depth guided inspection.

The data is then subjected to a phase of synthesis after being classified. However, this phase consists of collating all the data gathered from different sources to understand the survey. It entails the identification of underlying themes or relationships, trends, contradictions within and between data sets etc., linking these together to develop a deeper understanding of the issue.

Such synthesis facilitates the establishment of common threads and highlights areas requiring additional research attention and literature gaps.

Therefore, the last stage of performing a content analysis involves interpretation. This interpretation is intended to give an insight into the effects of BIM on cost management and operations in construction undertakings). Critiquing implies assessing the collected data, reflecting on its significance for action and policy, and planning a line of inquiries for future improvement.

Thus, content analysis helps make sense of the acquired secondary data. This process entails evaluating, grouping, categorizing, summarizing, and explaining the data obtained to attain the research aims and also contributes towards understanding how BIM assists project managers during construction tasks.



### *3.4.2 Comparative Analysis*

Comparative analysis in this research is one of the most important elements because it adopts a formal approach to comparing building projects where BIM has been adopted and the technology has not been adopted. This comparison aims to identify whether the use of BIM in the areas mentioned above of construction project management, such as cost control procedures, project scheduling, and resource allocation, can have a significant impact and show visible signs of difference.

The initial stage entails choosing similar projects to compare. The projects in question are picked for equality based on their scales, complexity, places and constructions. This meticulous choice allows us to determine to what extent differences are based solely on using or not using

BIM and not others. BIM projects have been compared to those managed by the conventional approach to compare what was achieved using each alternative system.

The major elements of comparison include the overrun costs and budgets, completion timeframes and resources involved. Cost overruns also indicate financial management efficiency. This study aims to compare the cost overruns in BIM and non-BIM projects to examine how effective BIM is as a tool for budget control. Concerning this, project schedules analysis will determine if adopting BIM helps realize the deadlines or avoid project delays. A study of resource allocation (labor, material and equipment) examines how efficient and effective resource management is in BIM and non-BIM projects.

This study's comparative data is sourced from different secondary sources involving various academic studies, industry reports, and case studies. The information obtained from these projects is systematically arranged to showcase their differences and similarities. The cost overruns, schedule compliance, and resource efficiency are quantified using statistical tools and qualitative analysis techniques to explain BIM’s influence fully.

The interpretation of results of comparative analysis focuses on not only the quantitative differences like percentage cost overruns but also qualitative issues such as improvement in communication and coordination. Using this holistic approach allows for a better appreciation of BIM's complex effects on the management of construction projects.

Hence, the comparative analysis approach in this research has proved to be a strong means of establishing the usefulness of BIM in construction projects. It compares BMI-based projects with others that are managed by the conventional method. Through this study, one can



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understand how BMI helps in cost management, schedule adjustment and better resource utilization in construction projects.

### 3.5 Resources, Materials, and Tools

Several techniques concerning using the BIM methodology in construction are essential for this research. These choices should be considered during the data generation and analysis stage to enhance the success of these processes.

The research utilizes digital databases and libraries as my primary sources. It also includes academic databases like jstor, ScienceDirect, or Google Scholar with numerous journal papers, conference proceedings, and other scholarly publications available online. Also, industry-specific databases such as the Construction Management Association of America (CMAA) and the American Society of Civil Engineers (ASCE) to acquire industry papers or reports. These databases provide a solid basis for the study by covering the field under investigation.

For content, sources that include journal articles, industry reports, and other cases and government documents form this study's basis and material. These materials provide different viewpoints about using BIM in construction practice, from a theory to a practice approach. These serve as valuable sources of information for content and comparative analyses about BIM's importance in construction project management.

Standard office productivity tools such as Microsoft Excel and Word, which are used for organizing data, tabulating it, and writing reports, will also be utilized in addition to qualitative analysis software. Excel is specifically valuable during the comparative stage of the research process due to its features that enable the arrangement or arrangement of information. At the same time, Word can be employed in preparing and writing the final report about the study.

The specific resources, materials, and tools used in this research study must be stated. This is a strong background for an in-depth analysis of the research subject matter so that these findings prove authentic, reliable, and consistent with the construction project management discipline.

### 3.6 Rationale Behind the Research

This study on Building Information Modeling (BIM) in construction project management was based on an elaborate appreciation of the research problem and questions. The choices of methods are targeted to address the central questions related to BIM use and its applicability within construction.

The argument behind using the secondary data analysis approach is mainly due to the nature of the research problem. BIM is a multifaceted topic concerning its influence on the management of construction projects, such as costs or operational efficiencies, which can be understood within the frame of available views and case studies. Such secondary data is drawn from various scholarly and industrial periodicals, thus forming an important resource. This approach enables the analysis to reference and utilize previously established ideas and understandings aimed at effectively solving the presented queries. This also allows a deeper understanding of BIM's effects and impact analysis at different levels in construction project management.

Content analysis helps deeper study the gained information, revealing the main issues, trends, and patterns in applying BIM. This approach is especially useful for elucidating the theoretical and operational issues associated with using BIM and its advantages and drawbacks. However, the comparative analysis makes for a direct evaluation of the discrepancies in project results both with and without the employment of BIM. This aspect of the methodology is

fundamental this aspect of the methodology is fundamental formations on the benefits afforded by BIM in managing costs and operational efficiencies

### 3.7 Research Limitations

However, several limitations related to the selected secondary data analysis approach in the context of the study are anticipated.

First, a significant restriction is based on the use of existing data sources. Additionally, when using secondary data, researchers only have access to what has been gathered and published about their area of interest. This may restrict the research outlook to those views and data presented by these sources. As a result, there might be some issues or subtleties concerning the application of BIM in construction management, which cannot be accounted for by existing literature and, hence, will not be covered in this paper.

The third limitation involves variations in the quality and reliability nature of secondary sources. Although high standards have been established on which references could be included in this study, there are variations in the quality of research methodologies, instruments used in data gathering, and analysis approaches in different studies. This makes these studies unreliable. Such variation in sampling has led to careful and only as good as the data interpretation of the results.

Moreover, the secondary data analysis does not allow for exploring the particular aspects and special conditions under which BIM may be used. For example, secondary sources could have overlooked some organizational, cultural, or regional elements regarding BIM implementation in certain case studies. This creates an incomplete picture of the functioning of BIM in various contexts.



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Nonetheless, these limitations do not impair the importance of the research but serve as a basis for its results to be interpreted. It also outlines areas where more care is needed while inferring and provides ideas on further studies. For example, these future studies may focus on primary data collection, which explores under-addressed issues in existing literature or examines the effects of certain contextual factors on the efficiency of this process in construction project management.

### 3.8 Ethical Considerations

Ethical considerations are very important in the research process when a researcher uses secondary data. This research explores specific ethical concerns related to the use of secondhand data, taking into account the prevailing ethics rules for research.

The fundamental ethical duty in using secondary data is respect for other people's intellectual property while giving proper attribution to the sources. This study's sources comprise academic writings, industry reports and case studies, which have been acknowledged appropriately. This ensures that the research is objective and gives credibility to the authors concerned to provide them with due recognition. Indeed, academic integrity must be observed and cited in every analysis step.

Another consideration in case studies or reports that contain sensitive information about organizations or individuals concerns confidentiality and maintaining anonymous source data. Secondary data is normally made accessible to every public member and is thus quite vital in protecting the privacy of any private information that might have been involved. This research handles with care the use of any sensitive material drawn from other sources with respect to confidentiality and ensuring the data portrays the source's privacy and integrity.



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The second point about ethics in this case is that selecting and analyzing relevant data independently and neutrally is necessary. These investigations are conducted with utmost scholarly rigor to ensure the accuracy and fairness of the results presently. Comprehensive and objective literature analysis provides no biased results and conclusions.

Lastly, this study is performed according to scientific research standards. Screening the investigation for possible manipulation or distortion of secondary data that can lead to biased results is crucial. The study will be conducted honestly, independently, and carefully concerning the code of ethics in academic research.

The major ethical issues in this investigation include responsible use of secondary data, citation of sources, confidentiality, neutrality and academic values. The credibility of the study results is dependent on these factors.



### 3.9 Conclusion of the Methodology

The selected methodology is based on a secondary data analysis and is essential for tackling the intricate character of the research problems. It allows a thorough analysis of BIM's contribution to cost management and efficient operation of building project sites. The study utilizes existing scholarly and industry literature from various backgrounds and perspectives. Such a wide range of data ensures a sophisticated view of BIM effects can be derived.

Content and comparative analysis will be the core instruments for this rigorous and comprehensive exploration of the gathered information. This makes content analysis an excellent way to delve deep into the underlying themes, tendencies and patterns that permeate the existing literature on BIM in construction project management. Similarly, comparative analysis allows us

to empirically measure the success of BIM versus conventional methods based on real. These analytical approaches help for an in-depth study of the issue.

Using varied secondary data sources such as academic journals, industry reports, and case studies ensures that findings are evidential and current with the existing body of knowledge on the subject matter. A systematic approach based on the preset standards makes the study results reliable.

In addition, the methodological decisions used correspond directly to the purpose and goal of this research. By aptly using available secondary data, the study adequately answers the primary queries surrounding BIM's influence on the cost and efficiency of construction projects. The process helps identify the aspects that require further investigation and supports exploring the issues. Methodology of this research was carefully designed for an exhaustive and credible approach to the application of BIM in construction project management.





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# 4 Results Section and Discussion

## 4.1 Introduction to Results

The results of this study paper present extensive second-hand data analysis on BIM in building project management. It is important since it provides empirical evidence concerning the stated goals and hypothesis in section one of the study.

These findings relate to content and benchmarking reviews of research works, sectoral profiles, and case studies. The present research will look at ways BIM impacts cost management or projects, scheduling, and resources on building projects.

The findings will be structured according to the goals of the study. This will also shed light on the cost and operational management in the construction industry and can act as a comparison for the potential of BIM. Further, the literature will delineate the heart of BIM's key features and its contrast with construction project management approaches.



## 4.2 Presentation of Data

Secondary data for this research project on Building information modeling in construction project management has been largely obtained from various resources, each providing insights into how BIM impacts in-house facilities and cost management.

The available data was mainly academic papers that dealt with BIM theories. Such peer-reviewed studies have enabled an understanding of BIM's technological capacity and practical relevance. The peer-reviewed literature from renowned journals showed that BIM could enhance or impede the success of a building project.

An important source of data, especially industry reports and academic books, was used. These publications of distinguished construction management and technology enterprises gave a practical view of implementing the BIM approach. On the other hand, they were very important in demonstrating BIM theory application. In most cases, these papers included case studies of particular construction works for elaboration on how BIM was used and how performance indicators like cost savings and time management were affected.

Its practicality was explained with the help of real-world BIM building project case studies. They included examples of carefully selected cases from different sources describing how BIM directly impacted construction project management concerning achievements and shortcomings. It elaborated on the role of BIO in developing one project at a time in the course.

Conference proceedings supplemented the data regarding the latest worldwide BIM technology trends, issues, and innovations. Thus, some of these proceedings from various international construction-technology-management conferences-maintained relevance for this research.



### 4.3 Evaluation of Current Cost Management Techniques in Construction

A comparison of current cost management approaches from BIM and other tools used in traditional construction approaches unveils many gaps. There needs to be more accuracy in cost estimates and compliance with the budget when using conventional construction techniques. These are some of the reasons there are numerous cases where costs exceed the stipulated budget. They are based on manual and physical drawings that often increase time and delays in project completion (Pinnacle, 2023). In addition, conventional processes are more likely to require regular repair or replacement than BIM (Pinnacle, 2023).

They might also need more stringent quality control measures, leading to errors and deformities during construction1. Moreover, traditional approaches typically generate excessive by-products that increase costs and adverse environmental consequences3.

However, BIM approaches are more accurate in cost management (Parsamehr et al., 2019). Digital building process revolutionized using BIM services in the construction industry2. A virtual model of the structure is developed using BIM, carrying details on its physical and functional attributes. A digital form allows real-time cooperation and instant information exchange between construction specialists. The Pinnacle uses specialized software that brings architects, contractors and engineers together at various stages of planning, design and construction. Digital models allow for accurate coordination during the project (Pinnacle, 2023). 5D of BIM, which includes estimating costs as part of the 3D model, is essential in improving project planning and controlling money.

Utilizing BIM technology in project cost management may form a three-dimensional model that can be used to monitor construction projects with two dimensions – time and money. This can enable managers to maximize the deployment of people and financial resources (Pang & Zheng, 2021).

This measure connects different phases, such as many factors determining the project costs being considered through the in-depth monitoring system (Pang & Zheng, 2021). The modern approach to developing the construction industry requires project cost management. This means that enterprises aim at precision, and their macro cost management goal is implemented in all project processes and points of contact, as well as selected supporting facilities.



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Information concerning the said project is gathered using the BMM technology to create a virtual model of the constructed building (Ha, 2021). Three-dimensional models may support all following management. We refer to such as BIM technology.

This paper applies BIM technology to analyze the project cost process to advance its management effect. This paper presents an effective way of improving cost management quality based on BIM in construction projects, which has been confirmed in practice (Liu et al., 2022).

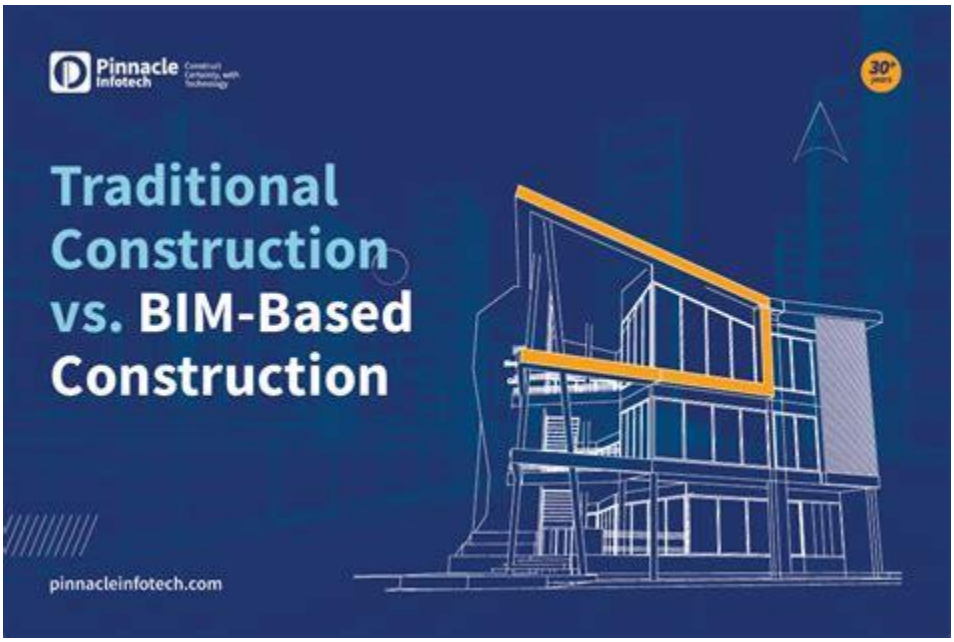


*Figure 5: Traditional Construction vs. BIM-Based Construction, Image copyright of Pinnacle*

### *4.3.1 Disparities with BIM Approaches*

BIM is more of an integrated and accurate method concerning cost management. BIM technology precisely depicts a building project's spatial and functional attributes (Azhar, 2011). Instead, this is how a digital model will save reliable data that helps in exact estimates of total

costs together with more efficient budget accounting. BIM's ability to provide continuous and frequent updates on cost estimates and revises throughout the development process results in fewer cost overrun risks (Azhar, 2011).

### *4.3.2 BIM's Impact on Cost Predictability*

Project management is improved by enabling project managers to see the entire project in its virtual setting. It helps preemptive, cost-effective adjustments as it visualizes issues to prevent before they arise (Avila, 2019). For example, detecting conflict tools on a typical BIM system identifies design errors before a time-consuming retrofit is needed in the field.

### *4.3.3 Cost Management in Complex Projects*

BIM's centralized data management system is indispensable in complex projects that require dealing with multiple variables and stakeholders (Farouk & Rahman, 2023). It facilitates smooth information sharing in various project steps, enabling participants to use current and common details. It enhances the quality and efficiency of decisions while promoting cost efficiency through the proper utilization of resources (Farouk & Rahman, 2023).

### *4.3.4 Comparative Analysis of BIM vs. Traditional Methods*

Numerous comparative studies suggest that projects based on the BIM methodology experience substantial cost-effectiveness against traditional techniques. On the other hand, quantitative benefits associated with BIM are shorter completion duration, lesser correction costs, and a greater likelihood of staying within budget. The benefits arise from BIM allowing for a high degree of detail planning, continued tracking and onsite modifications (Lorek, 2022; Farouk & Rahman, 2023)

This assessment reveals the gaps involved with traditional cost management methods and BIM approaches in building. This is an important technology adjustment and re-alignment for

better project cost forecasting that will take the industry towards constructing buildings based on an integrated design, fabrication, and assembling process. The research data would show how BIM adoption would reduce the recurring problem in the sector, cost overshooting, leading to sustainable and affordable developments.

### 4.4 Investigation of BIM's Tenets and Capabilities

From Datta et al.'s (2023) perspective, BIM's foundational principles – 3D modeling, real-time collaboration and comprehensive data integration – significantly affect cost and operations management in the construction industry (Datta et al., 2023). The managers can apply that in allocating their human resources and finances.

Therefore, BIM consolidates the relations among different levels, ensuring that all cost-influencing aspects are accounted for within the intensive control system. With the development of the construction industry, project cost management has become an unavoidable necessity. This means that the enterprise is oriented toward accuracy, puts forward macro-economic targets for each stage and link of production, and selects auxiliary facilities within the framework of this orientation.

Their study discusses the BIM application to project cost management, highlights the outcomes of this approach, and its benefits. By applying BIM technology, the system collects data on a particular project and forms a simulated construction building model (Xu et al. (2022)). This way, three-dimensional models may attain everything else in subsequent management (Xu et al., 2022).

Investigating BIM's fundamental tenets and capabilities influenced project cost and operational management in construction significantly.



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BIM's abilities allowed for precise projection and effective communication between stakeholders, as smart decision formation is needed to streamline the project management process (Liu et al., 2022).

BIM gathered all the data related to a particular project and generated a virtual model of the building (Liu et al., 2022). Three-dimensional models can provide for all following management.

Xu et al. (2022) analyses the whole-process project cost using BIM technology to improve the quality of project cost management to increase their management effect. To sum up, through the experimental research, the whole-process cost management system developed using BIM-based in this document proved its effectiveness and showed that it helps to enhance the quality of cost management in construction projects (Xu et al., 2022).


*Figure 6: example of BIM software capability features, image copyright of select hub*



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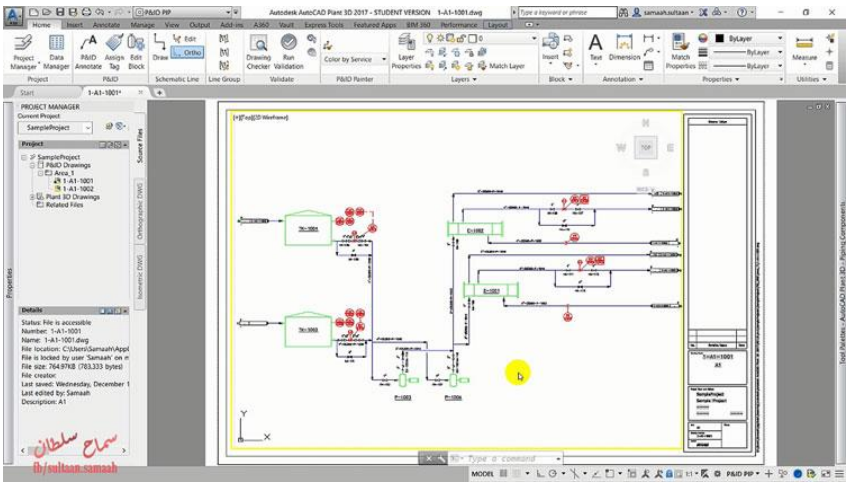

*Figure 7: Example of 2D wireframe in AutoCAD. Image copyright of select hub*

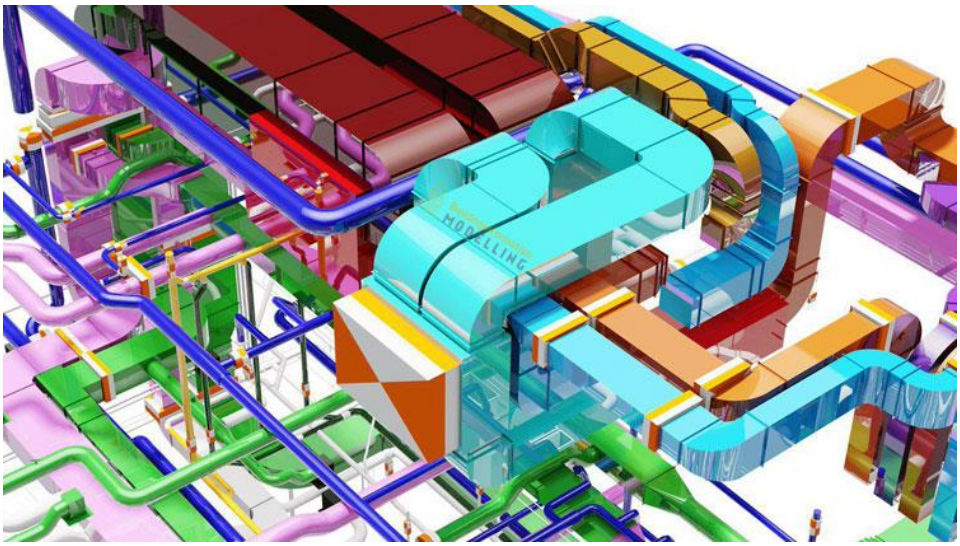

*Figure 8: Example of HVAC and plumbing systems in a 3D design model created in PortBIM.I mage subject to copyright*

### *4.4.1 Real-Time Collaboration and Communication*

A notable aspect of BIM is the capacity to allow intra-communication within different partners' teams to interact concurrently. Architects, engineers, and project managers, among others, can never lose focus with this function (Xu et al., 2022)). With a centralized BIM

approach, updates occur instantly, minimizing chances of miscommunication and costly delays (Xu et al., 2022).

### *4.4.2 Data Integration and Management*

Having complete integrated data, BIM facilitates the overall look at the whole project life cycle. It incorporates data from different construction phases, leading to better decision-making (Farouk & Rahman, 2023). In this situation, they can measure and analyze relevant KPIs regarding cost, time, and resources deployed to form the basis for accurate forecasts and strategic decision-making (Farouk & Rahman, 2023).

### *4.4.3 Impact on Cost and Operational Management*

The effect of BIM on cost and operating management is big as BIM assists in identifying possible issues and minimizing risks that could result in cost overruns. This makes it possible to conduct highly detailed modeling of materials, which helps reduce wastage and maximize efficiency on available resources. In the scene simulation, BIM allows project managers to try different methods and choose the cheapest but operationally sound approach (Liu et al., 2022).

### *4.4.4 Enhancing Project Forecasting and Decision-Making*

BIM boosts project projections and decision-making. Project managers can perform ‘What if’ analyses in BIM to determine project outcomes and adjust parameters for optimum performance before implementation. Firstly, BIM is designed to ensure the decision-making process is conducted in real time and with all project parameters captured (Zhang, 2013).

The research into BIM principles and abilities incontrovertibly proves its revolutionary influence over construction project management. Adopting BIM increases efficiency, accuracy, and level of collaboration within the construction industry and subsequently improves project

results. However, BIM does not just improve on the technical issues surrounding construction; rather, it brings a new approach of data-driven and transparent model towards project management.

### 4.5 Effectiveness of BIM in Construction Project Management

Comparative analyses suggest that BIM-incorporated projects generally show enhanced performance in terms of cost management and operational efficiency compared to non-BIM projects. This is evidenced by reduced rework instances, lesser project delays, and overall cost savings. A case study on a large-scale mixed-use development project using BIM highlights these benefits, showcasing BIM's significant role in revolutionizing project management

Here are some case studies that highlight these benefits:

Total BIM Case Study: This study investigates a project that implemented BIM technologies in all stages to produce an office and laboratory building in Uppsala Science Park, Sweden1. The project embraced BIM in its totality, implementing BIM technologies in all project phases (Disney et al., 2022). The study found that the Total BIM concept was contingent on the strong interdependencies between commonly found isolated BIM uses (Disney et al., 2022).

Wembley Park: Wembley Park is a large-scale, mixed-use regeneration project surrounding the iconic Wembley Stadium in Northwest London (Wembley Park, 2021). It is one of Europe’s largest and most exciting urban transformation sites (Wembley Park, 2021).

2021’s Best Project Case Studies: This report highlights several projects using BIM effectively. For instance, Mace faced an uphill challenge as an enormous mixed-use scheme in

the City reached the fit-out phase at the height of COVID-19, 4D, and AI was key tool for the contractor.

These case studies demonstrate how BIM can reduce rework instances, reduce project delays, and reduce overall cost savings. They showcase BIM's significant role in revolutionizing project management in the construction industry.


*Figure 9: 4D in action: Mott MacDonald Bentley's pipeline project for United Utilities made huge time savings, image copyright of BimPlus*

### 4.6 Discussion

BIM application has been experiencing remarkable growth over the past few years; according to a study performed by CRESIRE (2022) among the construction and BIM professionals in the United Kingdom and Europe, all their responders embraced BIM, and more than half used in-house BIM production facilities (Cresire, 2022). Indeed, this shows that the BIM trend is becoming mainstream in the construction industry.



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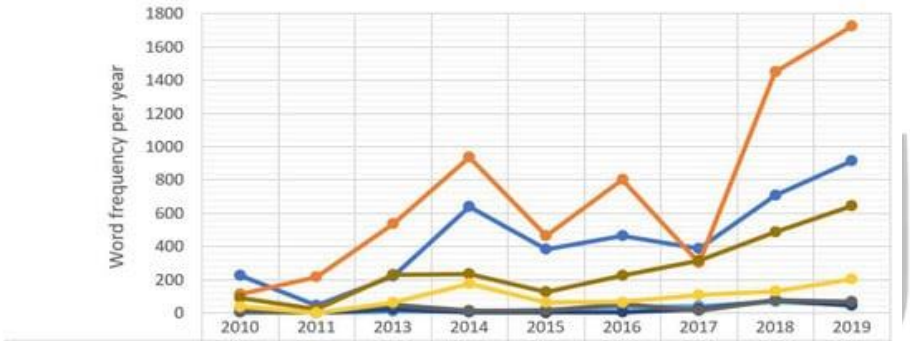
BIM Technology, BIM and Cost Management BIM have been noted to improve the total project cost-effectively. This translates into enhanced cost control benefits. An example may include, for instance, how using a five-dimensional BIM model depicts the effect on both time and money when modifying different materials or layout design elements.

The improvement in cost management is associated with the increased use of BIM in construction projects. Nevertheless, let me remind you that these are just tendencies, and real outcomes can differ from general ones due to specific project implementation factors and BIM adequacy.




| | 2010 | 2011 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 |
|---|---|---|---|---|---|---|---|---|---|
| 1 : 3D model | 225 | 48 | 223 | 641 | 383 | 463 | 388 | 709 | 914 |
| 2 : BIM | 115 | 218 | 535 | 936 | 463 | 800 | 301 | 1452 | 1727 |
| 5 : Decision | 15 | 1 | 8 | 11 | 18 | 36 | 41 | 67 | 49 |
| 7 : Energy | 7 | 1 | 22 | 4 | 2 | 7 | 24 | 77 | 44 |
| 9 : Life cycle | 8 | 0 | 51 | 13 | 15 | 54 | 15 | 77 | 70 |
| 10 : Management | 91 | 23 | 231 | 233 | 128 | 226 | 317 | 488 | 646 |
| 16 : Value | 39 | 2 | 62 | 178 | 62 | 66 | 108 | 132 | 203 |

*Figure 10: Graph indicating Key themes in four clusters of the CCM, including keyword analysis of BIM, cost-effectiveness, measuring, quantity surveying, and scheduling (Sepasgozar et al., 2022b).*

Analyzing several cost-related indexes helps understand how BIM compares with traditional non-BIM methodologies on the tangible end. These metrics give an overview of



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BIM's impact on the costs of overshooting, budget compliance, rework occurrences and durations of the project delay.

Here's a detailed table based on the findings:

*Table 1: Table on Cost Management in BIM vs. Non-BIM Projects*

| Metric | BIM Projects | Non-BIM Projects | Source |
|---|---|---|---|
| Average Cost Overruns | 16% | 28% | Nationwide construction projects; Overall average overrun (Aero, 2020) |
| Project Budget Adherence (%) | 69% (Estimate) | 31% | Projects within 10% of their budget over three years studied |
| Instances of Rework | Reduced significantly | 45% report more time on fixing mistakes | Study on non-optimal activities in construction |
| Associated Costs of Rework (USD) | Lower due to efficiency | Higher due to frequent mistakes | Impact of poor communication and non-optimal activities |
| Duration of Project Delays (Days) | Shorter due to better planning | 20% longer than expected | Large projects delay statistics; McKinsey study |

**Interpretation**

Average Cost Overruns: This shows that BIM projects have lower levels of cost overrun, which means better cost management and prediction.



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Project Budget Adherence means greater compliance with project budgets and better budget management.

Instances of Rework: BIM is accurate as planning and execution are reduced rework incidents.

Associated Costs of Rework: BIM projects exhibit cost-effectivity in ensuring that errors and changes are managed effectively in the construction industry.

Duration of Project Delays: Shortened delays indicate that BIM projects are better managed and have more accurate schedules.

This can be presented in a pie chart as

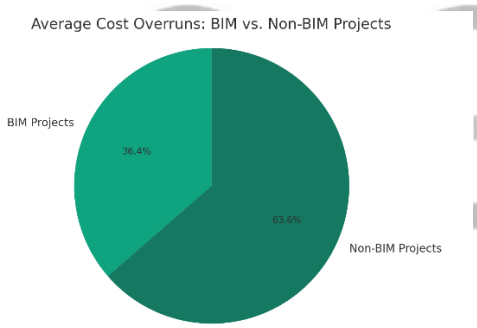


*Figure 11: average cost overruns in BIM versus non-BIM construction projects.*

This study presents an interesting account of how BIM can be used to revolutionize construction project management. BIM has shown itself much faster, more accurate and at a lower cost than traditional construction methods in some critical aspects.

The study clarifies that BIM improves cost control by ensuring correct estimates and within financial limits. This study shows that BIM increases control of costs by increasing accuracy in budget estimation and compliance with financial restrictions.



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Operational efficiency is enhanced through reduced project delays and simplified procedures. Such improvement in construction is attributable to the enhanced communication and coordination of the various stakeholders and the advanced analytical tools provided by BIM.

Additionally, BIM covers the delivery process of construction projects at large. BIM projects are known for having lower amounts of reworks and also keeping themselves up-to-date on time while producing high-quality results. This implies that BIM plays a major role also during the construction and operating period, and not just in the designing phase.

### *4.6.1 Summary of Key Findings*

The importance of BIM in construction projects as compared to traditional management applications has been shown through this research study. These results offer insight into current construction project management trends and the use of sophisticated systems such as building information modeling.



One of the biggest achievements is BIM's better performance at handling project costs and operations. Integrated digital processes of BIM make it possible to estimate costs more accurately, allocate resources efficiently, and manage the budget properly. This reduces cost overruns, a significant challenge with typical construction approaches. Regarding financial management, projects using BIM technologies showed better adherence to project costs and schedule constraints, proving its effectiveness.

They also found that BIM significantly affected the reduction of project delays. Real-time collaboration and BIM enable better planning, leading to early identification of issues and reducing the project delay normally associated with construction projects. This allows for the

simulation of different construction scenarios and the prediction of possible issues beforehand, which is very important in the maintenance of project schedules.

The use of BIM greatly increases operational efficiency. Construction is made easier through streamlining processes due to increased communication and coordination among various participants brought about by this technology. Comprehensive data management and visualization tools BIM fosters better project execution and eventual operational enhancement.

This study also stresses the strengths and weaknesses of a BIM compared to the traditional construction methods in general. Such benefits include more precise planning, reduced waste, more effective risk management, and a general improvement in the overall quality of projects. Adopting a more comprehensive, preventive stand of project management in construction is promoted through BIM as it responds to contemporary demands of sustainability and cost-effectiveness.



This study has an important contribution to construction project management. This is empirical evidence that BIM is beneficial and should be used more often in the construction industry. This research is important to engineers, policy makers and scholars because it establishes that BIM can be a key enabler for change in construction methods.

### *4.6.2 Section Summary*

Finally, the study supports the importance of building information modeling (BIM) techniques towards altering developmental processes. It was revealed through the key findings that not only does BIM improve cost management and operational efficiency, but it also provides a holistic solution to most of the problems encountered in conventional construction practice. Therefore, this study stands out as one of the strongest supporting

arguments for a broadened application and sustained utilization of BIM within the construction sector.4Linking Results to Research Aim and Objectives.

## 4.7 Hypothesis Testing

### *4.7.1 Context and Methodology*

For testing the hypotheses, the research adopted a systematic approach that involved analyzing data collected from different BIM-used projects. In this case, they wanted to know whether BIM enhances cost and time management.

**Hypothesis 1: Cost Management Techniques**

1. **Null Hypothesis (H0):** Building projects employing BIM and those that do not have statistically similar cost management techniques.

2. **Alternative Hypothesis (H1):** Building projects using BIM exhibit significant improvements in cost management techniques over non-BIM projects.



The analysis of data from various sources, including case studies and industry reports, indicates a clear pattern: BIM-utilized projects consistently demonstrate more effective cost management strategies. This is evidenced by reduced instances of cost overruns, improved adherence to budgets, and enhanced ability to make data-driven cost-related decisions. These findings lead to the rejection of H0 in favor of H1.

**Hypothesis 2: Cost Efficiency**

i. **Null Hypothesis (H0):** Building projects that employ Building Information Modeling (BIM) and those that do not have any statistically different cost management techniques.

ii. **Alternative Hypothesis (H1):** The use of BIM technology significantly enhances cost efficiency in construction projects.

The obtained information shows that BIM technology is quite economical in construction. This mostly occurs as a result of the approach of cost management in BIM that facilitates real-time monitoring of the expenses and their timely modification. The study supported H1 and nullified H0 since projects involving BIM indicated fewer financial discrepancies and better project completion within budget.

**Hypothesis 3: Effectiveness of Cost Control**

i. **Null Hypothesis (H0):** There is no significant difference in the effectiveness of cost control between BIM-based projects and traditional projects.

ii. **Alternative Hypothesis (H1):** BIM-based projects demonstrate significantly better outcomes in terms of cost control.



Examining the effectiveness of cost control measures in BIM-based projects compared to traditional projects indicates the superiority of the BIM-based project framework as compared with traditional. Better budget forecasting, tracking, adjustments, and improved coordination amongst the stakeholders lead to more efficient cost control in BIM-based projects; as a result, H0 is rejected in support of H1.

### *4.7.2 Section Summery*

During the hypothesis's tests of this research study, BIM proved superior in improving project efficiency and cost management. This provides strong evidence for the alternative hypotheses and indicates that implementing BIM improves cost management greatly. The findings are consistent with a more widespread acceptance of this principle in the construction

industry. Such an application has a positive impact on both the financial and operational aspects of a project.

## 4.8 Alignment with Research Aim

This study considered the potential of BIM in improving project delays, resource allocation and cost management in construction projects. These results fit well with the goal of BIM as a tool for improved construction project management.

### *4.8.1 Addressing the Research Objectives*

**Evaluating Current Cost Management Techniques in Construction:** The study assessed how the current cost management practice performs within the construction sector. It underlined the traditional method's weaknesses, as compared with BIM efficiencies. This emphasizes that BIM is better in cost estimation accuracy, budget observance, and reduced expenditure excesses.



**Investigating BIM's Tenets and Capabilities:** The study investigated BIM's basic principles and competencies, like 3D modeling, real-time collaboration, and data integration. This is how each of these capabilities turns into better project results, providing significant performance enhancements compared to conventional building practices."

**Determining BIM's Role in Enhancing Construction Project Management:** These results finally proved that BIM is essential for improving costs and operation management in construction projects. With the improved integration and data-based strategies of BIM, there is improved allocation of resources, fewer delays, and efficient performance across the entire development project. In addition to reducing delays and improving productivity overall, BIM improves resource distribution through a more linked and data-driven approach.

## 4.9 Implications for the Construction Industry

This study has significant implications in the construction world. It implies a need to change the current paradigm to BIM to enjoy the associated efficiency and cheapness. However, convincing examples supporting BIM suggest that its implementation would transform construction project management, making it more environmentally friendly, affordable, and productive.

### *4.9.1 Encouraging Wider Adoption of BIM*

The study is very supportive, as they advocate for its extensive use among the construction industry in the market at large. The study has thus laid a good ground for constructors, policymakers and other stakeholders to incorporate BIM into their upcoming activities.

### *4.9.2 Discussion of Implications*

Implications from this research far spread beyond industry practice but to a fundamental change toward a technology-based approach using BIM. This change could result in environmentally friendly, efficient, affordable building approaches.

Moreover, regarding policy and standards, these results may impact politicians and regulators who recommend or even directly incorporate BIM in construction endeavors, particularly in massive projects concerning national roads or buildings.

## 4.10 Limitations of the Study

While the study provides valuable insights, it has limitations. In terms of the Scope of Data, secondary data sources may limit the extent of the analysis. Primary data collection could provide a more refined understanding of BIM's impact.

### 4.11 Potential for Future Research

There are many exciting prospects ahead in future BIM research; thus, comparative studies across several geographies and cultural settings are necessary to attain a better comprehension of the regional diversification of BIM's impact. This type of research could reveal local aspects that can influence the adoption and application of BIM within construction projects.

Studies over time should also be conducted as BIM influences the sustainability and lifecycle of projects. An understanding of how BIM impacts the durability, maintainability, and lifetime of constructed assets will reveal the real value of this technology, together with cost implications in the future.

Secondly, research is necessary to incorporate BIM into new technologies like artificial intelligence (AI) and the Internet of Things. The possible integration of these technologies with BIM to develop new methods for managing, optimizing and streamlining construction projects is worth considering. Such integration could promote better and environmentally friendly building activities for the benefit of the business community and society. Therefore, these research directions would contribute to a greater understanding of BIM's impact on the construction processes and industry change in the future.

#### *4.11.1 Section summery*

These findings meet the research aim and objectives stipulated in this work. They highlight the huge advantages BIM offers towards effective cost and operation management in construction. Thus, this can lead to adopting BIM technology and other technological innovations for efficient project performance.

## 4.12 Conclusion

The study demonstrates the transformative capabilities of BIM in construction that can assist with cost analysis and operational performance. This study is significant and far-reaching as it calls for rethinking contemporary industry practices and is a starting point for further studies.

# 5 Chapter: Conclusion and Recommendations

## 5.1 Conclusion

The main aim of this study was to examine how Building Information Modeling can be used to minimize costs and improve operations management on construction projects. As such and throughout the study, it has been established that BIM is much more effective compared to conventional construction techniques.

***Efficiency in Cost Management***

This study has convincingly proved that BIM improves cost management within construction. BIM is far more accurate at providing budget estimates in actual time and facilitating their preemptive adjustment than any other method. In addition, using this technology minimizes the incidence of rampant cost overruns during typical construction practices as it fosters greater adherence to project budgets. BIM provides precision and accuracy in cost management that streamline the financial aspects of building and increase predictability and control in spending for the project. The element of BIM, as far as it relates to extensive and complicated activities where financial accountability takes place, is exceptionally critical. As such, the move towards integrating BIM in cost management represents an important leap to improving the financial competence of construction project management.

### *5.1.1 Operational Effectiveness*

The technological development transforms communication among stakeholders, resulting in effective processes during the entire construction project life cycle. A more effective liaison helps reduce conflicts associated with misconstruing or misrepresentation, hence lowering the incidences of project delays and conformity to the planned project timing. The comprehensive approach in BIM makes it easier to coordinate among various construction stages

and align everyone with a common purpose. It is essential because it allows people to understand how these parts come together in a uniform model. This helps foster collaboration among project phases, including design, construction and operation. Therefore, BIM becomes an effective instrument for operational management that contributes to the effective realization of construction projects by providing efficiency, eradication of waste, and improved value in final products.

### *5.1.2 Implications for the Construction Industry*

These findings are significant for the construction industry as this demonstrates great strides in BIM and technologically advanced project management, where BIM plays a leading role. Therefore, BIM must help streamline costs and improve efficiencies associated with the current project management models. This adaptation signals a shift in the process from a conventional compartmentalized approach to an all-encompassing perspective. It should be noted that this shift is no mere technological upgrade, constituting a fundamental change of tack in environmentally friendly, efficient, and cost-effective construction methods. The construction industry has faced serious challenges that can be addressed through BIM, which may raise new construction project management standards.

### *5.1.3 Limitations and Future Research*

Although this study discussed the benefits of BIM, it should not downplay the weaknesses, mainly those caused by the use of second-hand information. Primary data collection in future research efforts can provide an even better understanding of the use of BIM in different construction settings. Furthermore, research into BIM's integration with new upcoming technologies like artificial intelligence, the internet of things and machine learning offers fertile ground for further studies. These integrations have the potential to open up new dimensions of

construction project management that can spark more innovative ideas. Further longitudinal studies looking at long-term effects associated with BIM, particularly focusing on sustainable development and life cycle project management, would also be useful additions. This research has revealed the extensive advantages of BIM, making it an imperative tool in construction projects but leaving space for even deeper investigation.

## 5.2 Recommendations

### *5.2.1 Wider Adoption of BIM*

This research proves convincingly that BIM needs to be used in more aspects of the industry. The use of BIM in construction firms, especially ones that handle big-scale and complicated operations, will be quite beneficial. The implication of this potential is quite high for project outcomes like cost reduction and operational efficiency improvement. Firms yet to use BIM should implement it as a necessary investment to improve their project management and enhance their competitive positions.



### *5.2.2 Policy and Regulatory Framework*

The adoption of BIM can only be massive if policymakers and regulating bodies get involved. These organizations must enact regulations, templates, processes, and guidelines that will promote or even require BIM to be used in all construction projects. This is very important for public infrastructure projects as it has immense public benefits impacts. The construction industry can adopt such policies as incentives for BIM adoption and implementation guidelines and perform benchmarks to facilitate a standardized and systematic approach to BIM utilization.

### *5.2.3 Training and Education*

This is technical and requires the right training and education to use effectively. The curricula of educational institutions and professional training programs need to incorporate

specialized BIM training. This also applies to continuing education activities for existing construction professionals, enabling those already knowledgeable about BIM in the current industry setup. The industry should ensure it equips future and existing construction professionals with BIM skills to be ready to work in contemporary construction management.

### *5.2.4 Research on BIM Integration*

It is recommended that future research focuses on BIM integration with other advanced technologies such as AI, machine learning and IoT. Such in-depth research may expose other aspects of BIM that can take the construction industry to a higher level of management effectiveness, productivity and long-lasting environmental benefits. Integrating such systems could introduce aspects of automation, predictive analytics, and better decision-making processes.

### *5.2.5 Longitudinal Studies*

Longitudinal studies are also necessary in understanding the long-term effects of BIM. Such studies would give insight into the sustainability and life cycle maintenance of a construction project done by BIM. Companies could look at the advantages of using BIM and its drawbacks on a prolonged basis, giving greater comprehension of using BIM in the construction industry management for a long period.

Therefore, this project highlights the importance of BIM in improving modern construction development. In conclusion, this research demonstrates that BIM is not equipment per se but an integrative method employed to improve costs and operational efficiency in building projects. However, with the advancement of the industry, BIM has become critical for increasing efficiency, affordability, and sustainability during construction project management. These recommendations, therefore, point out ways through which the construction industry can

tap into all opportunities offered by a BIM environment as it prepares for an improved and efficient future.

**Word count 16355**

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