ROLE OF BUILDING INFORMATION MODELLING IN REDUCING LIFE CYCLE COST BY OPTIMIZATION OF TIME AND COST

A

THESIS

Submitted in partial fulfillment of the requirements for the award of the degree of

MASTER OF TECHNOLOGY

IN

CIVIL ENGINEERING

with specialization in

CONSTRUCTION MANAGEMENT

Under the supervision

of

Dr. Ashok Kumar Gupta (Professor & Dean (Academics))

&

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by

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to

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MAY– 2025

STUDENT DECLARATION

I hereby declare that the work presented in the Project report entitled **"ROLE OF BUILDING INFORMATION MODELLING IN REDUCING LIFE CYCLE COST BY OPTIMIZATION OF TIME AND COST"** submitted for partial fulfilment of the requirements for the degree of Master of Technology in Civil Engineering with specialization in Construction Management at **Jaypee University of Information Technology, Waknaghat** is an authentic record of our work carried out under the supervision of **(Dr. Ashok Kumar Gupta (Professor & Dean (Academics)) & Mr. Chandra Pal Gautam (Assistant Professor (Grade-II)).** This work has not been submitted elsewhere for the reward of any other degree/diploma. I am fully responsible for the contents of my project report.

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CERTIFICATE

This is to certify that the work which is being presented in the project report titled **"ROLE OF BUILDING INFORMATION MODELLING IN REDUCING LIFE CYCLE COST BY OPTIMIZATION OF TIME AND COST"** in partial fulfillment of the requirements for the award of the degree of Master of Technology in Civil Engineering with specialization in Construction Management submitted to the Department of Civil Engineering, **Jaypee University of Information Technology, Waknaghat** is an authentic record of work carried out by **Sunil Sharma** (**232601)** during a period from July 2024 to May 2025 under the supervision of **Dr. Ashok Kumar Gupta (Professor & Dean (Academics)) & Mr. Chandra Pal Gautam (Assistant Professor Grade-II)**, Department of Civil Engineering, Jaypee University of Information Technology, Waknaghat.

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ABSTRACT

Building Information Modelling (BIM) transforms construction operations through digital modelling and real-time collaboration along with data-driven choices making traditional project management completely obsolete. The study investigates the fundamental function of BIM to reduce construction life cycle expenses through effective time and cost management and optimization and enhanced operational efficiency and sustainable methods.

This research delivers a thorough investigation regarding BIM's effects on building cost estimation and project scheduling systems together with sustainability efforts. BIM improves financial forecasting while reducing design errors through its implementation with Navisworks, Revit and CostX. The system allows for minimized rework and improved accuracy. Studies reflect BIM-enabled cost estimation that decreases budget overruns to thirty percent followed by project scheduling automation which accelerates timelines between twenty and forty percent. Using BIM technology for green building projects results in higher energy efficiency and reduced waste production as well as improvements in environmental sustainability goals.

BIM implementation encounters barriers because of its expensive setup requirements and employee resistance to change and incompatible model standards. A set of strategic proposals for barrier suppression is outlined within this research which incorporates government oversight and industrial educational programs in combination with AI-powered BIM models and digital twin systems.

The study confirms that Building Information Modelling has the power to change construction by enhancing operational efficiency while strengthening budget management and environmental responsibility. Digital transformation implementation within the construction industry requires new technology adoption to fulfill long-term goals of operational excellence as well as cost-effectiveness and environmentally sustainable operations. This research provides direction to construction industry experts and governmental makers along with research faculty who aim to optimize the advantages of technology used in current building practices.

Keywords: Building Information Modelling, Cost Optimization, Project Scheduling, Digital Construction, Sustainability, Artificial Intelligence , Digital Twin Technology.

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INTRODUCTION

1. Introduction

1.1 Background of the Construction Industry

The construction industry is crucial to economic growth because it directly affects GDP and infrastructure progress. The constructed environment influences people's daily lives and places of employment by supplying essentials like housing, schools, hospitals, and business districts. Furthermore, the sector's demand for goods and services contributes to the success of other businesses, leading to the creation of millions of jobs. It influences technological advancement, urbanization, and national development goals. “Building information modelling” is extensively used in the structure industry for project visualization, coordination, and design. This makes it easier for stakeholders to work together in real-time. Identifying and resolving potential conflicts between building systems before construction is its principal use in detecting clashes, which seeks to reduce errors and redos. Building information modelling (BIM) for cost estimation, materials take-off, and construction scheduling also improves project scheduling and resource allocation. In addition to its obvious construction-related applications, building information modelling (BIM) has long-term benefits for asset management via its implementation in facility management (FM) and lifecycle maintenance (LCM).

1.1.1 The significance of the building and construction sector

Given the strategic importance of the construction sector, it is essential that the data associated with it be accurate, reliable, and comprehensive. In 2003, the UK's Construction Research and Innovation Strategy Panel (CRISP) launched an Economic and Social Task Group to examine how the industry influences sustainable development. One of the group’s key objectives was to provide an overview of construction-related research in the UK, highlighting how the sector contributes to the economy, as well as to public health and social well-being.The United Nations defines the construction industry as follows: the, engineering-related land improvements, and the construction of infrastructure like roads, bridges, dams, and the like. Number three. In addition to contributing significantly to GDP and employment in the majority of nations, the construction industry is a huge buyer of goods and services produced by other sectors of the economy. Taking a broader view (which encompasses the mining of raw materials for construction, the production of building materials, the sale of finished construction goods, and a host of related professional services), construction contributed about 10% of GDP, while construction in its narrow sense (on-site construction activity) contributed around 5%. The CRISPR Task Group thought about expanding its scope to encompass property, land, and facility management, but they halted their efforts due to data availability issues and the realization that they "had to stop somewhere."

1.1.2 Challenges and Problems in the Construction Industry

Despite the high demand, construction has been discovered to be extremely inefficient due to practitioners' lack of sophistication in communicating. For the sake of efficiency, clarity, and the elimination of misunderstandings, it would be beneficial for the owners of the industry to share a common language.Though it has far-reaching effects on the economy and other sectors, the construction industry faces obstacles in the areas of product delivery, IT, and design. This industry's low productivity is a result of the fact that, despite its massive size, very little has changed. Costs associated with project delays, changes, duplication of effort, lost materials, etc., amount to billions of dollars annually in this sector. About 30% of the nearly $1 billion spent on construction in the US every year goes to waste. The financial success of construction projects is crucial in this context, but conventional systems fail to produce the desired results due to the selfish actions of stakeholders. Private sector investment is sought after by industry owners due to the limited funds available for large-scale projects. Therefore, it is crucial to keep this capital and make plans to use it. The strategy used to carry out the project is crucial to its outcome. Defining, designing, building, and maintaining a project are all steps in the implementation process.

Constant challenges and problems in the construction business include inadequate project management, misallocation of resources, and unforeseen site circumstances, which lead to budget overruns and delays. The problem is made even more complicated by environmental concerns, such as excessive energy consumption and garbage production. Relying on traditional methods usually results in poorer production, which is compounded by project inefficiencies caused by a lack of trained labour. Another obstacle to modernization and sustainability is the sluggish uptake of new technologies. Upcoming Events in the Construction Industry: One of the most remarkable technological advancements in the construction industry, Building Information Modelling has grown in popularity for usage in project planning, visualization, and collaboration in the past insufficient years. The extensive use of AI and automation in the construction industry has led to increased precision, simplified processes, and reduced opportunities for human error.A growing number of green construction projects are being undertaken with the goals of promoting sustainable design, utilizing renewable energy sources, and utilizing energy-efficient materials. The construction industry is being pushed towards more sustainable practices by these innovations, which are cutting costs, making things more efficient, and enhancing the impact on the environment.

1.1.3 Recent Developments Related to Construction Projects

Controlling the cost of building maintenance is an essential aspect of managing construction project expenditures. Successful project completion within the authorised budget requires careful planning, estimation, budgeting, financing, management, and control of costs.The construction phase is when most construction projects see their budgets go over budget. This is a big problem all over the world. Despite the use of various models and techniques for cost control, construction projects still fail to finish on time and under budget. Cost control systems are still under review because of these constant project cost variances. To keep costs down, various construction companies use similar or different techniques. The primary goal of the Quantity Surveyor (QS) is to keep meticulous records of all construction-related activities so that site expenditures can be monitored to the nearest accuracy. To ensure spending stays within budget, the on-site QS collects, records, analyses, and reports cost data daily. In most developing and impoverished nations, this is just the way things are done when building something. To improve the efficiency and accuracy of construction data for cost-effectiveness, various technologies are currently being used and various methods have been implemented. With the use of new software and technologies, cost control systems are being reshaped by the current technological trends and innovations. Due to recent innovations in construction, there have been new methods for controlling costs. With an emphasis on construction innovations and technological advancement,this study presents the latest developments in controlling construction project costs during the construction phase. How modern cost managers are making use of these innovations was analysed through X-ray analysis of the various technologies currently used to implement cost control.

1.1.4 Solutions to the Problems Facing the Construction Industry

Distinctive features of the world's largest industry construction include highly decentralized organizations, one-of-a-kind projects, brief production cycles, outdoor and unstructured work environments, and labour-intensive tasks.A large number of interdisciplinary and, at times, geographically dispersed team members must work together to complete construction projects successfully. Resolving conflicts, speeding up solutions, and keeping projects on time and within budget all depend on participants sharing accurate information in real-time. To fulfil the requirements of contemporary building projects, precise project planning, scheduling, and management are essential.This will allow for the overall optimization of time, money, and resources. Due to the client's and store manager's potential lack of familiarity with the technical terminology used in the schedules and graphical representations, the previous method of "using MS Project and Primavera for scheduling" and AutoCAD drawings was extremely laborious and time-consuming. One can generate a four-dimensional model of the project by integrating conventional methods like computer-aided design (CAD) drawings and schedule sheets into a platform. A lot of project managers still rely on outdated methods of planning and tracking progress, such as bar charts, CPM, PERT, etc. Because they do not supply the essential geographical features and data, these are a huge drawback when it comes to decision-making. In recent years, project managers have been under increasing pressure to reduce costs and shorten delivery times without sacrificing product quality. One of the most prominent areas that could use some improvement is the planning and control of the construction process. Relevant research and case studies back up common issues with decoupling planning and execution and detecting factual variance. Several scholars have pointed fingers at the inadequate application of IT and conventional project management theory as the primary reasons for these issues. At this point, management is more worried about money and contracts than they are about getting the job done on the job site.In addition, the necessity for methods and tools for planning execution, and managing resources is brought to light by an examination of IT applications in 634 constructions. One tried and true method for managing and planning construction projects is the Critical Path Approach, which has been around since the 1950s. The CPM applications have been tremendously helpful in many areas, including managing resources and personnel, creating a basis for progress payments, coordinating with subcontractors, and preparing project proposals. Nevertheless, it has come under fire for being unsuitable and has three main flaws. One of these is that it can't handle real-world constraints like precedence. Construction sites have all sorts of restrictions, including physical ones like topology, space, safety, and environment, as well as contractual ones like "time, money, quality, and special agreements". Then there are information and resource constraints like availability and perfection. Regrettably, the only constraints that CPM takes into account are time and precedence among activities. Its inadequacy in representing and integrating additional construction management problems is demonstrated by its underlying network representation. The urgency of the time goal is magnified by the rapid pace of modern development.The contractor experiences a direct rise in construction-related financial losses due to the postponement of project activities. Clients have to wait longer to get their money back because the building isn't ready to be commissioned yet. Furthermore, the contractor and the client end up at odds due to the delay, which usually leads to protracted legal processes to settle the disagreement. It is clear that the results of using traditional methods of project development that do not make extensive use of information technology solutions are undesirable; for example, it takes a long time to resolve variation orders during the design and construction stages, and a lot of time to check and recheck documentation. Comprehensively analysing and synthesizing the available alternatives in that location is incredibly challenging. Consequently, it is very difficult to come up with reasonable solutions and to ensure that sufficient expenses are incurred for the development of the necessary premises. Complex projects necessitate interdisciplinary teams, which frequently engage in unnecessary repetition of tasks. To generate a four-dimensional representation of the building project, the three-dimensional model will be combined with Navisworks and Microsoft Project. Finding out the quantitative and qualitative aspects of the project is the main goal of the research. A “building information model” can help you optimize the “time and money” spent on the project. The idea that a design is an integral part of a structure's life cycle forms the basis of the Building Information Modelling (BIM) approach. The modified procedure supplants the distributed work of the design's components and members.To accomplish this, a significant shift is made in design technology. Instead of creating 2D drawings, a 3D computer-aided model of a building is created, which includes all aspects of the design process, including architectural, “structural, mechanical, technological, and construction management” tasks. No amount of resource allocation, smoothing, or levelling can guarantee a production crew or process complete continuity. Field staff find the CPM schedules confusing and unhelpful for complicated projects. Redrawing and replanning the network is required for every network update, which is a huge pain. In addition, the CPM isn't expressive enough and isn't flexible enough to handle the field's varied construction patterns. The future system needs to be quick and adaptable so it can deal with the unpredictable nature of construction constraints that impact the status of work. Time in the fourth dimension (4D) and virtual reality are two examples of advanced visualization techniques that could be used to better communicate and evaluate schedule and constraint information. Planners should be able to use the system to model different construction options while keeping in mind potential limitations such as information and resource availability, spatial conflicts, dangerous working conditions, and technological dependencies.

1.2 Overview of BIM in Construction

At the moment, the most important digital tool for the planning of various building tasks is the Building Information Modelling approach. Throughout a “building information modeling” project's development, all experts work together on a technological platform to create, modify, and add the necessary and generated information. Procedures for possible demolition are governed by the methodology, which also aids in planning, building, maintaining, and managing the project, and allows for sufficient interoperability between various systems about various forms of investigation or simulation. The development of various project components is also facilitated by it. Around the turn of the century, building information modelling began to make waves in the construction industry as a technology-enabled, immersive innovation. Impressive projects were born out of the seamless coordination of related processes and the open communication between partners with expertise in various areas of construction, demonstrating its worth right away. The BIM computational tools greatly aid in the enhancement of the project's different disciplines due to their facilitation of parametric simulation and easy access to the data contained in the BIM model, which is developed during the project's elaboration.The construction owners, designers, builders, and managers have all confirmed the advantages of using BIM methodology in every aspect of the project. Government entities have set regulations and required implementation dates in public construction due to its exponentially increasing global acceptance. Further, the school has the important social responsibility of educating the next generation of engineers in the basics of various construction-related issues, with an emphasis on technological advances with practical applications. With this outlook in mind, it's no surprise that construction-related businesses are pushing for training programs that equip workers with the building information modelling (BIM) skills necessary to succeed in today's globalized and increasingly competitive industrial sector. The methodological concepts and broad sector applicability of building information modelling (BIM) platform development are covered in a short course that will be offered in March 2022. Course materials and learning outcomes are detailed in the text.

1.2.1 Definition and evolution of BIM:

"Building Information Modelling" is a numerical illustration of a building's "physical and functional characteristics that facilitate the planning", modeling, or collaborative design of construction projects. Originally developed as a tool for architects, building information modeling is now a platform that facilitates collaboration between architects, engineers, and construction site managers. The four-dimensional (moments), 5 D (cost), and 6D (sustainable) modeling capabilities that this tool has acquired over the years have completely transformed project planning and management. The creation, storage, and exchange of information between AECO specialists and other stakeholders have been progressively altered by emerging building information modeling tools and bits of knowledge to assist "engineers, architects, and managers in achieving best practices" throughout a project's life cycle, the AECO industry is currently heavily utilizing computer-based technologies such as "Building Information Modelling and the Internet of Things".

1.2.2 Current uses of BIM in the construction industry

Modern construction relies heavily on Building Information Modelling (BIM) to facilitate design coordination, collaboration, and project visualisation. It improves communication and efficiency by letting project stakeholders work together in real-time. The ability to discover and resolve design conflicts among different building systems prior to construction begins is one of its primary purposes, which helps to minimise expensive mistakes and redo's. In addition to facilitating more efficient use of resources and shorter project durations, BIM allows for more precise cost calculation, material quantification, and scheduling. In addition to its many uses in the construction industry, building information modelling also makes important contributions to FM and lifecycle maintenance in the long run. A building information model (BIM) is a digital model of a building's physical and functional characteristics, as described by the National Building Information Model Standard. From the start of a project all the way through to its decommissioning, it acts as an information hub that helps with informed decision-making

1.2.3 Principles of Building Information Modelling

Since its launch in September 1995, the Global Association for Interchange has introduced three major iterations of the Manufacturing Basis Classes, laying the foundation for object-based data modeling. Building Information Modeling (BIM) emerged from this groundwork as a powerful tool capable of addressing some of the most intricate aspects of construction—especially complex junctions like corners. These models go beyond 3D, extending into 4D and 5D by incorporating time and cost dimensions. By syncing design plans, procurement details, and construction schedules with 3D CAD data, 4D models allow users to visualize project timelines and track progress within a dynamic 3D environment.

The widespread adoption of BIM gained momentum when Autodesk acquired Revit—a move that positioned Revit as the industry-standard platform, supported by Autodesk's dominance in the digital design space through tools like AutoCAD. For years, professionals in construction and engineering have sought ways to accelerate delivery times, cut costs, and boost project outcomes. BIM helps make these ambitions more attainable. Furthermore, its alignment with Integrated Project Delivery (IPD) reinforces collaborative strategies by uniting people, systems, and organizational structures across every phase of the project lifecycle, eliminating silos and driving efficiency.

1.3 Revit Software

The demand for housing, one of the most fundamental human needs, rises in tandem with population growth. Buildings with multiple stories are being erected to meet the demand. Performing the breakdown and enterprise of a multi-story building manually can be an arduous and time-consuming process that can take up to a month. Learning and practicing the use of construction software is essential in today's world. To facilitate better outcomes with less effort, software is developed. The software allows us to save time and effort while accurately estimating building "shear force, bending moment, reinforcement, deflection, quantity, and cost". It also allows us to accomplish multiple tasks simultaneously. The program's integrated code books facilitate building analysis and design by the necessary codes. Columns, beams, slabs, reinforcement steel, and concrete types are all pre-programmed into the program, allowing the user to create a structure that perfectly suits their needs. Depending on the needs of the analysis and design, a variety of load combinations can be defined and dissimilar logical approaches can be employed to examine the structures. Safety and construction costs are two "of the most important factors to consider" when building a structure. In the pre-construction stage, these two principles are defined and evaluated. Several distinct phases make up the pre-construction stage: planning, design, analysis, schedule, and quantity. To determine the soil bearing capacity (SBC) and to precisely document the plot's dimensions, a site survey is conducted during the planning phase. During the design process, a standard 2D layout is created using the building's general parameters by applicable government regulations. The analysis phase involves the manual and automated calculation and verification of reinforcement details, shear force, bending moment, and other related metrics. Government organizations have established safety standards that these parameters must meet. Construction time, total material needed, and cost are all factors that must be calculated during the schedule and quantity phase. Structural engineers and architects should conduct the pre-construction. Revit, Robot, and E-Tabs are the most common programs used at this stage. One program that helps with BIM is Revit Structures.A building's 4D model (planning, analysis, design, and estimation) can be created using this program. Robotic Structures, an expansion of Revit, is used to conduct the building analysis. Beams, columns, walls, and slabs can be designed in this program, and then their safety, reinforcement, and building estimate can all be done in one place. E-Tabs is an analytical program that can be used to design multi-story buildings.

1.3.1 Features and capabilities of Revit in building design and analysis: Engineers and architects can create accurate building models with Revit's powerful 3D modeling, parametric design, and integrated documentation features. Facilitating interdisciplinary teamwork, automating processes like collision detection, and alerting users in real-time on design modifications are all ways it helps projects stay cohesive.To be considered eco-friendly, construction materials must have low energy consumption.Reducing the quantity of artificially generated power needed at a construction site is the primary objective of utilizing energy-efficient materials. From production to usage to deconstruction, energy is typically consumed by building materials throughout their entire life cycle.. To simplify the energy analysis process, modern Building Information Modeling (BIM) tools now allow users to evaluate energy-efficient options early in the design phase—eliminating the need to repeatedly input building geometry and other relevant data. At this point in the process, combining BIM with Life Cycle Assessment (LCA) tools becomes valuable, helping guide the selection of materials and components with lower embodied energy. While functional, technical, and budget-related factors usually drive material choices, early sustainability integration can shift the focus toward more environmentally responsible options.

1.3.2 Examples of Revit's use in optimizing project materials and design: By facilitating accurate quantity calculations, waste reduction, and efficient material allocation, Revit contributes to material optimization. Decisions regarding energy performance, sustainability, and cost-effectiveness can be better informed through the rapid iteration of design alternatives,which enhances design efficiency. Building design development requires practical construction production information. However, this information is often lacking, especially early in design conception. Early decisions regarding construction and assembly processes are hindered by a significant data deficit. This is due to the complexity of construction operations and industry fragmentation. Lean construction, like BIM, aims to reduce inefficiency by eliminating waste through production methods. Lean construction generates accurate data while improving and standardizing processes. Design for Manufacturing and Assembly (DFMA) principles can enhance construction efficiency by optimizing early-stage design using production data. BIM's integration of lean construction and DFMA principles can lead to continuous improvement in the building industry. This study utilized lean construction principles and DFMA to create BIM-based material selection metrics for early design.

1.4 A Review of GDP's Role in the Building Sector

The building sector in India contributes around 9% of the country's GDP. A structured project is measured as successful when the "returns on investment (ROI)" are at their highest, just like other businesses. The two main determinants of a "project's success are the amount of time and money spent" For the project to be completed successfully and to yield the highest return on investment without sacrificing construction quality, scheduling and cost estimation must be accurate and optimal. Since India is still a developing nation, there is a lot of room for construction, so future projects will be much larger and more intricate. The traditional methods used today are labor-intensive and manual. Two-thirds of issues that arise in construction projects are caused by miscommunication.Therefore, traditional 2-dimensional modeling is not an accurate solution for today's projects and only results in time waste, inaccuracy, and financial loss. "Building Information Modelling (BIM)" is used to address this circumstance. BIM offers resources that may increase the effectiveness of project cost and schedule estimation. The main tool used by BIM is a 3-dimensional depiction of a building project, which provides all parties involved with a visual understanding of the project's progress.Therefore, BIM is a procedure that generates "a model that includes both graphical and non-graphical data" AEC (architecture, engineering, and construction) professionals and other stakeholders can work together on a "building's planning, design, and construction" using a single 3D model. Thus, this article focuses on the advantages of using the "BIM" method for cost estimation, scheduling, and steps for the 5-Dimensional BIM model as well as challenges that arise during "BIM implementation, based on a review" of recent research and a case study of a residential building.

Determining the scheme's cash flow constitutes one of the greatest vital mechanisms of managing a building project, after planning and scheduling. Throughout a project, cash flow includes both cash inflows and outflows, also referred to as cash expenditures and cash inflows, respectively.Cash flow forecasting entails estimating inflows and outflows of funds throughout the project. By showing a project's cash flow profile over time, “cash flow diagrams” are crucial tools for effectively managing its finances.They display the profiles of cash inflow and outflow, and the difference between them represents the net cash flow. A curve showing the contractor's increasing cash-out standards and anticipated progress through the project.The worker must ask for a down payment at the beginning of the project to cover mobilization costs and lessen the financial strain on them during the mobilization and initiation phase of construction work.One of the most important and difficult tasks in managing and carrying out construction projects is construction planning.It entails several tasks, including choosing the right technology, outlining the requirements for the work, estimating the resources needed, figuring out how long a task will take to complete, and figuring out how various work components interact. The ultimate objective is to create a thorough plan that efficiently schedules work and manages the budget. Providing a framework for the “budget, work schedule, and communication” between work parties is the planner's main duty. Establishing a predetermined plan of action for an expected environment is known as project planning. The planning process entails establishing and honing project goals and choosing the most effective options to reach them, “according to the Project Management Institute”.The planning function establishes and manages project schedules and ascertains the supplies, equipment, labor, and materials required for each task. For project management to be successful, planners need to concentrate on task organization, as illustrated in Figure 1.1. Construction planning takes into account the different components of a project and its circumstances based on schedule, cost, or both to finish the project.

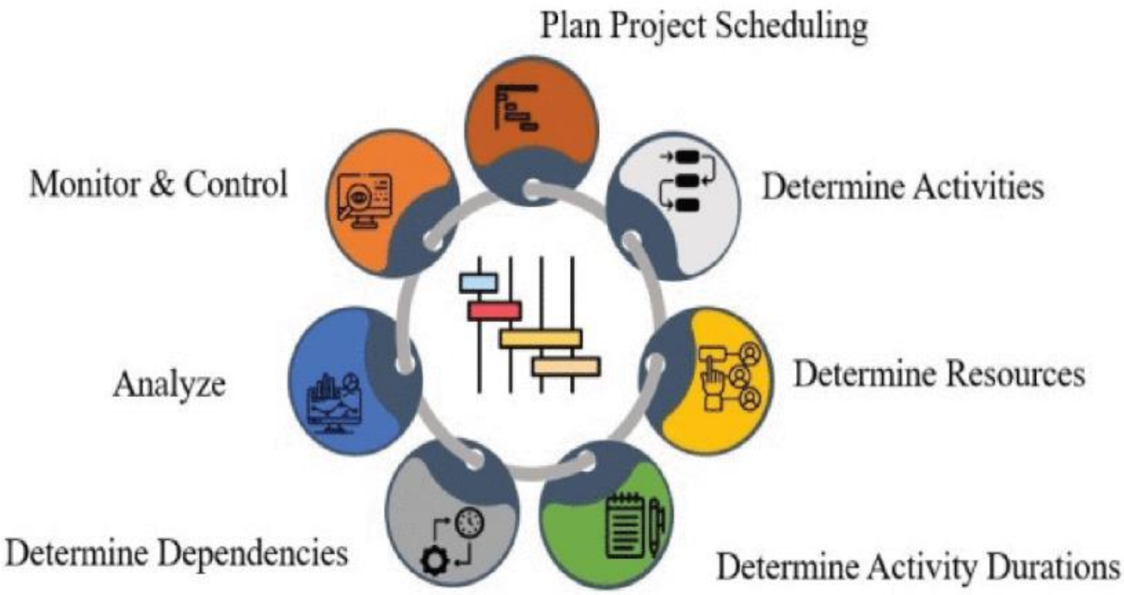

Figure 1.1: Benefits of Scheduling in Construction

In project planning, planners seek to reduce the time and cost required to complete a scheme, which can be accomplished by employing both time and cost optimization techniques. A project's price tag includes expenses directly and indirectly related to its activities. Planners can reduce project duration by carrying out a "time-cost trade-off analysis".This analysis aims to determine which Optimal scheduling within the specified constraints can be achieved by considering time-cost alternatives.

1.5 Collaborative Working and Productivity

One of the greatest benefits of using Building Information Modeling (BIM) tools, such as Revit, is how they transform the overall design workflow. A key goal of BIM is to emphasize the collaborative advantages that come from integrating efforts across all phases of design and construction.In practice, contractors frequently apply BIM in a range of partial ways—such as helping define project scope during bidding and procurement, supporting value engineering analysis, organizing construction sequences, and showcasing project strategies in marketing presentations.Research and development and optimal computer programs to increase productivity are often out of reach for small firms. Contractors often hesitate to implement cutting-edge technology due to a variety of concerns, such as uncertainty (legal/risk concerns, fear of change, fear of the unknown, etc.), high startup costs, lengthy software training requirements, and even a lack of backing from upper management. Integrating Building Information.For smaller construction companies, the software and training costs are too high to justify buying and implementing. Published in 2004 by Adrian, "Construction Productivity: Measurement and Improvement" details Adrian's ten-step program for increasing productivity was taken into account when calculating the effect of building information modeling on productivity.Multiple tiers of size, quality, and cost estimates are prepared by the architect “throughout the design phase of a project”. This is predicated on their estimation of how much the project will cost. Research confirms that BIM holds tremendous potential for the architecture, engineering, and construction (AEC) industry, particularly in enhancing productivity and efficiency for project managers. It acts as a vital link between a designer’s conceptual goals and the on-the-ground realities managed by construction teams.It also improves project execution, boosts constructability, enhances on-site productivity, and helps identify and resolve spatial conflicts before they become costly issues.

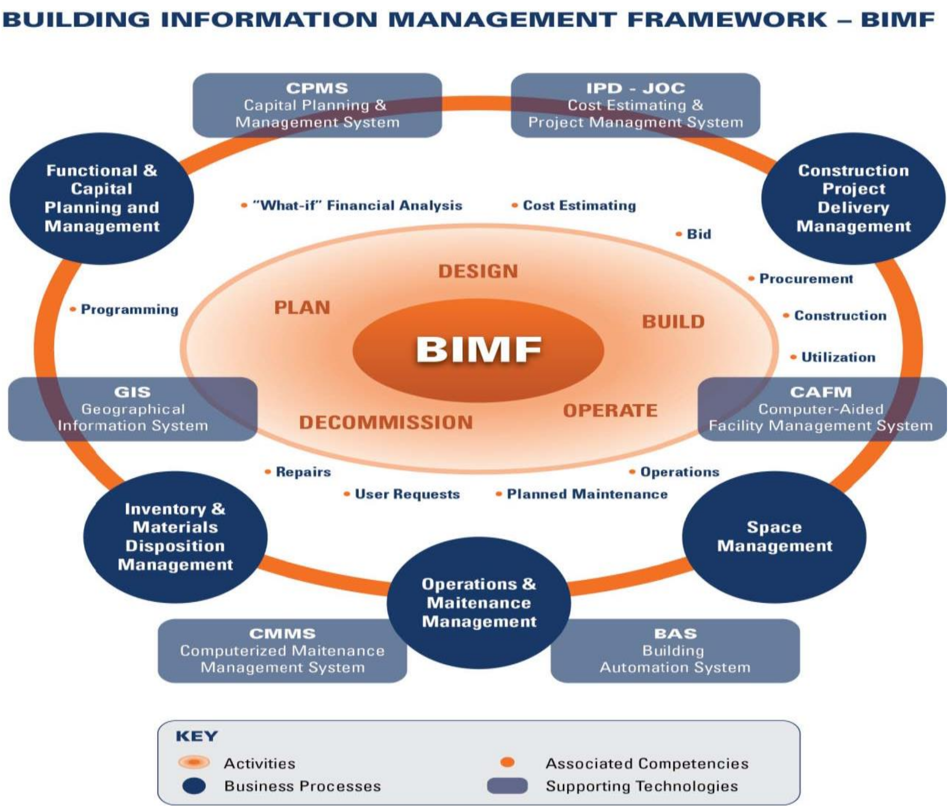

Figure 1.2: Building Information Management Framework BIMF

Because it is both a dynamic and complex factor, cost overrun has proven difficult to eliminate from construction projects, despite being one of the most impactful risks. The main worry of many construction projects and companies is cost overruns, even though there have been numerous studies on what causes project costs to fluctuate.The primary cause of this is the high resource sensitivity of the construction industry, which means that many projects encounter issues like insufficient resources, fluctuating material and equipment costs, unforeseen expenses, and accidents while working.Any change to the budget for a construction project that is not anticipated and could impact the total cost is called a cost overrun. Table 1 displays instances and proof of cost overruns from various years and contexts. Road infrastructure projects, according to Pilger and Machado, are complex and call for a wide variety of materials. Road construction is distinct from other types of building and manufacturing processes because of the wide variety of possible construction site conditions. Cost estimating is an important part of financial management, but there has to be more training and education on how to use digital tools effectively to improve the process. Methodically investigating construction costs and cost overruns is the first step in this work's identification of articles. To provide a comprehensive understanding of the existing literature, the following step is to perform a content analysis of the pertinent articles.

1.6 Understanding Claims in Construction

Completing construction projects within the specified work progress schedule has become increasingly challenging due to the compound, uncertain, and multi-lateral nature of the projects' environments. Modern technological advancements, changes in business owner priorities, and rising standards have all contributed to an explosion in the availability of complex construction projects in recent years. Therefore, one of the ways that disputes arise between the parties is through the construction industry. During construction, several things can go wrong, leading to claims, which in turn cause the project to go over budget or schedule. As a result of modifications to the previously agreed-upon terms of the contract, the claim can also be seen as a valid demand for monetary or time-based compensation, or both. Claims can be classified into various types due to the wide variety of reasons for their emergence. All parties involved in the project, including the owner, consultant, and contractor, share responsibility for any claims that may arise.Claims between the parties are the primary cause of construction project delays and overruns in both time and money. A thorough evaluation of the claims' effects revealed that the project's time and money went over budget by 25% and 10%, respectively.

Disputes also add an estimated 0.5% to 5% to the overall project cost. Every partner feels the pinch of these accusations. Each party's damage is thus reduced by a framework used to manage the construction claims.To keep relationships between participants strong, it is crucial to resolve claims as soon as possible. Neglecting to do so will cause the remaining activities of the project to be of poor quality. Despite the increased research efforts aimed at developing these methods, the growing number of conflicts in roads projects highlights the inadequacy of the current approaches to working on building claims.“Building information modeling” is one of the newest approaches that has emerged in recent years, and according to most building engineers, it is the greatest way to decrease claims. This method involves changing the old-style system into a numerical environment for efficient processing, which is made possible by the use of advanced “technologies by the construction” industries. Plus, “building information modeling (BIM)” is a great tool for handling construction claims and other project details.

1.7 The Prevalence of Miscommunication in the Construction Industry

Nearly two-thirds of all construction-related issues stem from misunderstandings about project details. In the construction industry, it is commonly acknowledged that the current methods of delivery and processes result in around 30% wastage. According to Davis (2007), once associated with other productions, efficiency in the building industry fell by 20%. In addition, a NIST study found that insufficient information sharing and process continuity results in a 15.8-billion-dollar annual loss. For the time being, 2D drawings are still the foundation of most construction industry planning processes . Managers currently look for dimensional details in 2D drawings and additional information about a building component in construction documents. On many occasions, the procedure is tedious, erroneous, and ultimately useless. This is why it's critical to choose a “building information modeling” tool that can be used extensively at every stage of the project. The project's physical tasks will become much more efficient and of higher quality as a result of this. The AEC industries have lately been very interested in building information modeling.Among the numerous advantages that follow, they make it easier to create top-notch designs that pave the way for better and more creative solutions. Through better cost estimation, the elimination of rework, and the anticipation of potential construction conflicts, several case studies have demonstrated that BIM led to time and cost savings. A greater understanding of the value of 4D computer-aided design applications has contributed to the meteoric rise in popularity of this form of 4D visualization technology over the last decade. Several of the aforementioned articles provide detailed descriptions of the advantages of 4D modeling techniques over more conventional tools; these advantages include, among other things, better project coordination, more efficient use of on-site resources, and higher productivity. Findings from some studies provide ways to use the BIM model's data to generate schedules and 4D simulations. The literature, however, argues that altering company workflow, not merely implementing technology, is the key to success.

1.8 Ancient Societies and the Techniques They Used For Planning

The plans' physical and digital versions have always consisted of visual components, with each line representing an abstract entity whose purpose is to convey the project's goals and, ultimately, the building's construction.

Figure1.3: Vedic Science Building Technology

Buildings became so complicated towards the close of the twentieth century that conventional methods of construction are now obsolete. The design specifications are extensive (spanning hundreds of pages) and necessitate collaboration across multiple fields. The project's participant count increases exponentially. With the rapid advancement of technology in the sector, the building's interconnected systems and networks are becoming increasingly complex. The author can no longer rely on rough estimates to evaluate the completeness and accuracy of a project's documentation. The “Building Information Modeling technique”, which translates to "construction information modeling" in Spanish, is a way of working together on a “project from start to finish”. The Hungarian firm GRAPHISOFT was an early adopter of the building information modeling (BIM) concept; in 1984, it was incorporated into ARCHICAD and VECTORWORKS, the first personal computer CAD software to support the creation of “2D and 3D drawings”, as well as the incorporation of a language capable of producing reports. The concept was originally known as Virtual Building (Virtual Building). AUTODESK began utilizing the BIM concept after purchasing the Texas company REVIT (Revise Instantly) Technology Corporation in 2002, while ALLPLAN also started development in 1984. Various technology providers now offer this capability, including Acca software, aecosim by BentleySystems, all plan by Nemechek, type, Graph iSOFT by Nemetschek, presto - cost, Revit by Autodesk, Colibri by Nemetschek, and TEKLA. From a "2D or 3D" model, the BIM cooperative environments enable a practical evolutionary growth that allows for the interactive evolution of implementing information related to planning or programming (4D).

Figure 1.4: Dimensions of a BIM Project

A manual has been prepared to help users with technical studies carry out construction projects using the BIM methodology up to the fifth dimension, minimizing the main drawback and maximizing the advantages of BIM.

1.9 BIM and the Controls Over Contractors' Time and Money

The global Architecture, Engineering, and Construction (AEC) industries are increasingly adopting Building Information Modeling (BIM) as a transformative technology. BIM enables users to access real-time, reliable data and a digital model of the structure, enhancing collaboration across the project lifecycle. Stakeholders such as owners, architects, engineers, and contractors are utilizing BIM to improve decision-making and project outcomes. Contractors, in particular, play a vital role in ensuring projects are delivered on time and within budget, and BIM is proving to be a powerful tool in achieving these goals.This thesis focuses on the application of BIM in managing project schedules and costs. It begins by introducing the concept of BIM and contrasts it with traditional computer-aided design (CAD) methods.

Figure 1.5: Lifecycle of a structure

1.10 Project Status of BIM

Building Information Modelling is finally seeing widespread approval in the building industry after years of development and testing in the market. "Building Information Modelling" was the name of the "Smart Market Report that McGraw Hill Construction" released: in the text. In 2008, the author transformed the design and construction industry to achieve greater productivity. The report is derived from in-depth interviews conducted with a large number of individuals involved in the construction process, including owners, architects, architects, mechanical, electrical, and plumbing engineers, building contractors, and trades people. The purpose of this report was to gather information from the interviewees' companies regarding their views on “Building Information Modelling” adoption, implementation, value, impact, and even plans for BIM development. Has sent out a survey questionnaire to 39 U.S. owners, 80 contractors, 101 engineers, and 82 architects. Using 2008 as a baseline and 2009 as a forecast, the report on building information modeling usage in the AEC industry published the survey's results.To illustrate the various uses of “Building Information Modelling (BIM)”, a survey was sent out to 424 construction firms, asking them to select a particular BIM project and respond to its questions. A total of 76.6% of the projects that were considered were for commercial buildings, 18.5% were for residential buildings, and the remaining projects were for transportation, power stations, and industrial facilities.3D building information modeling has been used for more than ten years in the process industry and heavy engineering.

1.11 Implementing BIM: Overcoming Obstacles

The term "Building Information Modelling" (BIM) refers to a set of procedures that facilitate the reuse and interoperability of data pertaining to buildings through its inception, upkeep, dissemination, and interchange. It entails creating a digital model of a building to mimic its design, building, and running processes. The final product is a BIM (Building Information Model) that is intelligent, parametric, and data-rich.This allows different project stakeholders to extract and view specific data relevant to their roles, enhancing decision-making and streamlining facility delivery. Information can be derived from the model to support a wide range of analyses, contributing to improved efficiency and accuracy.

The scope of BIM extends across all aspects of the construction industry. Beyond just visualizing geometry, BIM encompasses material specifications, mechanical characteristics, and physical properties. It plays a role from the earliest design stages such as form generation and technical analysis through budgeting, construction planning (including phase-specific geometry), and ultimately, building operation and maintenance.

BIM is structured into multiple dimensions, or nD models:

- 3D BIM includes the building’s geometry, spatial configurations, and material properties, aiding in visualization and technical planning.
- 4D BIM integrates the time dimension, supporting schedule development, site logistics, and safety management through dynamic simulations.

- 5D BIM ties into cost estimation, quantity take-offs, and real-time budget management.
- 6D BIM is focused on facility management and supports building maintenance after project handover.

For BIM to reach its full potential, successful collaboration must be built on software interoperability. Traditional project workflows often lack a centralized source of truth, leading to isolated efforts and data loss between stages. In contrast, BIM fosters integration by connecting participants through a unified platform.

The “building information modelling” approach is transforming data management in “the construction industry”.It integrates parametric design, “3D models, element-level data, coordination, communication, and visualization” throughout the entire building lifecycle. The modern work methods are meant to be improved upon by the BIM concept. Integrating processes is the foundation of this new approach, which is backed by an information-rich 3D model that lets you track the whole enterprise lifecycle seamlessly. That being said, it is anticipated that the entire process will also become more user-friendly for the various parties involved in the enterprise, whether they are working on the design or managing the building afterward.

As part of their master's degree coursework, students at a school for civil engineering and architecture came up with a few ideas for BIM applications. The building process is at the heart of the problem. The use of 4D and BIM models in construction planning; the use of 3D and BIM models in project coordination and preparation; the analysis of conflicts involving architectural, structural, and MEP models.

In contrast, BIM models are information-rich. Each component is not only geometric but also categorized—such as architectural, structural, or mechanical—making it possible to detect design conflicts automatically. These parametric objects represent a major leap forward, offering substantial support for project development.

A notable advancement in project scheduling is the 4D BIM model, which incorporates time as a fourth dimension. Created using tools like Navisworks (a BIM visualization software), this model is relatively simple to develop and allows users to access detailed information directly from the model throughout the construction process.

1.12 Project Management's Function in Eco-Friendly Building

From initial site selection and design to construction, operation, maintenance, renovation, and destruction, sustainable construction encompasses all phases of a building's life cycle by utilising environmentally conscious and resource-efficient approaches. For project managers, a key focus during the construction phase is developing sustainable schedules that support efficient and eco-conscious project execution. These schedules are designed to remain effective even when conditions or parameters shift during implementation.It is widely acknowledged that sustainable scheduling is an important aspect of construction management. This aspect refers to the ongoing optimization of time and resources throughout a project's lifespan. Specifically, building processes often involve a lot of manual labor and often call for expensive resources to be used on a large scale. A wide variety of contracted works necessitate numerous participants in the construction industry, many of whom juggle multiple responsibilities at once. On top of that, affected by factors unique to each site and

With an increase in both the frequency and magnitude of design changes during construction, this issue becomes more apparent and has a direct impact on the schedule through the need for revisions and the introduction of new activities and relations.So, regardless of the complexity or phase of the project, the underlying motivations for increasing the "level of automation in construction scheduling" (e.g., by integrating optimization and PMT as discussed here) are straightforward: to acquire quantitatively evaluated information (the schedule) as fast as possible.

In the construction industry, scheduling contract work typically involves the use of commercial Project Management Tools (PMT) that lack built-in optimization capabilities. As a result, planners often rely on time-consuming, repetitive processes within PMT to develop feasible—though not necessarily optimal—schedules. Alternatively, some create standalone optimization models to improve scheduling effectiveness.However, one critical challenge that receives far less attention is the complexity involved in gathering and processing the data needed for these independent optimization models. Feeding accurate data into these systems often demands substantial time and effort. Due to frequently changing inputs and the limited time available for updates, construction schedules during the execution phase often suffer from insufficient optimization. This can compromise the achievement of key project goals, particularly when timely and efficient resource allocation is essential.In response to these issues, this article presents a review of current efforts to integrate optimization techniques with PMT to enable more sustainable construction scheduling. A key focus of this survey is on the emerging field of "active Building Information Modelling (active BIM)," which incorporates real-time data streaming into automated scheduling, plan analysis, and update processes.

1.13 Construction Scheduling Optimization Platform

Sustainable quantitative decision-making processes are possible with optimization, which encompasses a broad range of methods including heuristics, meta- and hyper-heuristics, and exact mathematical programming.Today, most construction scheduling optimization problems are classified as NP-hard, making the selection and application of suitable solving algorithms a complex task. One of the most common objectives in construction scheduling is minimizing total project cost relative to its duration. This cost typically comprises direct expenses like labor, equipment, and materials, as well as indirect costs such as overheads and operational expenses.There is a wide range of tools available, including algebraic modeling languages, spreadsheets, and simulation software, that support the creation and analysis of construction scheduling optimization models. These tools vary in capabilities, and the literature offers a detailed comparison of their advantages and limitations.

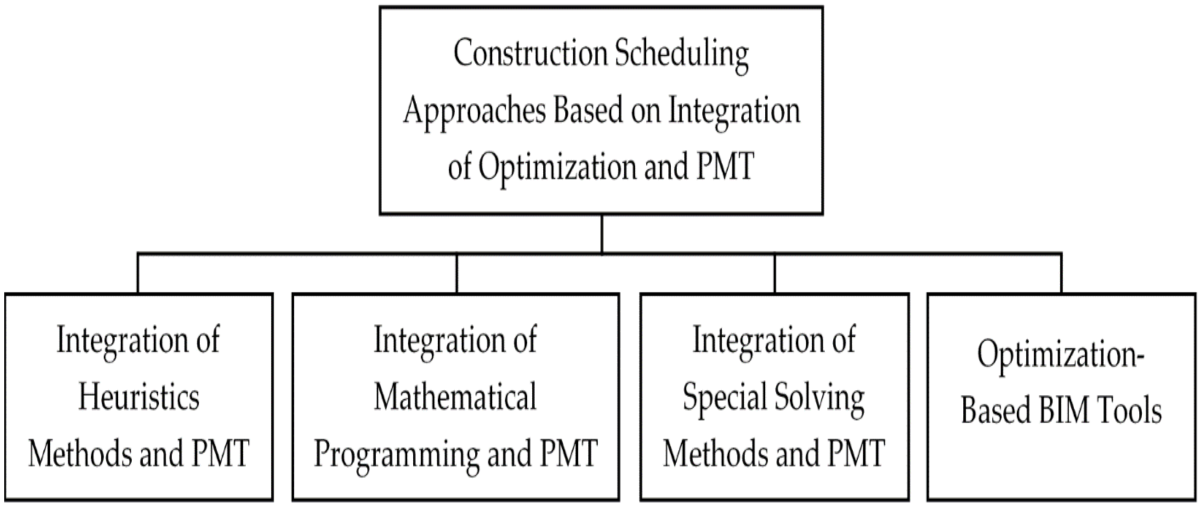

Figure 1.6: Methods of Construction Scheduling that Integrate PMT and Optimization

1.14 significance of finishing a construction project on schedule

Because they supply the actual places and systems for people to live, work, and travel, construction projects impact people's lives daily. For project management and performance evaluation, a construction project's on-time completion is of the utmost importance. As a result, scheduling is critical for a construction project's planning and control of time-oriented processes and events. Bar charts,network-based methods like the Critical Path Method (CPM), and scheduling techniques based on simulations have all been developed in the last few decades Construction project schedules incorporate resources to more accurately reflect their actual conditions. All of the building components, temporary structures, workers, supplies, and equipment must occupy a small fraction of the total available site space.But when road projects are planned, space is often overlooked. Scheduling methods based on the CPM and other conventional network models simply take the activities' temporal interferences into account.A time-space conflict is defined in the literature on space management as an interference between the necessary workspaces for two activities that are either running in parallel or are running in full tandem. Typically, a time-space conflict happens when various kinds of site spaces, like the spaces needed for "activities, temporary facilities, or machinery", interact with each other simultaneously. Because of its intricate and ever-changing nature, manual time-space planning is extremely difficult, even for seasoned site engineers, to do on crowded construction sites. This is why construction projects require an integrated approach that takes into account spatial and temporal aspects and automatically manages the interfaces between all the activities. Improved constructability, shorter waiting and stoppage times, higher productivity, safer worksites, fewer worker conflicts, no need for expensive temporary facilities, fewer reworks, and better protection of completed works are all possible outcomes of an effective site-space management system. As a result of these benefits, construction quality is enhanced, and time and money are saved. What follows are the remaining sections of the paper. First, the current research gaps in time-space management are highlighted in a thorough literature review. After that, the suggested BIM-based simulation approach's methodology and framework are detailed. The next step is to present a case study that exemplifies the suggested approach.

1.15 Building on the Construction Industry's Significance

Due to its central role in the development of infrastructure, the building industry is of tremendous economic importance on a worldwide scale. Short efficiency, high costs, recurrent delays, compromised quality, and safety risks are just a few of the massive obstacles it still faces. "The construction industry's labor productivity increased by 1% annually" between 1995 and 2014, according to a 2017 study by the McKinsey Global Institute, whereas the manufacturing industry's labor productivity increased by 3.6% annually, according to the same source. The widespread presence of "nonhomogeneous and unstructured data within the industry” is a major barrier to the advancement of construction industry technology and the implementation of Integrated Project Delivery as an alternative to “the traditional project delivery approach”. This data severely limits the ability of multiple stakeholders to collaborate, communicate, and work efficiently, as well as to integrate management and engineering. Inefficiencies, mistakes, and misunderstandings are more likely to occur when the engineering and management parts of a project do not use a unified and automated system to exchange data. As an example, when looking at these two sides of the coin, it becomes clear that the construction schedule serves as the management aspect's data source because it is the most important tool for “keeping tabs on and managing the project”. Since it is fundamental to many construction management procedures, including communication, risk assessment, and cost estimation, it is also essential for developing “an integrated project management system”.

1.16 Critical Obstacles Encountering the Building Sector

Several software tools are available to support the construction schedule. These tools mainly help planners with resource-leveling, creating Gantt charts, and implementing the “Critical Path Method (CPM)”. The planner's expertise is still crucial for creating activities, allocating “resources, developing logical sequencing”, creating a “WBS”, and manually deafening schedules to meet the project deadline. This vital part of construction management is currently suffering from a lack of investment in technology within the industry. The scheduling process is both extremely laborious and prone to errors because of this technological shortfall. When planners use their discretion to crash the schedule, they run the risk of picking activities with long durations at random or depending on their own past experiences. Not considering every possible solution fully results in crashed schedules that are suboptimal and wasteful of resources. The study also revealed that when it comes to scheduling/planning, 62% of SMEs have never used BIM, and 70% have never used it for drafting. The study went on to say that software interoperability problems and the high adoption cost of BIM are to blame for its low level of use. In addition, research has highlighted the benefits of “4D Building Information Modeling (BIM)”, which combines “3D spatial dimensions with temporal” components, to improve the efficiency of construction scheduling and planning Only a small percentage of top engineering news-record firms have adopted “4D BIM”, and even then, it's only used for a handful of projects. In addition, 4D BIM is typically only used for the pre-construction phase and then isn't used again. The perceived difficulty lies in the fact that 4D BIM creation is labor-intensive, which makes one wonder about the ROI of the project as a whole. Therefore, it is necessary to automate the development of 4D and 5D simulations to reduce the effort required and to ease the transition to BIM for SMEs.

In addition, previous studies in this area have offered promising but limited feature solutions. This includes efforts that were made before building information modeling technology existed to automate the process of creating schedules from historical data. Following this, attempts were made to automate schedules using BIM models; however, these attempts did not incorporate 4D or 5D simulations and did not have smooth integration with scheduling software

1.17 Using BIM for Clash Detection and Elimination

Efforts made to complete mundane tasks do not qualify as projects because they do not lead to the development of anything new. A one-of-a-kind project's completion time and associated costs can range from a few hours to several years. The goal or objective of every project is clearly defined. The purpose of the "Project Management using BIM" initiative is to evaluate the practicality of proposed construction timelines and workflows through the use of four-dimensional simulation.Improvements in the management and completion of construction projects of any scale or complexity may be possible with this BIM-centric 4D modeling approach to project management. Complex projects in India's construction industry have seen a steady decline in productivity and sluggish overall progress. On page 100, Therefore, it consistently struggles with the issue of project lateness. The traditional method of managing construction projects and the reliance on 2D CAD software are the key reasons why the industry is stuck in a never-ending loop. The Indian construction industry is still heavily reliant on 2D drawings for most of its current planning processes. And there's no way to integrate schedule and cost with the drawings using the 2D CAD method. “The construction industry is falling short when it comes to” implementing the necessary technology that can boost productivity and shorten project duration. The “adoption of building information modeling (BIM)” is just one example of how the construction industry has finally grasped the significance of technological progress and its advantages. Activities and the time required to complete them make up a typical construction schedule, which is typically a complex chart or network.Because they rely on manual data collection, traditional procedures are laborious and prone to mistakes. When carrying out or conveying the construction sequence, field personnel must conceptualize this schedule information about the physical building. This can be challenging if any change impacts the overall sequence of the project. With a complicated project and the increased effort required to redraw and replan the network with each update, the CPM schedule becomes difficult to understand and implement. Improved construction work visualization, enhanced project team communication, and more efficient planning are all necessities.

1.18 Obstacles and Cost Management in the Construction Sector

Problems like project delay, “cost overruns, and poor efficiency and performance” persist in today's digital age, despite the fast advancement of technology . Many people have issues with “the construction industry in China and other countries”. They say there are too many people involved, projects take too long, there is too much risk and uncertainty, and nobody is working together. They also say that there isn't enough data sharing and integration of resources. As a result of the worsening economic climate and increasingly saturated market, the majority of construction companies are currently experiencing a survival crisis . To stand out in the cutthroat construction industry, companies are under constant pressure to find ways to lower their costs without sacrificing quality or service. The same holds for customers; they want to buy something that offers the most bang for their buck. One of the key criteria for determining the success of construction projects is cost control since these endeavors use up substantial amounts of resources and investment capital.It is common practice to obtain the client's or architect's approval before testing any suggested changes to a project or design. This study aims to integrate VE with BIM and highlight its benefits using a circumstance “study of a high-rise building construction in China”. The purpose is to determine how to do this integration. What follows is a summary of “research on building information modeling for cost management and VE/BIM” integration.

1.19 Integrated Framework for VE and BIM

After WWII, when resources were scarce, the manufacturing sector developed value engineering (VE), also called value analysis.The ratio of a project's or element's function to its cost is one way to evaluate its value. VE entails holding a workshop (also known as a value study) to learn about the project, break it down into its parts and functions, identify problems like nonvalue elements, brainstorm solutions, narrow it down to a few good ones, put them into action, and then check it all over. A growing number of construction projects are utilizing “building information modeling”, which greatly aids in the timely and error-free completion of these endeavors. Direct “engineering cost, project change cost, measurement of cost, and dynamic cost monitoring” are just a few of the cost management processes that have benefited from BIM's usage for cost control. There are a few studies in the literature that discuss the integration of BIM and VE. Reengineering the process of shop drawing generation was suggested by using a BIM-based workflow. Using a window as an example, they demonstrated how this method can improve efficiency in the workplace., Green building design can be enhanced by utilizing "BIM and VE". Various alternatives to the building envelope were developed using simulation in the study to achieve optimal energy consumption. Nevertheless, the study failed to demonstrate the implementation of VE in improving the design or selecting an appropriate alternative. During the value engineering workshop's creativity phase, created a "BIM-based prototype" to help with idea "generation and retrieval". The VE workshops can be made more efficient with the help of the BIM-based idea bank. This literature review shows that there are still some gaps in the BIM and VE integration domain. A suggested framework for integrating VE and BIM throughout a construction project's various phases is shown in Figure 1.7.

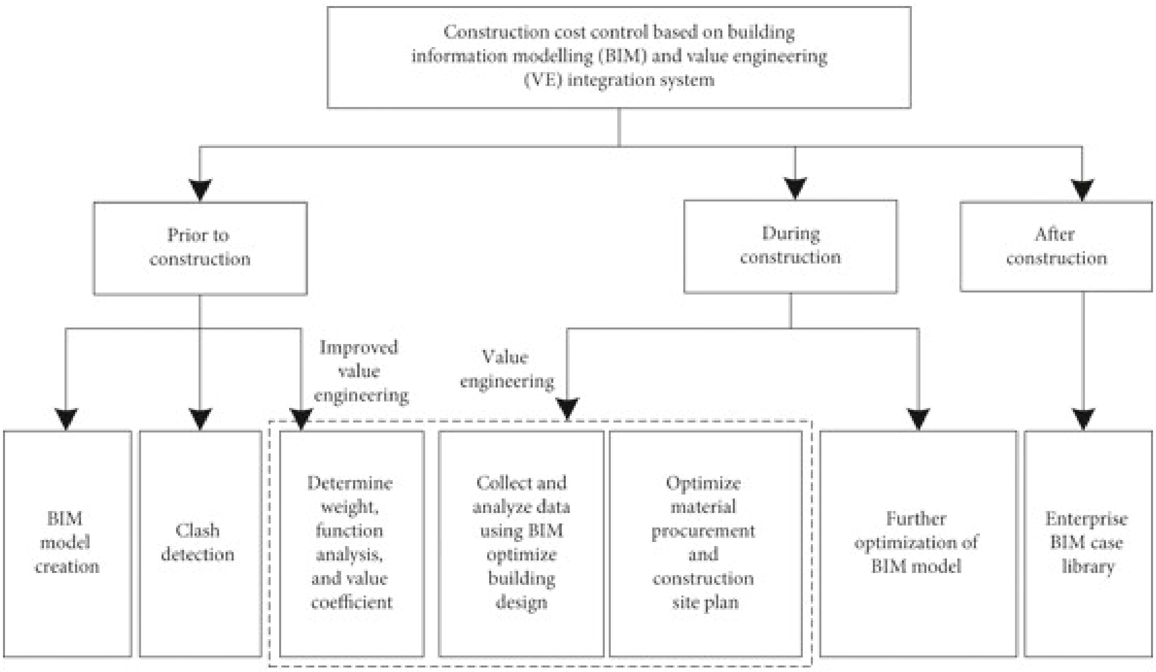

Figure 1.7: The framework for construction cost control that integrates VE and BIM.

1.20 Construction Industry's Economic Significance

For better or worse, the building sector is a lifeblood of any national economy. There are a lot of people and organisations engaged in the building process at various stages, and their goals often conflict with one another. In the construction sector, several sourcing and contracting tactics are usually used to get the final result. The methods' applicability to various tasks varies. All of the above contributed to rising prices, delayed project completion, and poor quality in the construction sector throughout the world. while it comes to technical advancement and economic growth, Syria's construction sector ranks among the worst in the world. This is mainly because of the limits and challenges that arise while trying to accomplish project goals in terms of time, money, and quality. The total 118 In order to fully grasp the complexities and challenges of the construction industry, one needs to either adopt a new work method that keeps up with the rapid pace of technological advancement worldwide or come up with a new way to improve sector efficiency, facilitate information exchange, and provide data in the correct format and at the correct time. Building information modeling's significance has increased over the past few years.Technically speaking, virtual design and construction is "the use of advanced technology to assist in both the design and construction phases," according to the National Institute of Building Science. Building information modelling is a common context in which the phrase is employed. Virtual design and construction is an approach that utilises modern building information modelling technology to collaboratively plan, design, and manage projects prior to their completion. Multiple studies have shown the benefits of utilising BIM and VDC. Using them makes it easier for all parties involved in a building project to do their jobs well, which speeds up the process and enhances the final product.

1.21 Issues Facing the Construction Sector and Effective Management

A great deal of technological and regulatory change has occurred in the construction industry during the last several decades. Project owners are increasingly picky about the commissioning process because they care about the project's effect on the environment and the safety of stakeholders and end-users.However, according to some observers, the construction industry has hardly altered its approach to the job. Worktime, budget, and quality are all negatively affected by the disparity between the rate of rule and standard changes influencing demand and the rate of change experienced by those involved in providing the necessary resources. The project setting necessitates the participation of stakeholders with diverse profiles to accomplish predetermined goals. The approach taken to plan, organize, and oversee all the tasks and activities that need to “be completed within a certain time frame” and the constraints imposed by both inner and outside factors determine the project's success or failure. One crucial aspect of managing a construction project is the planning and scheduling of the work. To finish the project on schedule and within budget, it is essential to have a well-planned strategy that allows for the distribution of resources (including labour, materials, and equipment) to different tasks throughout the project's duration

The level of development (LoD) of a building information modelling model can be anything from 100 to 500, with 500 being the most developed.This allows for the specification of “the appropriate amount of information required for specific uses”. There is more than one axis in this digital model, each of which represents a different aspect's capacity to process information; this makes it n-dimensional. By including “time-related data into the 3D model”, the fourth dimension, also known as 4D BIM, improves and mimics the construction process.Through the use of objects representing units of work, the “geometric 3D” model is linked to “the construction scheduling activities” in specialized “software such as Navisworks or Synchro Pro”.Incorporating scheduling data into 3D BIM has allowed for “the development and integration” of numerous use cases, which in turn have improved the quality of construction planning. These encompass a wide range of applications, such as logistics management, health, and safety management, site layout design monitoring of construction progress, “waste management, augmented vehicle tracking and transportation route planning, spatial conflict detection, and workspace congestion avoidance”, among others. All things considered; conventional planning methods are 40% less effective than 4D BIM simulation. The building process can be better understood with the help of 4D-BIM visualizations, which in turn enhances collaboration and communication amongst all project stakeholders.

In addition, there is a lack of literature on the optimal combination and use of “4D BIM with AI tools”, such as those that automate the generation and simulation of various structure scenarios to optimize and “develop more effective strategies for construction project management” . To address this knowledge gap, this study details a real-life project's use of 4D building information modelling during construction to show how the tool could have aided the team's objective. Additionally, to facilitate process automation and the development of 4D tools, this study introduces an ontology that is specifically tailored “to scheduling, planning, and 4D simulation”. The ontology is a valuable artificial intelligence tool for formalizing “domain knowledge, including concepts, relations, and constraints”.To showcase its use, the corresponding database is populated, and a digital tool is created “for application within the context of deep renovation projects” under the RINNO project, a large-scale European research initiative. Theoretical and empirical data sources are presented. One of these is a survey of “4D BIM” practice in France, and another is a literature review of 4D BIM applications. The “new building at the CESI campus in Nanterre-Paris” sparked a comprehensive study of a recently suggested method for implementing 4D building information modelling, which is described in. Next, “the Nanterre 2 CESI” Project showcases the suggested approach. The author presents the proposed ontology and a digital tool that automates the process of 4D BIM simulation for renovation project scheduling. While the “RINNO project case study and the” research team's plans are covered, the more general applicability of the CESI 4D BIM methodology to the construction industry is also covered. The “methodology was applied under unique circumstances”. Figure 1.8, down below, summarizes the content.

1.22 Effects of Building Information Modelling on Regular Building

The planning and execution of construction projects have been revolutionised by the use of Building Information Modelling software. Building constructions may be evaluated and their technical, economic, and environmental benefits and drawbacks can be identified with the use of "building information modelling" and digital construction. Common opinion holds that broad use of building information modelling (BIM) will have a positive impact on sustainability across the board in the construction sector.When it comes to design processes, there is a severe lack of frameworks and examples for return-on-investment calculations. The authors have chosen to create a new approach to return on investment (ROI) calculation that would work for both large and small design firms because the results produced by Autodesk Revit, the most popular ROI tool, raise some concerns (discussed later in the article). This study aims to examine the advantages of building information modeling technologies in design firms. Based on what is known now, the author looks at how to apply the ROI method to measure BIM efficiency. Additionally, a model for calculating return on investment is suggested. Lastly, the method's implementation is demonstrated using data collected from a design company in Lithuania.

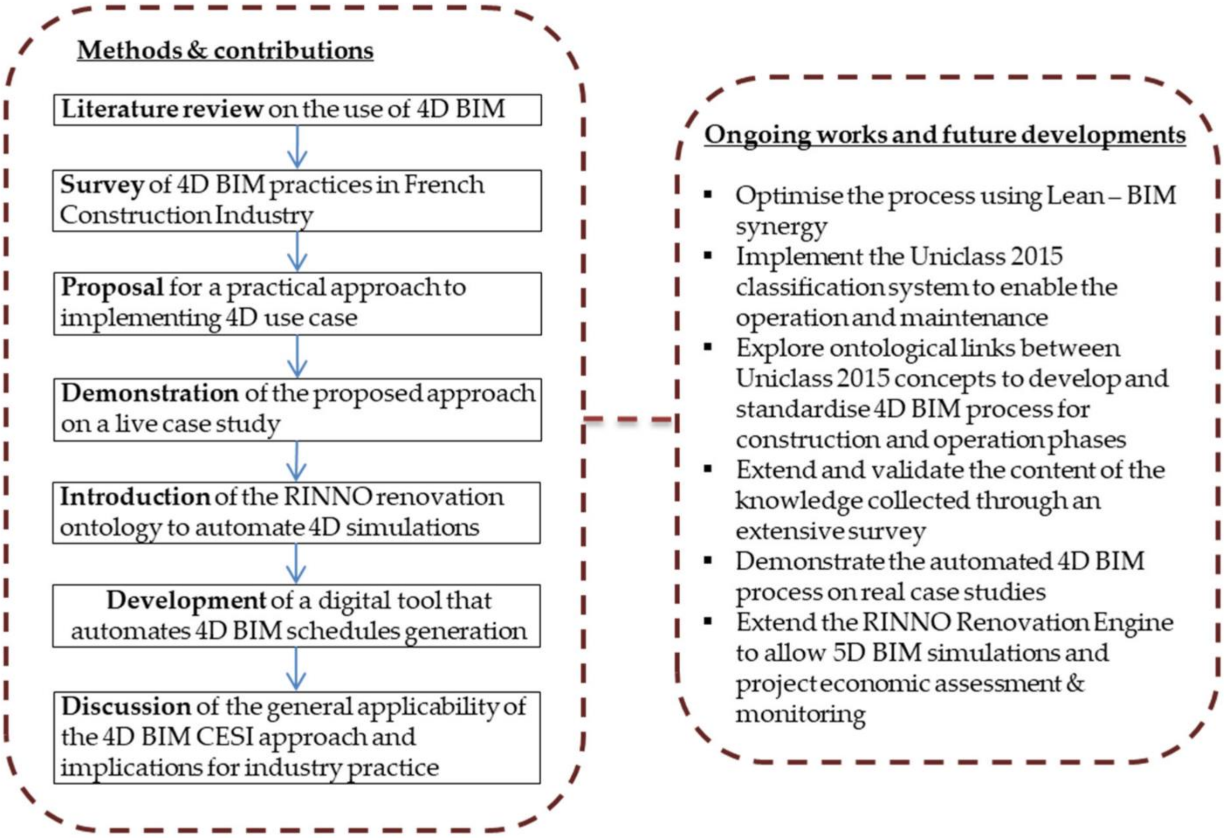

Figure 1.8: Techniques, insights, current projects and upcoming initiatives

1.23 Collaborative BIM and Environmental Sustainability

The steps involved in Building Information Modelling are as follows: (a) using modelling and computer simulation to develop a comprehensive strategy for a building's "design, construction, and life-cycle management" ; (b) creating and using a system for integrated graphical data management and information flow about the construction process description; and (c) transforming individual contractors into teams that work as decentralized units to solve complex problems and integrate separate tasks into coherent processes. As a result, numerous operations across the building lifecycle should become more efficient while spending less money. As a result of implementing PLM (Product Lifecycle Management) into building projects, "traditional 3D BIM is evolving into 4D, 5D, 6D", and eventually "8D versions". Figure 1.9 shows the combined elements that make up the BIM framework.

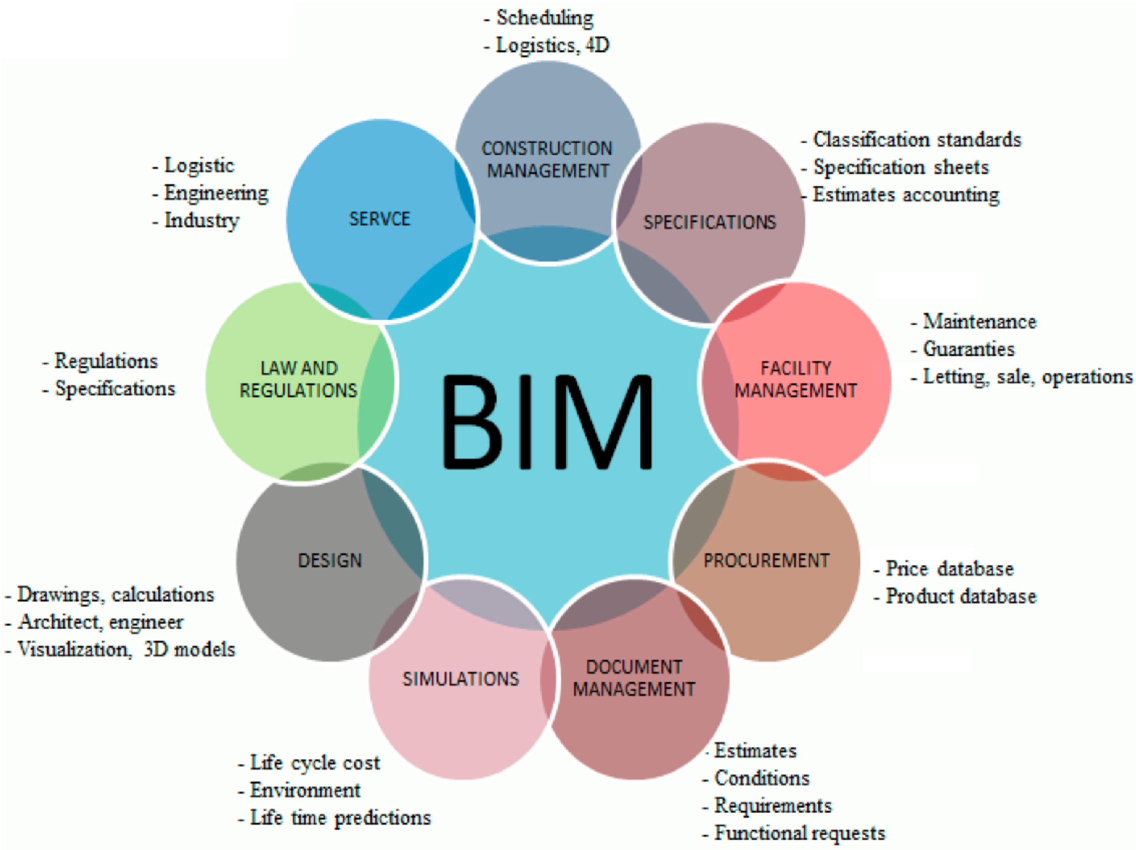

Figure 1.9: A perspective on the BIM lifecycle design

A 3D model is integrated with the construction schedule and cost data in the 5th dimension. The fifth dimension of building information modelling could lead to more accurate and predictable project changes and more trustworthy cost analyses of various construction scenarios.

This aspect is concerned with three things: first, finding potential dangers that might arise as a result of the design and construction solutions that have been chosen; second, suggesting less dangerous alternatives to those solutions; and third, indicating that certain risks on the job site need to be controlled. Sustainable building design, construction, maintenance, and decommissioning are all within reach as a result of BIM's development, according to proponents of the sustainability paradigm. Sustainable (green) design, which has been “defined as the creation and operation of a healthy built environment based on resource efficiency and ecological” design, is the most prevalent way that the positive “impact of Building Information Modeling” “(BIM) implementation on the sustainability of the construction sector is expressed”. It is believed that economic and social sustainability factors, in addition to environmental ones, will benefit from the increased use of building information modelling (BIM) technologies.

Social sustainability—helping to make communities healthier and more liveable by reducing noise pollution, improving indoor air quality, managing construction site safety, making operations on municipal infrastructure more precise and less disruptive, and making maintenance activities easier (with better timing and synchronization). Involving building occupants in establishing shared sustainability objectives, tracking progress, and commemorating successes can transform the sustainability-related data continuously collected and analyzed through BIM into a tool for social engagement.

1.24 Offsite Construction and Modularization

Construction projects include hazards due to a lack of communication and coordination among the many organisations involved, in addition to risks related to the environment, other organisations, technology, and resources.Ideas like offsite building and modularisation arose to lessen the impact of these risks while maximising the related processes. The typical onsite operations may be done in a factory ahead using these building methods, which saves time, cuts costs, and improves quality and safety on the job site. Factory workers tasked with these procedures have to study a wide range of project details, some of which are unrelated to their work and others of which might be daunting. Unfortunately, in a real-world module manufacturing setting, most of these rely on mathematical analyses, which severely restricts their capacity to conduct multiple analyses of different variables . Additionally, managers and factory workers who aren't experts often find these methodologies too complicated to use effectively. Among the most recent approaches to process, material, and cost management, building information modeling (BIM) stands out here.Visualizing processes and resources in construction is made possible through a 4D simulation that links process data to a 3D model built on parametric data. This approach has the potential to be highly beneficial for “modular construction processes”, as “4D visualization technology” takes advantage of the interdependencies between entities to simplify operations and cut out or eliminate those that don't contribute value.

The importance of construction activity scheduling in meeting project goals has kept many researchers and practitioners interested in the topic. When it comes to construction scheduling, there are a few methodologies that are commonly used to organize and communicate project activities to all parties involved: PERT and Critical Path Method

(CPM)The complexity of building projects, however, necessitates better and more efficient communication of project details. As a result, BIM has grown in popularity as a tech-enabled, integrated process that can be seen as a useful tool for encouraging teamwork in the efficient management of multidisciplinary data.One of the building information modeling technologies, four-dimensional (3D) BIM is a useful tool for project planning and management in the building industry because it combines digital construction models in three dimensions with information about time and schedule. By providing a visual depiction of the structure process over time, this technology improves communication and decision-making for all parties involved in a project.Although 4D BIM offers numerous technological advantages to the construction industry, no research has been conducted on how to enhance 4D BIM to better aid in project scheduling and planning, particularly in improving decision-making and eliminating "non-value-adding activities from construction schedules".

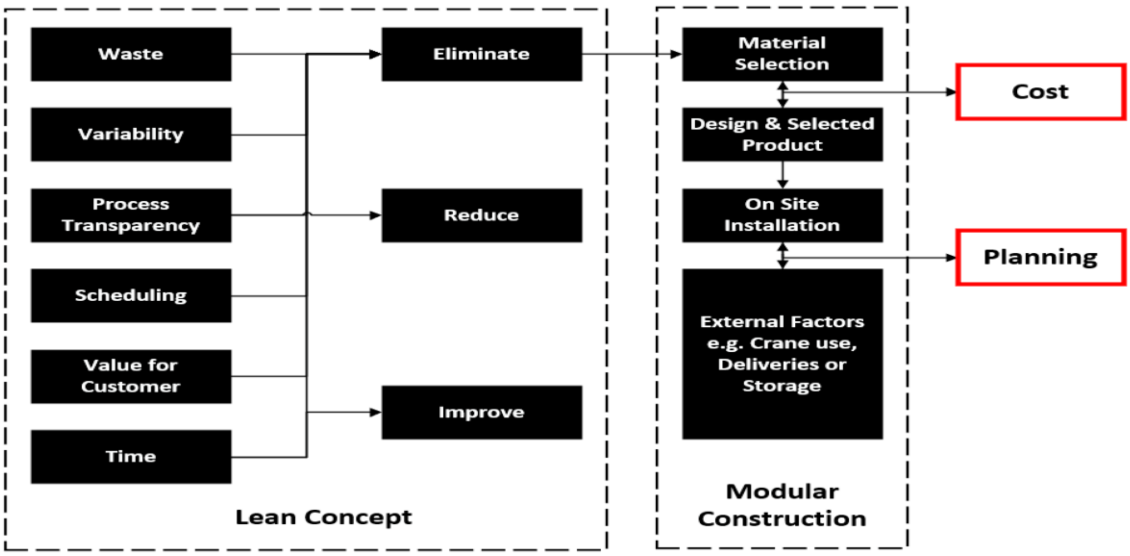

Figure 1.10: Combining lean principles, modular construction shows how cost and activity planning would be affected.

Recognizing the capacity to learn and cultivate continuous improvement through the mitigation of non-value-adding activities, or construction waste, throughout all project phases and processes, the lean construction concept has been extensively utilized.Research on 4D building information modeling has mostly concentrated on three areas: workflow optimization, scheduling problem-solving, and process automation. Despite its usefulness for 4D BIM, it ignores the new ways of thinking about lean construction, like modular building.

The modular building takes place in a controlled setting that allows for the integration of interdisciplinary data, such as production schedules and product interface interconnections, with design and drawing information This highlights the modular unit's lifecycle, which begins with production and continues through logistics and assembly.From manufacturing to on-site assembly, modularization can be made as efficient as possible with the right adaptation of the lean concept and “4D BIM capabilities in modular construction” .This study seeks to develop a lean-integrated process model that will revolutionize “4D BIM-based construction scheduling in modular construction projects”. It aims to fill this vital research gap.

CHAPTER 2

LITERATURE REVIEW

2. Overview

In modern construction management, one of the most important focuses is on optimizing time, cost, subject matter, and labor in building projects. This is driven by the need for productivity, environmental sustainability, and cost-effectiveness. BIM (Building Information Modeling) software, which includes programs like Revit and Navisworks, has brought about a revolution in the industry by making it possible to take an integrated approach to the planning and execution of projects. Revit reduces the number of design errors and the amount of work that needs to be redone by providing powerful design and documentation capabilities. It also enables real-time collaboration and visualization. Revit is complemented by Navisworks, which enables comprehensive planning and cost estimation, as well as facilitates simulations in both four and five dimensions. When used in conjunction with one another, these tools simplify construction processes by identifying and reducing potential clashes through the detection of conflicts, optimizing the distribution of resources, and improving decision-making.

Several studies have demonstrated that Building Information Modeling (BIM) is an effective method for addressing conventional challenges, such as fractured communications and cost overruns, through the integration of data from multiple disciplines into a coordinated model. To ensure that the best possible results are achieved, analytical approaches that make use of these tools provide managers of projects with insights that allow them to strike a balance between the constraints of time, materials, and labor. Recent technological advancements, such as automation and the integration of data in real-time, further expand their applicability to complicated projects. In addition to lowering the risks associated with a project, the synergy between Revit including Navisworks also encourages environmentally responsible practices. This is accomplished by eliminating waste, ensuring the effective application of materials, and connecting construction goals with timelines for projects and allocations of funds.

2.1 Literature Reviews

Dashti Mohammad Saleh, et al. (2021) It is stated that time-space conflicts have the potential to significantly affect the safety and productivity of building sites. Site space systems are inherently dynamic, but researchers have paid little attention to creating automated, integrated solutions to efficiently manage these conflicts. This study adds something new to the literature by presenting a fresh, unified paradigm for the autonomous identification and settlement of time-space disputes. The suggested hybrid approach integrates Building Information Modelling (BIM), Discrete Event Simulation (DES), and Rapidly-exploring Random Tree (RRT) path planning. Any time-space conflicts that may emerge throughout the course of the building timeline will be automatically identified, analysed, and resolved by this system, which acts on preset if-then principles. In a real-world case study, the method was used to predict the length of a project while taking into consideration the geographical restrictions present on-site. This helped verify the strategy. The results show that this technique improves project productivity and site safety by reducing the negative impact of time-space conflicts, which is especially important in crowded construction situations.

NusenPornpote, et al. (2021) Highlighted the fact that renovations are known to be a form of construction job that is known to be difficult and prone to faults in comparison to new projects. An important obstacle that has an impact on construction performance is the requirement to carry out renovation work while maintaining normal business operations. This, in conjunction with stringent rules imposed by the government regarding building rehabilitation, offers a significant difficulty. Because of the widespread availability of powerful hardware and software at the moment, building information modelling (BIM) and optimisation tools have evolved into indispensable instruments for enhancing the planning, scheduling, and resource management processes in the construction industry. The purpose of this work was to investigate the possibilities of implementing a multi-objective genetic algorithm (MOGA) on the existing BIM. The information was obtained from a renovation project that took place between the years 2018 and 2020. For the purpose of developing a BIM-based MOGA model, the direct and indirect expenses of the project, the actual timeline, and the utilisation of resources were tracked and retrieved. Following the completion of 500 generations, the ideal results were presented in the form of a Pareto front, which included seventy different combinations of total cost, time utilisation, and resource usage. Using a mix of existing BIM and MOGA into professional practices, the BIM-MOGA can be utilised as an effective tool for construction planning and scheduling. This can be accomplished without sacrificing efficiency. In light of the Pareto front data that was shown, this strategy might be beneficial in terms of enhancing decision-making during the construction phase.

Caterino Nicola, et al. (2021) Noted that the selection of the most appropriate seismic retrofit approach for an existing building may constitute a tough undertaking due to the abundance of technological solutions that are accessible and the contradictory criteria that are involved in the process of decision-making. The purpose of such an evaluation is to offer a thorough understanding of the as-built conditions as well as the specific design possibilities. This is accomplished through a series of procedures that involve the collection, storage, management, and interchange of significant data sets across the various stakeholders involved in the project. In this context, Multi-Criteria Decision-Making (MCDM) methods are a viable decision support system that can be utilised when a number of different alternatives need to be evaluated according to a group of criteria. On the other hand, the Building Information Modelling (BIM) methodology is a consolidated collaboration tool that can be utilised for the management and visualisation of data for construction projects. An integrated framework is provided in this work with the purpose of increasing the level of awareness of the Decision Maker (DM) in the process of making decisions by utilising the capabilities offered by BIM methodology integrated inside an MCDM approach. In the beginning, the MCDM-BIM framework is introduced, and the possible advantages that could be gained from using BIM in MCDM problems for seismic retrofitting are emphasised. A case study of an RC-frame building is then modelled in a BIM environment, and the notion is then applied to the case study. A simulation of three different decision-making situations is carried out by taking into consideration various DM profiles and retrofit strategies. The alternative interventions are evaluated using data that was retrieved from the BIM model. This evaluation is done in accordance with a set of characteristics. After that, the best possible option is evaluated for each of the different decision-making scenarios.

Katke S. S (2020) The conventional approaches to project monitoring, planning, and cost estimation are being progressively superseded by the more massive and intricate nature of the next construction projects. The market demands a more advanced method that can handle the complex nature of the project with ease and provide reliable results. One innovative method that might fill in the gaps left by more traditional methods is Building Information Modelling, or BIM for short. Its implementation and potential impacts are the subject of ongoing investigation by AEC industry experts and academics. The creation of new instruments made use of the medium of information technology. With this software or hardware, it's feasible to do the same jobs as a more conventional method, just more precisely. Building Information Modelling (BIM) may be utilised at every step of a building project, from property acquisition through operation and deconstruction. Hence, Building Information Modelling (BIM) is more than simply a 3D modelling tool; it's a methodology that can be used from pre-construction to post-construction, seamlessly integrated into the building project. The primary focus of this thesis is on the time and cost aspects of the construction project through the use of the building information technique during the pre-construction phase and the evaluation of the method's advantages and disadvantages using a case study. Furthermore, it provides a means of generating a five-dimensional simulation model by linking the three-dimensional model of a G+24 home project made in Autodesk Revit 2020 with the construction schedule and costing data.

Abbasi Saman et al. (2020) Because of the complexity of construction projects, the utilisation of building information modelling (BIM) has evolved into a solution that is more effective. Conventional approaches, such as the critical path method and the program assessment and review technique, have a number of drawbacks, the most significant of which is that they are not very accurate in terms of projecting the amount of time that will be required for the construction process. In order to reduce the amount of uncertainty, one method is to combine planning models with discrete event simulation (DES) and building information modelling (BIM) in order to simulate the dynamic environment. It is also possible to implement just-in-time (JIT) with the help of DES. The construction sector faces a challenge when it comes to implementing JIT utilising DES since there is a lack of reliable measurement of the optimal amount of time for each operation individually. In the meantime, takt time, which is one of the primary strategies in JIT, was utilised in this research by combining it with DES in order to tackle this problem. The aimed was to determine the ideal amount of time for each operation. To begin, a four-dimensional building information modelling (BIM) model was created in order to extract data. Following that, takt time was utilised in order to determine the best amount of time for each action, and finally, a DES was carried out. Based on the findings of this research, it can be concluded that the framework that has been proposed, which incorporates takt time and DES in order to integrate BIM with JIT, will result in planning that is both realistic and optimal.

Ma Hui Hongbin Zhang, et al. (2020) There is a possibility that multiple parallel lifting operations may take place concurrently on a prefabricated construction site. This will most likely result in workspace overlap, which will most likely cause the project to be delayed and may even result in accidents. In light of this, it is clear that the workspace is becoming an inadequate resource, which is something that needs to be addressed in the scheduling of the project. In the course of this research, a four-dimensional conflict detection strategy was suggested as a means of locating the workplace conflict. The first step was to differentiate the allocation of entity space, safety working space, and efficient working space depending on the parameters of the prefabricated construction project. This was followed by an examination of the implications of three various types of space interference. As a consequence of this, a framework for the development of workspaces was developed, this framework took into account the motion of construction machines as well as the requirements of labourers. Following this, the severity evaluation formula was developed in accordance with the framework. A hybrid axis-aligned bounding box (AABB) and orientational bounding box (OBB) technique was proposed as a means of identifying workspace conflicts on the basis of this information. Lastly, the Navisworks Software Development Kit was utilised in order to create modules for identifying and assessing workspace conflicts. The findings of empirical research demonstrated that this method is capable of effectively predicting the time–space conflicts that will arise during prefabricated construction projects. Through the utilisation of the framework that has been provided in this research, project managers are able to identify potential conflicts in the workplace in advance and optimise the schedule in order to prevent delays in the schedule and additional costs, as well as to enhance safety.

Dasović, Borna, et al. (2020) However, in practice, the majority of construction schedules are based on commercial project management tools (PMT) that do not have optimisation features. To get ideal schedules, planners usually need to construct their own optimisation models with the help of professional tools. The optimisation results, however, need processing and editing by PMT to meet the standards of project management. There is a significant amount of additional work required for comprehensive and coordinated schedule updates throughout construction execution since optimisation and PMT are not integrated. Project goals may be inadequately or not at all accomplished if construction schedule is inadequate throughout execution owing to the aforementioned difficulties and time restrictions. This article gives an accomplishment assessment on the combination of optimisation and PMT that allows sustainable construction scheduling, which is important since it ensures optimal time and resource allocation throughout a project's lifecycle. This work intends to fill a gap in the literature as no one has done a comprehensive job of it thus far. After a short introduction, the article provides the optimisation foundation for construction scheduling. Integrating heuristics, mathematical programming, and special solution methods with both traditional PMT and optimization-based BIM tools was the main focus of the author's exhaustive investigation, which primarily aimed at construction scheduling. After that, they write up their results. Finally, the paper offers some last reflections on the topic as well as recommendations for further research.

Munagala Devi Priya and Venkatesh Kone (2020) Declared their position Time, money, and quality are the three components of a construction project that are considered to be the most significant elements. The successful or unsuccessful completion of a construction project is ultimately determined by the careful control of these three criteria. It is possible to use traditional methods and tools to assist with this process; however, these methods and tools are frequently expensive and prone to errors. Building information modelling (BIM) is one example of how the construction industry has benefited from the abundance of cutting-edge software and tools brought about by recent technological breakthroughs. BIM is an acronym that stands for "building information modelling." Today, building information modelling (BIM) forms the backbone of project management for many international megaprojects. This study attempts to investigate the practical challenges and opportunities of applying building information modelling (BIM) to smaller projects, however it offers few solutions to these problems. By adhering to these tactics, additional benefits include a decrease of twenty to thirty percent in the overall cost of the project as well as a reduction of eighty percent in the amount of time required to finish the project.

Jalaei, et al. (2021) Stated that To this day, the two biggest issues facing the construction industry are worker safety and worker training. Improving construction workers' safety is the primary motivation for this study, which aims to examine the efficacy of safety training in a real-world setting. If one want to increase the degree of safety awareness among employees, it is crucial to create safer training methods. This study examined the effectiveness of safety training in improving construction workers' safety, with a particular emphasis on the instructional delivery technique's efficiency. Improving the delivery of teaching is one technique to increase its efficacy. The degree to which the instruction is understood determines its effectiveness. First, there is the tried-and-true lecture style of safety training, and second, there is a new way that uses 3D Building Information Modelling (BIM) simulation to mimic the real-life dangers of the job site. In this experiment, we test out two different training approaches and see how well they work by having trainees show what they know. Compared to the group taught using the BIM simulation, the personnel trained using the traditional technique showed a lower level of understanding. Each training approach was evaluated based on the workers' perceptions of its lifelike character, active learning potential, and ability to produce satisfaction. Furthermore, a survey was conducted to identify safety managers as the intended recipients. The results of this study will allow us to conclude that a hybrid approach combining traditional lecturing with cutting-edge VR technology yields superior results.

Zhen, Xu et al. (2020) Stated that repairing structures after an earthquake is a crucial aspect of making them seismically robust. Having a good grasp of the repair process before assessing and making judgements on seismic resistance of structures is helpful. Given this, the author proposed a BIM-based, five-dimensional (5D) simulation approach for earthquake restoration procedures. This approach enables the depiction of repair tasks in a manner similar to a three-dimensional model, with the addition of time (the fourth dimension) and related expenses (the fifth dimension). A decision-making model including the interval index of the possibility degree must be developed prior to deciding on repair plans to be executed following an earthquake. Based on the selected repair schemes, an algorithm based on a separate flow-repetitive process automatically generates a repair plan for a BIM platform. An algorithm is developed to automatically map the building information modelling (BIM) components to their respective repair schedules, allowing for the creation of a five-dimensional model of the post-earthquake repair process. The proposed 5D simulation method details the procedures for repairing a six-story office building following an earthquake, including the overall cost of manpower, materials, and equipment. In addition to helping with decision-making for seismically vulnerable structures, the study's results provide a detailed outline of the restoration procedure.

Naik M. Gopal (2019) As a result of the development of Building Information Modelling (BIM) software, the Designer or Architect is now able to design the building, and the software will provide the relevant drawings and sections that are required for construction. The concepts of 4D and 5D, in which a 3D model is related to its time of execution (4D) and its associated cost (5D), are two of the most frequently utilised concepts with the backing of BIM technology in the planning, organisation, and scheduling of projects. These concepts are among the recently developed concepts and applications of BIM. The objective of this research is to create a Building Information Model (BIM) for visualizing building information to fulfil the requirements that are associated with the construction and design programs that are specifically designed for architects and builders. For the purpose of this case study, the World Trade Centre that is going to be constructed in Kochi, Kerala, has been chosen. The two-dimensional AutoCAD designs have been combined with Autodesk Revit to produce a three-dimensional model. After that, a prototype of a four-dimensional building information model was developed and it was investigated. In addition to this, the BIM-based timetable was incorporated into the four-dimensional model, and the cost estimation that corresponded to it was also carried out in five dimensions. It is demonstrated by the findings of this study that BIM may be utilized to enhance the efficiency of construction sites. The results of this study provide a clear picture of the benefits that can be acquired by utilizing the BIM process, including the reduction of construction time and costs, as well as the ease with which construction documentation may be accomplished.

Zhao Linlin et al. (2019) Improved project constructability and cost certainty are two of the many advantages of prefabrication, along with a decrease in energy use, labour demands, waste, and delivery time. Choosing the right material source is critical for a prefabrication project because the material cost makes up around 70% of the entire cost. This research aimed to provide a strategy to aid in the prefabrication project's supplier selection process. Three components make up the suggested approach. The first step in determining which supplier options were most suitable was to compile a set of evaluation criteria. As a second point, the adoption of Building Information Modelling (BIM) allowed for the storage and sharing of information by providing enough details regarding the project needs and supplier profiles. Lastly, in order to rank the assessment criteria and acquire the score of the supplier options, the Analytic Hierarchy Process (AHP) was employed. Based on the aggregate scores, the vendors were placed in a ranking. The suggested method was demonstrated by applying it to a real-life prefabrication project. By efficiently disseminating enough information and enhancing comprehension of the project needs, the suggested approach streamlines the supplier selection process.

Heigermoser Daniel, et al. (2019) Stated that the AEC industry has far-reaching effects on the economy, the natural world, and society as a whole. But compared to other industries, its productivity over the last several decades has been dismal. Modern technology and the rise of Building Information Modelling (BIM) are causing a sea shift in the architectural, engineering and construction (AEC) industry. Incorporating these with lean concepts has the potential to increase productivity and efficiency on construction projects. Both Lean Construction and Building Information Modelling (BIM) have substantial impacts on the industry, despite their divergent aims. Many studies have shown that the Last Planner System (LPS) is beneficial, although it is still not fully used when combined with BIM technology. We introduce the Last Planner technique of Production Control, a production planning approach that aims to create a more reliable project plan, and we discuss the notion of fostering continuous improvement. Using the synergies between Lean Construction and BIM, this research proposes a solution for construction management that combines Lean Project Management (LPS) with 3D visualisation of road projects. The goal is to boost productivity and minimise construction waste. While the project is being created, the prototype tool's principal function is to assist with construction management. The application offers a colour-coded 4D construction simulation, an automatic quantity take-off, and the capability to split road projects into work zones, all of which are useful for the LPS's short-term planning process. It allows for a systematic evaluation and analysis of construction planning in terms of productivity, labour allocation, and waste quantification, which promotes continuous improvement of future construction planning in light of the short-term planning process.

Romanovich, Marina, et al. (2018) The construction sector in China has grown rapidly since the country's reform and opening up, particularly after 2011, thanks in large part to the widespread use and fast expansion of Building Information Modelling (BIM) software. This article primarily focusses on the development of building information modelling (BIM) technology and how it has improved the administration of China's construction sector.The study also explores software usage in China, with a particular emphasis on Revit's role in 3D modelling (the design stage) and Guanglianda's role in construction management (from start to finish). This study's aimedwas to investigate Guanglianda and talk about what it can do. Materials management, site acceptance, integrated project management information, video surveillance in construction, and labour management information are just a few examples of these uses. The study also delves deeply into another area, which is the partnership between Revit and Guanglianda at different points. Moreover, a Chinese road project is examined extensively in this research. It begins by explaining the difficulties caused by cranes, facts, and time, and then moves on to examine what has caused China's building boom. The viability of China's method of building management in light of Russia's integration is another consideration.

Hyun, Changtaek, et al. (2018) Acknowledged that reinforced cast-in-place concrete work necessitates formwork construction, which is inherently labour-intensive, costly, and challenging to plan and design. It is common practice to entrust the task of choosing the best formwork design to the field manager or engineer, but this individual may lack the necessary resources to thoroughly investigate all of the potential options and ultimately choose the least inefficient one. Even if it's a lengthy and intricate process, this is nonetheless the case. Among the many factors that must be taken into account while constructing formwork are features such as concrete pressure, bending, deflection, and horizontal shearing. Calculating each of these characteristics for each concrete formwork application is still a very time-consuming operation, even if there are formulae and computations for them in the design of concrete formwork. Because of this, it's not uncommon for construction managers to depend on their past experiences and choose formwork designs that are similar to what's typically employed. By automating the extraction of data and attributes from a BIM model, this project aims to improve the formwork design process, which is essential for performing the calculations required for the design of the formwork. An automated formwork design system based on Building Information Modelling (BIM) will be developed to make this improvement. This case study shows that using the IFC extension, the suggested method of formwork design may automate formwork design in BIM models. To do this, we compared the prices of the different materials. Findings from the case study show that the formwork design process might be made much more successful by using the suggested approach.

Davtalab Omid, et al. (2018) Using concrete 3D printing for robotic building, the construction sector is now experiencing a revolution. Although much work has been achieved in addressing the challenges associated with the hardware, the software and information aspects of these creative systems are still not given the recognition they deserve. Ultimately, this effort aims to provide a software platform that can optimally utilise data retrieved and analysed from building information modelling (BIM) projects at every level. Previous debates have touched on the idea of using BIM for automated construction, but this research focusses on the mechanics of how it may be implemented, which have not been thoroughly addressed in those conversations. A framework that integrates building information modelling (BIM) into an automated construction system has been proposed to achieve this objective. A Planning and Operations Control Software for Automated Construction (POCSAC) is currently in development with the aim of easing the integration of Building Information

Modelling (BIM) with Contour Crafting. The goal of the construction system's and the BIM platform's interaction is to make the most of the advantages that come from working together.

Politi, Ruti Ruth. (2018) Highlighted the increasing importance of using efficient techniques and resources for project management in the construction industry, particularly as project sizes increase. With large-scale projects comes a dilemma for the industry: as the number of tasks, elements, and limitations increases, so does the complexity of the project. What's worse is that these variables and demands interact with each other, further compounding the situation. The use of building information modelling (BIM) has increased in recent years due to the fact that it significantly simplifies dealing with complicated tasks. Even if there's bound to be a need to discover new methods to deal with complexity, this remains true. With the help of Building Information Modelling (BIM), a three-dimensional digital representation of a building or structure may be created. The most important thing is to make sure that the model includes all of the semantic data related to the project, even if the necessary geometric data is also included. This encompasses all aspects of the element, including its function, the properties of the material, and the specifications and timelines of the structure. The goal was to make sure that everyone involved in the project could use a single, flexible model at any point. After outlining the potential benefits of BIM-based project management, this paper provides a critical examination of the primary issues with traditional project management approaches. The Building Information Modelling (BIM) methodology and its numerous project management applications are explored in depth in this thesis, as are the data collection techniques required to generate a BIM model. We go over several ways to integrate BIM into project management, such as four-dimensional scheduling, five-dimensional cost estimating, six-dimensional sustainability, seven-dimensional facility management, and structural analysis. In this case study, the author demonstrates how nD BIM software may be useful during the building process.

Sampaio, Alcínia Zita (2017) Building Information Models (BIM) have shown to be a valuable tool for improving construction operations due to its ability to centralise all project data in one digital model and promote collaboration and communication among all stakeholders. To be a civil engineering instructor is to keep up with the newest innovations in the field's tools, techniques, and procedures. Therefore, the school should try to update its curriculum to include new technology-related subjects. The goal of this research is to shed light on the various ways in which building information modelling (BIM) improves the construction process. Graduates of a civil engineering school created a number of BIM application themes. construction information modelling (BIM) is demonstrated clearly in the text through its detailed coverage of the following themes: creating and utilising a 4D/BIM model to assist with construction plans; coordinating a road project using BIM methodology; and performing conflict analyses for architecture using a 3D/BIM model. Implementation of suggestions followed modelling and analysis of several case studies that contrasted BIM with the conventional approach of completing the same tasks. From a pedagogical perspective, this study primarily aims to demonstrate the advantages of building information modelling (BIM) over the conventional technique for construction activities in order to provide future civil engineers with competitive abilities.

Li Jinmin (2016) It should be mentioned that the construction manager is the one who must estimate the time and money needed to finish a building project. This is a crucial position that will help the project's owners, engineers, and contractors. When planning a project from the ground up, two factors that greatly affect the final product are the amount of time and money needed to build it. Traditional techniques for estimating the time and resources needed for building projects rely on two-dimensional models. Engineering, estimating, and scheduling professionals who are directly involved in the creation of these models devote a great deal of time and energy to their work. Reason being, everything is done by hand, which isn't ideal and becomes much more complicated when there are many design possibilities for the project. The use of building information modelling (BIM), a tool that facilitates better data sharing and guarantees collaboration among architects, engineers, and contractors, can provide a useful method for planning scheduling and cost estimates. Why? Because building information modelling (BIM) is a tool that makes sharing data easier. This is because there are many societal, environmental, and economic impacts associated with building a project. Meanwhile, the building industry has been paying more and more attention to sustainability. Modular construction has shown to be an excellent way to guarantee sustainable construction by reducing negative impacts on the environment, shortening the building time, and improving staff efficiency. The goal of this research is to create a unified model that links BIM (Building Information Modelling) with the conceptual design phase of project sustainability, scheduling, and cost prediction.

Table 2.1: Previous Studies of the Literature Review

S. No.	Authors and year of publication	Title	Journal name	Critical Observations
1	Inzerillo L et al. (2024)	Exploring 4D and 5D analysis in BIM environment for infrastructures: a case study	The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, Volume XLVIII-2/W4-2024	Emphasises automated 4D/5D BIM simulation and analysis to lower project costs and uncertainty. Presents a Riyadh North-South railway station case study to demonstrate BIM automation benefits.
2	Wefki Hossam et al. (2024)	BIM-based schedule generation and optimization using genetic algorithms	Automationin Construction(ELSEVIER)	BIM, GAs, and 5D simulation are used to optimise scheduling and cost management in this innovative system. Case study on cast-in-situ construction highlights BI dashboard integration for efficiency.
3	Yilmaz Selcuk et al. (2024)	A PMBOK-based construction cost management framework for BIM integration in construction projects	International Journal of Construction Management (TAYLOR & FRANCIS)	Introduces a PMBOK-aligned cost management framework with BIM for better decision-making. Finds issues with bi-directional quantity-cost linkages, risk-centric budgeting, and customisable reports.

4	Katke, S. S. (2023)	Time and Cost Control of Construction Project using 5D BIM process	International Research Journal of Engineering and Technology (IRJET)	Describes BIM as a construction method for time and cost control from pre- to post-construction. Shows Autodesk Revit and Navisworks 5D BIM integration on a G+24 residential project.

2.2 Research Gaps

- Maximum work has been done for the high residential building not for small residential buildings.
- Cost estimation has been done manually.
- Clash detection work is done manually.

2.3 Research Objectives

- Analysing the benefits of various software in reducing life cycle cost.
- To compare quantities calculated manually and by using softwares.
- To justify the use of technology for small residential houses.

CHAPTER 3

METHODOLOGY

3. General

Optimal use of time, money, and other resources is essential in today's construction business, and this can only be achieved with meticulous project planning, scheduling, and management. Problems arise when trying to update clients on the project's progress using the antiquated methods of using AutoCAD drawings and Microsoft Project and Primavera for scheduling; this is especially true if neither the client nor the store manager is familiar with the technical words used in these documents. One can generate a four-dimensional model of the project by integrating conventional approaches like computer-aided design (CAD) drawings and schedule sheets into a platform. Project managers still rely on antiquated methods of planning and tracking progress, such as bar charts, CPM, PERT, etc. The lack of essential spatial elements and data makes these extremely unsuitable for use in decision-making. Project managers are gradually under more and more pressure to reduce costs and shorten delivery times without compromising product quality. One of the most prominent areas that may need some improvement is the planning and control of the construction process. Case studies and relevant literature back up common complaints in distinguishing between planning and execution, as well as detecting fact variance. The major reasons for these problems, according to several academics, are the inadequate use of information technologies and traditional project management theories. Rather than focusing on output on the job site, management is currently overly preoccupied with contracts and costs. In addition, the necessity for methods and tools for planning execution and managing resources becomes apparent when one examines the IT applications used in the construction industry. The construction industry has made extensive use of the time-tested Critical Path Method (CPM) for planning and control approaches since its introduction in the 1950s.

Revit, Building Information Modelling (BIM), and Navisworks software are utilized in this study to optimize time, money, materials, and labour in construction projects. To ensure the longevity and efficacy of the project, the methodology is structured to combine analytical procedures with cutting-edge digital tools. Data collection, model building, simulation, and analysis are the steps in a methodical procedure. All structural, architectural, and MEP (Mechanical, Electrical, and Plumbing) components are included in the comprehensive 3D models of road projects that are built using Revit and BIM. Coordinating, detecting clashes, and scheduling projects in Navisworks helps find inefficiencies and optimize operations. To guarantee accuracy and conformity with project objectives, the approach emphasizes collaborative design, real-time data exchange, and iterative improvement.

The study technique is designed to tackle specific objectives, such as improving cost control, reducing material wastage, and minimizing project delays. By simulating and analyzing real-world construction projects, a case study-based approach can verify that the suggested strategies work. The effect of various design and scheduling choices on resource utilization can be evaluated through the use of simulations. We also quantify performance parameters like material efficiency, cost variation, and time savings to give you the information you need to take action. Practical application and adherence to industry standards can be achieved through the integration of stakeholder feedback and iterative reviews, which are highlighted in the chapter as well.

3.1 Benefits

- **Lack of Integrated Frameworks:** Many current approaches don't provide a consistent framework for important characteristics like time, money, material, and labour. The full optimization potential of Revit, BIM, and Navisworks when used together has not been fully investigated, despite their standalone effectiveness.
- **Underutilization of Predictive Analysis:** Projects are often managed reactively rather than proactively due to the lack of use of predictive analytics and scenario-based evaluations in current procedures.
- **Region-Specific Challenges:** Local issues, including material availability, labour skill levels, and the effects of regulatory frameworks specific to regions on project efficiency, have received little academic attention.
- **Inefficient Collaboration Mechanisms:** Data silos, misunderstandings, and postponements in projects are common outcomes of non-standardized procedures that prevent interdisciplinary teams utilizing BIM tools from collaborating seamlessly.

3.2 Scope of Utilization

- **Developing a Comprehensive Framework:** Optimizing road projects in terms of time, money, materials, and labour can be achieved through the use of an integrated framework that incorporates BIM. The purpose of this framework is to offer a methodical way to improve project efficiency.

- **Identifying Key Inefficiencies:** To identify key areas that need improvement to achieve better performance metrics, it is necessary to analyse and quantify inefficiencies in resource utilization and project scheduling.
- **Simulating and Evaluating Scenarios:** To test out different options on project results and find the best solutions by simulating alternative design, scheduling, and resource allocation scenarios.
- **Incorporating Sustainability Metrics:** During project optimization, suggest ways to incorporate sustainability factors including minimizing material waste and reducing the carbon footprint without sacrificing cost-effectiveness.

3.3 Background Study

Recent years have seen data digitisation have an impact on the building industry. Building information modelling (BIM) is a cutting-edge technique that may foretell a structure's lifespan, energy consumption, cost, and efficiency. It is now easier than ever to increase the precision of BIM time and cost estimations with the use of evolutionary algorithms (EA). Incorporating AI, EA incorporates current algorithms like GA, EP, PSO, DE, and ES, which stand for evolutionary programming, particle swarm optimisation, and evolutionary strategies, respectively. This study explores the integration of a code (plugin) produced by GA into the BIM-5D model using Navisworks. The goal is to reduce the overall cost and length of construction projects. Using Microsoft Visual Studio and C++, we developed an interface that uses five different project time scenarios to increase the accuracy of construction stage time and cost estimates. This interface is provided by the plugin code. The research shows that the suggested plugin can save project time and costs by around 20% and save a few amount.

3.4 Research Problem Formulation

Optimization of processes in construction projects to overcome inefficiencies in time management, cost control, material utilization, and labour allocation is the central research subject in this study. Due to disjointed workflows and an absence of integrated optimization tools, construction projects often encounter issues such as lengthy delays, increased costs, unnecessary material waste, and ineffective labour deployment. Utilizing digital tools like Revit, BIM, and Navisworks, this research employs a structured methodology that includes problem identification, data collection, model development, and analysis methodologies to address these difficulties. Finding critical inefficiencies in existing procedures and proposing a strong optimization framework, the study conducts a thorough literature analysis and involves stakeholders. To improve decision-making and maximize project results, this framework incorporates cutting-edge methods such as sustainability evaluations, scenario modelling, 4D BIM simulations, and collision detection. The research intends to contribute to more effective and sustainable construction practices by applying this framework to real-world case studies. Measurable improvements in project performance will be achieved through key performance indicators such as time savings, cost reduction, material efficiency, and labour productivity.

3.5 Methodology

An organized, step-by-step framework is followed by the methodology, which is described in more detail below:

3.5.1 Problem Identification

In the first part of this study, we will look at how current workflows for construction projects are inefficient and how we may improve them. We will focus on issues like time management, cost control, material utilization, and labour allocation. Inefficient labour deployment, budget overruns, excessive material waste, and delayed projects are common in the construction industry because optimization frameworks are not connected and workflows are fragmented. An exhaustive literature review is carried out to methodically address these difficulties. Examining the strengths and weaknesses of digital tools like BIM , this article delves into the present situation of project optimization and the obstacles it faces. Talking to people who matter in the industry, such as engineers, architects, project managers, and construction workers, helps as well in gathering industry insights. Interviews like these are great for learning about operational inefficiencies, bottlenecks, and persistent problems with project execution from the ground up. In this phase, we will analyse the literature and engage stakeholders to discover where current practices are lacking. Our goal is to lay a solid groundwork for designing an optimization framework that will be effective.

3.5.2 Data Collection

- Schedules, budgets, material inventories, and labour utilization records are some of the real-world project data collected from prior years.

- Environmental impact studies, project design files, and regulatory requirements are additional pieces of data.

3.5.3 Model Development

Building a solid digital model of the chosen case study projects in Revit and Navisworks during the model creation phase is an important part of the research. Revit is used to create thorough 3D BIM (Building Information Modelling) models that utilize architectural structural components to create a digital foundation that is detailed and multi-disciplinary. The intricacies of road projects can be better understood and analyzed with the help of these models. After development is complete, the Revit models are easily imported into Navisworks so that project analysis may take advantage of Navisworks' advanced features. To minimize expensive rework during construction, Navisworks allows for clash detection, which identifies conflicts between various components. In addition, workflow simulations make use of the models to show how a project will be executed and how planning may be made more efficient. This phase also addresses scheduling, which is crucial. Navisworks allows for 4D and 5D simulations that incorporate cost and time dimensions, providing a comprehensive picture of the project's development and its financial repercussions. Custom scripts are created using Python or Dynamo to fulfil the individual requirements of each project and to improve the analysis. Automating monotonous operations, performing complex computations, and adding functionality like sustainability checks or material optimization are all possible with these scripts. Making sure the digital framework is correct and ready to tackle varied project difficulties effectively is achieved through this integrated approach to model creation.

3.5.4 Analytical and Optimization Methods

- **Clash Detection Analysis:** To avoid expensive rework and construction delays, it is essential to identify and resolve design inconsistencies and conflicts during the collision detection phase early in the project lifecycle. The Revit BIM models are checked for possible overlaps or collisions between different design components using Navisworks' sophisticated clash detection features. This includes things like structural beams interfering with HVAC ducts or plumbing systems colliding with electrical conduits. Automating this procedure, Navisworks enables a thorough evaluation of designs involving multiple disciplines, allowing for the detection of conflicts before physical production. By identifying potential conflicts early on, teams like architects, engineers, and contractors may work together more effectively throughout the planning process. This preventative method greatly aids in keeping projects on schedule and within budget by reducing interruptions and improving coordination.

- **4D BIM Simulation:** Building information modelling (BIM) with time (4D) dimensions improves project management and visualization. By associating building tasks with their respective 3D model components, this step utilizes 4D BIM simulation to generate a live depiction of the project timeline. This helps everyone involved in the project to see how things are moving along, keep tabs on development, and spot any possible setbacks. The incorporation of cost data into 4D BIM simulation allows for a comprehensive study of the budget consequences linked to each phase of the construction process. When these factors are considered together, project managers are better able to determine the financial impact of schedule or design modifications. When it comes to scenario planning, this integration is a lifesaver. It lets you see how different approaches will affect your budget and timeframe, so you can make sure your project stays on track.
- **Scenario Simulation:** One of the most important ways to test out different scheduling tactics, resource allocations, and design choices is with scenario simulation. To discover possible answers to project problems, Navisworks makes use of BIM models to run various "what-if" scenarios. Determine the most efficient and sustainable strategy by analysing the impact of utilising different materials, adjusting building sequences, or reallocating labour resources, among other things. By iteratively exploring the interplay between the variables, we may better understand the trade-offs that exist between time, money, and quality. Project stakeholders may optimise plans, manage risks proactively, and ensure improved resource utilisation and overall efficiency by modelling numerous scenarios.
- **Sustainability Metrics Evaluation:** Aligning building techniques with environmental goals requires incorporating sustainability measures into the project optimisation process. Critical sustainability metrics like material waste, carbon footprint, and energy consumption are assessed using custom plug-ins or scripts created in Python or Dynamo. The environmental impact of various design decisions and building tactics can be assessed with the help of these tools, which analyse data from BIM models. For instance, the scripts can find places to cut back on materials or recommend HVAC systems that use less energy. The methodology makes sure that sustainability isn't just an afterthought in decision-making by including these evaluations in optimisation. This method encourages

environmentally conscious actions, which boosts the project's social and financial worth while also helping it comply with environmental regulations.

- **Cost-Benefit Analysis:** To ascertain the monetary viability and ROI of the suggested optimisation methods, a cost-benefit analysis is an essential first step. In this step, we weigh the potential savings, time savings, and enhanced resource efficiency against the potential costs of executing each scenario. Decisions about the implementation of strategies can be driven by data when stakeholders can measure the worth of results such as less material waste, quicker project completion, or improved labour productivity. In addition to ensuring that optimisation efforts are in line with budgetary objectives, this study helps uncover potential trade-offs. In addition to laying out the rationale for specific strategy adoptions, the cost-benefit analysis is a powerful instrument for garnering support from stakeholders by showing them the real monetary benefits.

3.5.5 Validation

- By comparing project performance data both before and after following the suggested techniques, the created framework is applied to real-world case studies.
- To make sure it works and is in line with industry standards, stakeholders assess it and provide input iteratively during validation.

3.5.6 Performance Evaluation

During the performance evaluation phase, clearly defined Key Performance Indicators (KPIs) are used to gauge how well the optimisation framework is working. To quantify the success of the solutions that have been adopted, metrics like labour productivity, material efficiency, cost reduction, and time saved are used. These key performance indicators show how the framework affected the project's outcome. A comparison analysis is carried out to validate the outcomes. This involves comparing the baseline data collected before the implementation with the findings obtained after the implementation. Process simplification, material waste reduction, labour allocation, and project schedule adherence are just a few of the areas that have benefited from this study. To prove its worth for future building projects, the evaluation phase must show that the framework not only fixes the identified inefficiencies but also brings concrete advantages.

3.6.7 Block Diagram of the Study

This graphic depicts the study's approach in an organised flow diagram. The first step is to split the data in half, 80% for training and 20% for testing. This ensures that each phase gets the appropriate amount of data. To find inefficiencies in construction workflows including time management, cost control, material utilisation, and labour allocation, the first big step is to identify the problems. This is done by analysing real-world projects from past years. Schedules, cost estimates, and material inventories are just a few examples of the important project data that is gathered during data collection.

The information is included in building information modelling (BIM) models through the use of Revit, which incorporates structural, architectural, and other elements. Subsequently, software tools like Navisworks are employed for model analysis and development.

Phase two involves implementing methods including analysis of collision detection, scenario simulation, cost-benefit analysis, and evaluation of sustainability metrics in 4D building information modelling. By using methods like cost-benefit analysis, project timeline simulation, scenario modelling, and early conflict detection, these approaches hope to improve project workflows.

The following block diagram offers a graphical description of the procedure that was followed during the entire research project:

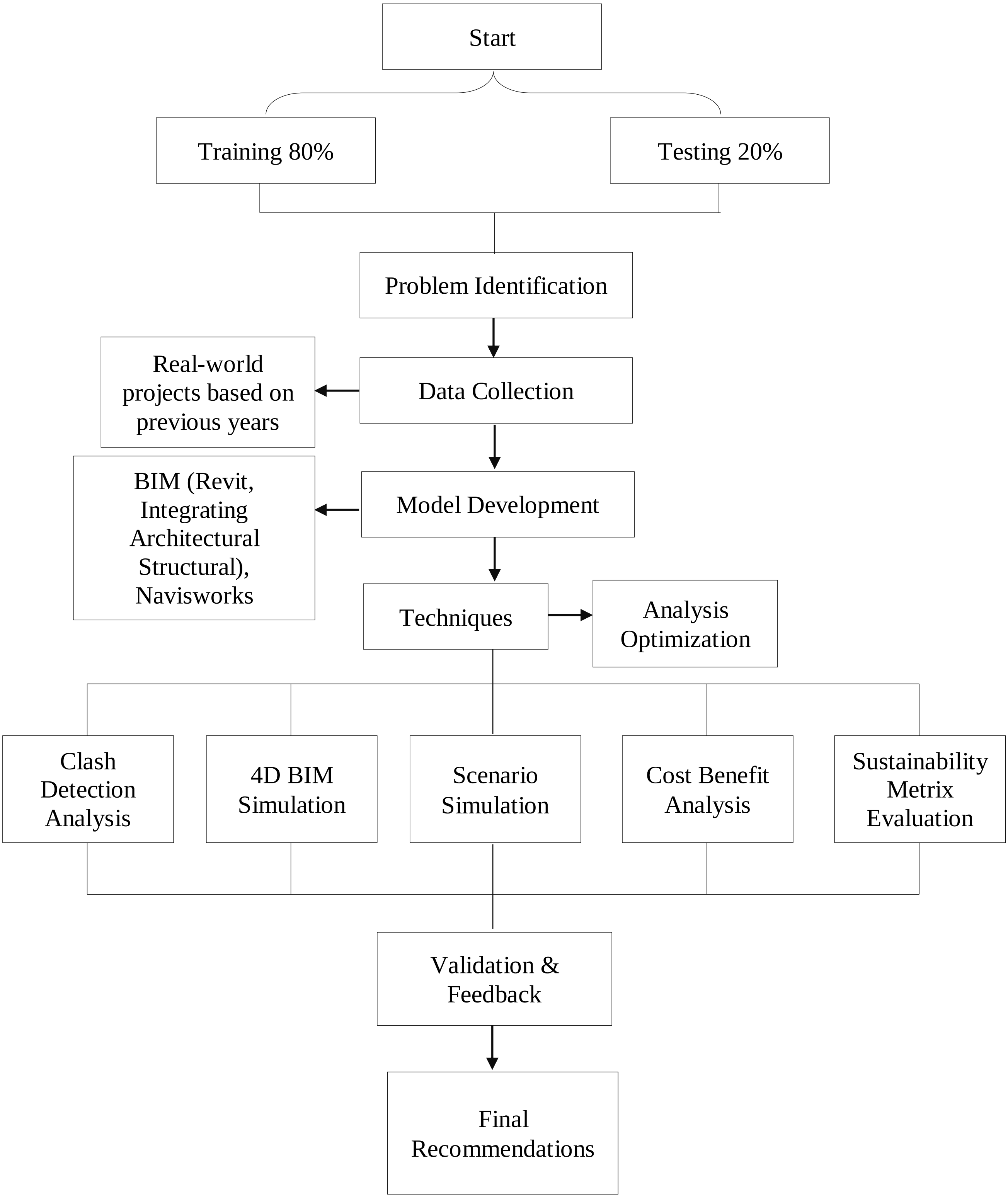

Figure 3.1: Research Methodology Layout

- **Revit:** Made use of to develop detailed 3D BIM models that incorporate all aspects of the building design, including architectural, structural, mechanical, electrical, and plumbing components.
- **Navisworks:** Utilised to detect clashes, coordinate projects, simulate workflows, and conduct 4D analyses of the effects impacting time and money.
- **Custom Scripts:** Automation of tedious operations, evaluation of sustainability metrics, and customisation of project analysis can be accomplished through the use of Python or Dynamo scripts.
- **Microsoft Excel/Power BI:** The purpose of this is to evaluate performance, visualise results, and publish key performance indicators.

This all-encompassing methodology guarantees a robust, data-driven approach to optimising the performance of the building project, while also embracing sustainability and cooperation for improved project outcomes.

CHAPTER 4

RESULTS AND DISCUSSION

4. Introduction

The survey findings I acquired while investigating the potential of Building Information Modelling (BIM) to lower building projects' lifetime costs are thoroughly analysed in this chapter. In order to accomplish the study's stated goals, understand the participants' answers, spot key trends, and find out how efficient BIM is in reducing costs throughout different stages of a project, the results are examined in detail. Descriptive statistics, response visualisations, and a review of the relevant literature round out the analysis.

The discussion is organized in regards to the main categories of the questionnaire: characteristics of participants, BIM comprehensions and adoptions, perceptions on reducing costs during design and construction, perceived effectives of BIM during operation and maintenance, and perceived impact on lifecycle cost savings.

4.1 Comparison of Traditional Cost Management and BIM

The use of Building Information Modeling (BIM) for construction cost management has fundamentally altered traditional estimation practices. Traditional cost management systems depend heavily on manual processes and data inputs and are inaccurate, slow and filled with unrealized cost overruns. BIM evolves conventional cost management practices to a model-centric cost management method that greatly enhances the accuracy and efficiency of cost estimating practice with automation, data links, and multi-dimensional project modeling.

The majority of cost estimating activity is still done manually with spreadsheets or CAD based take-offs.Thisapproach is open to human error, mathematical errors and communication errors among multiple stakeholders that result in differing estimates or costs between projected and actual work. Moreover, these systems also lack the ability to coordinate and address the evolving costs associated with changes to the design or the added costs associated with resolving unforeseen construction issues, further complicating the underlying budgeting throughout the project.BIM, on the other hand, allows for automated quantities and costing (i.e., 5D BIM), which minimizes manual entry and the possibility of errors. By incorporating costs in the design model, BIM allows for transparent, current, and coordinated costing and project planning. Additionally, 4D BIM incorporates the scheduling aspect into the discussion and allows costing to be forecasted, thereby equipping teams to make informed decisions about the resource allocation, timing, etc.; all throughout the life of the project.

4.1.1 Cost Overruns in Traditional vs. BIM-Integrated Projects

Cost overruns have historically been a major issue in construction projects for many reasons including design inconsistency, varied interpretation of the project scope, lack of communication and coordination, and inaccurate estimates. Cost overruns are especially common with traditional linear project delivery methods, which do not provide a project collaborative and dynamic project tracking platform for the project team.The figure 4.1 shows the general plan of 1BHK house which was analysed to know the outcome on the basis of traditional and Revit analysis.

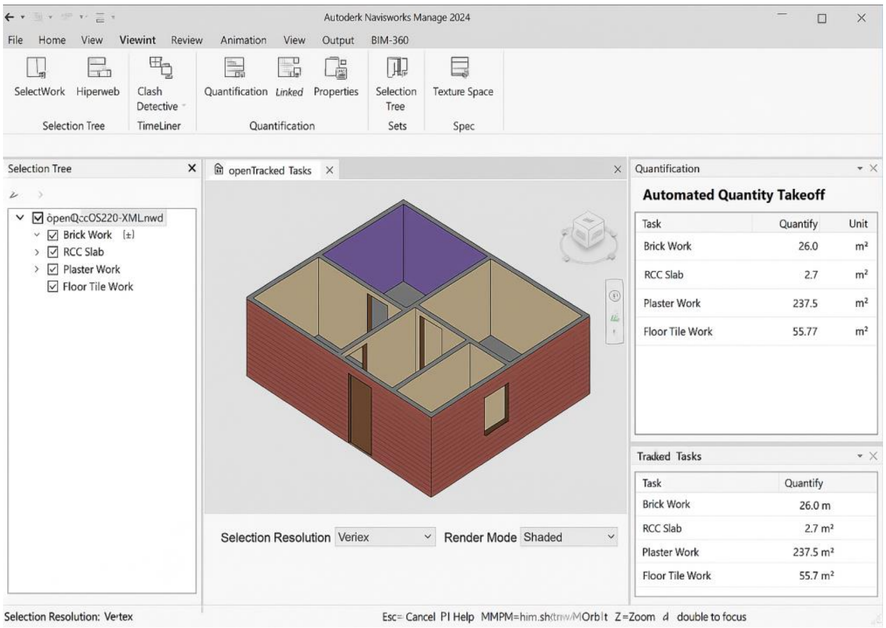

Figure 4.1: Plan of 1BHK Residential House

This study compares cost overruns as a percentage for various project types; residential, commercial, and infrastructure to see the differences between traditional and BIM-integrated projects in table 4.1. The conclusions show that BIM can reduce cost overruns through risk avoidance, visual clash detection, and integrative cost controls.

Table 4.1: Cost Overruns in Traditional vs. BIM-Integrated Projects

Project Type	Traditional Approach (Over Budget)	BIM-Integrated Approach (Over Budget)
Residential	15-25%	5-10%
Commercial	20-30%	8-12%
Infrastructure	25-35%	10-15%

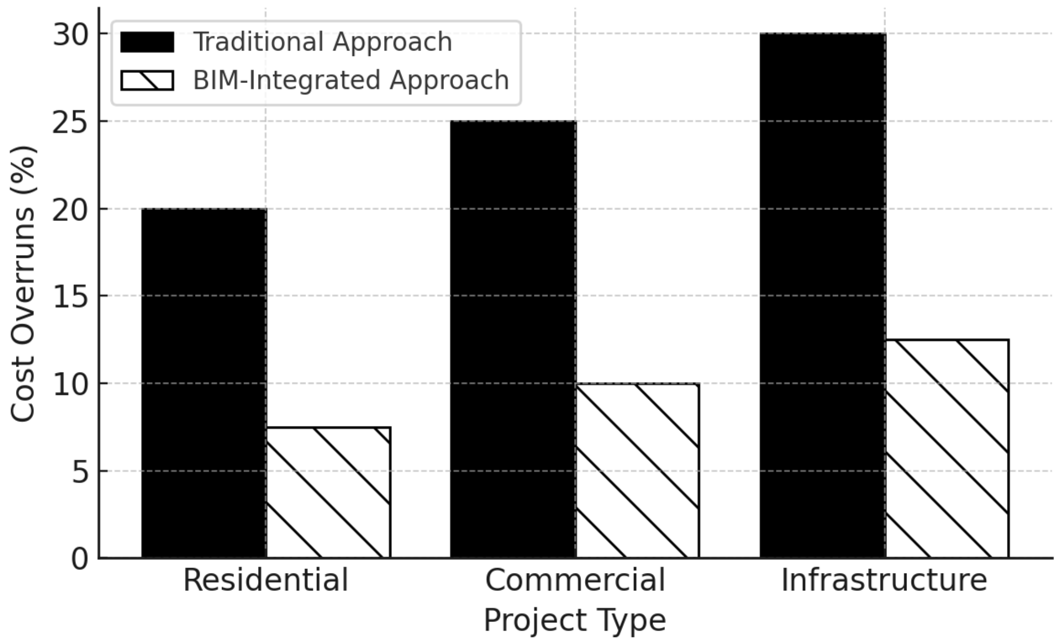

Figure 4.2: Percentage that were reduced in Cost Overruns with BIM

The findings indicate that traditional processes have significant and routine budget overruns that average around 20% for residential projects, 25% for commercial projects, and perhaps even 30% for infrastructure projects. This is in line with previously highlighted aspects of traditional processes (for example, unreliable communication, poor estimating tools, and quickly resolving problems). The drawbacks of traditional systems are consistent with the theory of traditional project life cycles, which is too rigid to adjust to the dynamic nature of today's construction processes.

Conversely, the BIM-driven method has significant reductions in cost overruns (8% on average for residential projects, 10% for commercial projects, and 13% for infrastructure projects). These reductions are largely attributable to the underlying features of BIM - including: Model-centric visualization: The identification of scope at an early stage minimizes design related mistakes. Clash detection; Automatically identifying clashes eliminates (or at least minimizes) rework that emerges from mistakes regarding the technical aspects of a project.Real-time estimating: It can avoid large surprises if you continuously estimate during design development.Implementation of scheduling: Bringing together scheduling tools defines your understanding of what the financial and resource implications may be.

The most impactful reductions are with infrastructure projects (up to 17% cost overruns). The evidence reinforces both the scalability and effectiveness of using BIM-type solutions within complex construction environments that have multiple disciplines working together. In large or high-outcome infrastructure projects, the value of BIM in coordinating multiple systems, phasing and construction logistics becomes critical.

It is important to consider the findings from a theoretical level, which reinforces the position that BIM represents not just new technology but a framing of strategic project cost containment and risk. BIM is integrated with the Lean construction and Integrated Project Delivery (IPD) ideas of removing waste, bringing early whole stakeholders into the process, optimizing performance, etc.

Additionally, the evidence supports including BIM in cost-risk integration models and demonstrated its ability to add transparency, accountability, and quality to project outcomes. Although cost overruns are notable in terms of value, the universal rate of cost overrun reduction matters in all projects. BIM is capable of rectifying inefficiencies that have been plagueing traditional construction management models.

4.2 Impact of Building Information Modeling on Time Optimization

One of the most powerful aspects of BIM is the potential to streamline time management within all phases of construction projects, but particularly when planning is combined with preconstruction. To leverage time in construction process means utilizing 4D BIM, in which the chronological aspect is integrated into the 3D model. This kind of scheduling uses a flexible framework that allows for continual synchronization with the project task schedule. Conventional scheduling methods rely on fixed Gantt charts and are inadequate means of communication within the project teams. In contrast, a schedule enabled with BIM can adapt to real time changes to task sequencing by visualizing the completion of the project to full capacity. Updates with BIM can be timely, based on advances within the construction process, supporting a increase in overall workflow efficiencies.

Static tasks and schedules have a failing to accurately characterize the inherently dynamic nature of construction environments, therefore they have limited use when there are multiple trades working simultaneously on a job site. This results in coordination problems, ultimately leading to bottlenecks and true rework situations. The delays, conflicts, inefficient schedules lead to prolonged timelines, budget overruns, and ultimately client dissatisfaction. Construction scheduling uses project estimates and costs to underpin the task duration of the project schedule - however, scheduling is done independently of design and cost estimating. Rather than functional, its fragmented quality means it is not properly decision-specific.

Tackling scheduling with 4D modeling will allow decision-makers to assign time elements that relate to discrete building items when reviewed through a model, as well as provide visual simulation of the unique construction sequence of events for both pre-construction and pre-supplementary events. Working in an integrative manner allows inherently two collaborative outcomes - decision making can take place, communication inter-disciplinarily can occur with improved efficiency, preparation, and effective translation, and problems can better be predicted.

Modern software tools fully equipped, such as Autodesk Navisworks, Synchro, and Vico Office, drive the capability of providing advanced scheduling facilitated by visuals which ultimately lead to improved readiness to proceed with the work and accomplish project milestones successfully.

4.2.1 Time Savings with BIM Implementation

The following table presents a detailed comparison of time required for critical activities in traditional and BIM-optimized construction workflows.

Table 4.2: Time Savings with BIM Implementation

Activity	**Traditional Time Required**	**BIM-Optimized Time**	**Reduction (%)**

Clash Detection	2 weeks	3 days	78%
Cost Estimation	3 weeks	5 days	76%
Project Scheduling	1 month	10 days	67%

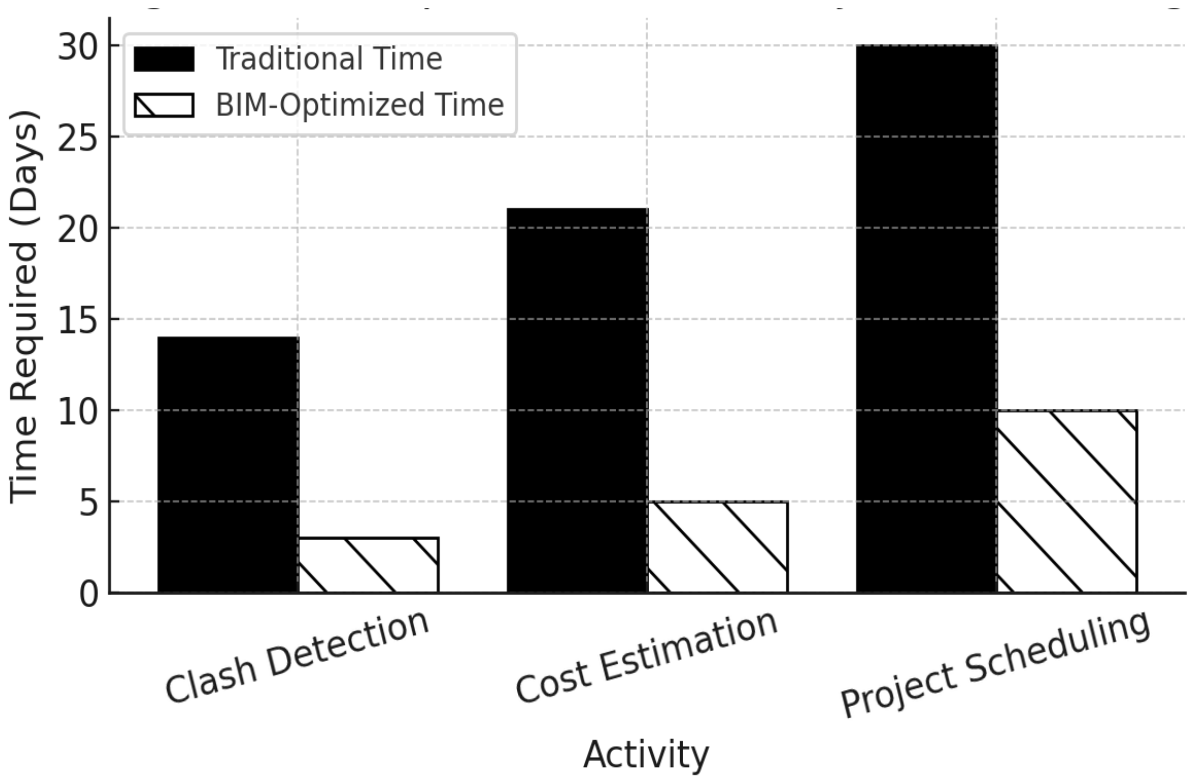

Figure 4.3: Impact of BIM on Project Scheduling

Impact of BIM on Project Scheduling, offers a theoretical and empirical comparison of the time required for key construction planning activities using traditional methods versus BIM-optimized workflows. The three categories analyzed—Clash Detection, Cost Estimation, and Project Scheduling are critical to early-stage project planning, where accuracy and speed heavily influence downstream performance.The black bars represent Traditional Time (in days), while the white bars with diagonal hatching illustrate BIM-Optimized Time, highlighting BIM's ability to drastically reduce task durations:

1. Clash Detection time drops from 14 days (traditional) to just 3 days (BIM). This underscores BIM’s integration of automated clash detection tools such as Autodesk Navisworks, which identify spatial conflicts in 3D models before construction begins. Theoretically, this demonstrates the application of model-based conflict prevention and supports Lean Construction’s pull planning principles, where delays are minimized through early coordination.

2. Cost Estimation shows an even more pronounced reduction—from 21 days to 5 days. BIM tools like CostX and Revit enable automated quantity takeoff and 5D modeling, linking material specifications directly to cost databases. This shift is grounded in 5D BIM theory, where embedded cost attributes allow near-instantaneous recalculation of project budgets following design changes.

3. Project Scheduling time decreases significantly, from 30 days to 10 days. BIM facilitates 4D simulation by associating construction activities with model elements and time data. Software such as Synchro or Navisworks enables visual sequencing, which improves communication and coordination across disciplines. This directly aligns with construction operations modeling and critical path visualization in project management theory.

Overall, the chart reinforces the theoretical foundation that BIM serves as an accelerant to preconstruction activities, offering real-time intelligence, integrated data environments, and automation in planning. These capabilities reduce human error, speed up decision-making, and improve reliability—key metrics in agile project delivery models and digital construction strategies.These findings illustrate that BIM streamlines project scheduling by mitigating delays, reducing rework, and automating task coordination. The usage of BIM with project scheduling software such as Navisworks, allows construction teams to visualize project timelines and identify bottlenecks before they become critical issues.Additionally, BIM facilitates resource allocation by linking construction activities with material delivery schedules, labor management, and equipment usage. This prevents idle time and ensures that resources are optimally utilized.

4.3 Cost-Saving Analysis Using BIM

To determine the monetary gain from using Building Information Modelling (BIM) at each step of the project, a comprehensive life cycle cost study was carried out. Building information modelling (BIM) allows for a more comprehensive view of costs linked with a facility's entire life cycle, from design and construction through operation, maintenance, and demolition, in contrast to conventional cost estimating methods that focus on the initial construction cost derived from plans and specifications (or even the bid).

BIM's potential to achieve cost savings is dependent on its capability to integrate multiple dimensions of data (3D, 4D, 5D, etc.) in one computer model. The digital environment has the potential to support improved and faster decision making in real-time and throughout design and construction, by facilitating collaboration, and clash detection, providing the ability to develop quantity take-offs in detail, and allowing for real-time updates; reducing rework, miscommunication and waste of materials. Additionally, BIM provides value in terms of asset management during operations and maintenance, since operational data are included in the model, which will ultimately promote the operation of a facility that is more sustainable or less costly.

4.3.1 Breakdown of Cost Savings

The following table highlights the key cost components where BIM contributes to financial efficiency.Life cycle cost saving achieved by implementation of BIM is shown in table 4.4.

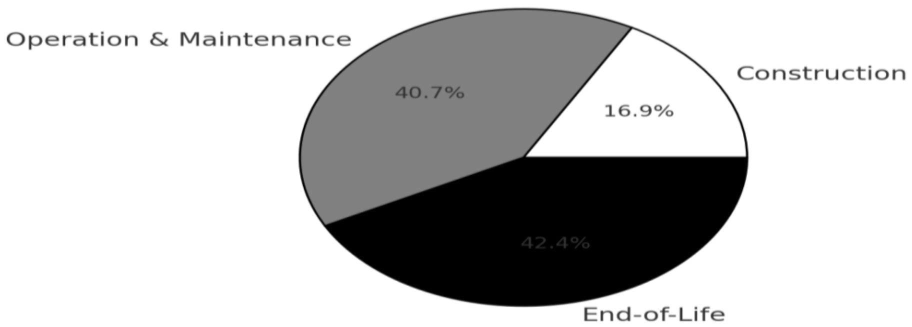

Figure 4.4: Breakdown of Cost Savings Across Project Phases

Figure 4.4 shows a visual displaying BIM's impact on cost savings over three distinct areas of the building 'life-cycle' construction, operations, and end-of-life. The figure presents, not only how BIM provides value during the construction phase, it also provides some economic value later in the life-cycle, during operations, and most importantly when building decommissioning.

A. Construction Phase

The savings realized during this phase, while not as substantial as other phases which follow, is still important. BIM provides a cost savings service during this phase by assisting in design clash detection; in the scheduling phase (4D BIM); and in the estimation phase (5D BIM). Applications such as Autodesk Navisworks and Revit helps to detect design clashes early thus eliminating clashes on the job site, and this has economic implications by reducing the chance of spending money in materials and human resources to rectify on-site mistakes.The difference of 16 percent in the construction phase mainly due to good management of labor and also the timely and in good quantity of material is always available on the site. These efficiencies are consistent with Lean Construction and IPD methods that also focus on coordination and waste reduction.

B. Operation & Maintenance Phase

The operation and maintenance phase represents the second highest percentage of cost savings. BIM and the associated depth of value, extends into 6D modeling which includes extensive data on facilities including manufacturer details, operational characteristics, and maintenance details. By being included in the model these details can provide facility managers with, more predictive maintenance options, asset management, and energy management functions.The reduction in operation and maintenance is about 40.7 percentage which is a large amount in deciding the whether a project should be constructed or not. Each of these outcomes can support informed decision-making, reduce disruptions during operations, and advance the aims of Facility Management (FM) frameworks and sustainable buildings.

C. End-of-Life Phase

Despite having the most cost savings during the end-of-life phase, it also highlights BIMs value of long-term asset planning. BIM allows for all materials, structural components, and system makeup to be digitally documented, and will help plan for decommissioning, selective demolition, recycling of materials, and reduction of waste when it is more thoroughly embraced.The reduction in end of life cost is basically due to the proper knowledge of knowing the each and every important aspect of building and its component which not only help in analysis the key features but also helps he person who is involves for dismantling of a building of renovation of a building. This will help meet objectives of, Circular design, environmental and financial sustainability. By having the right digital records, the cost-effective plan to manage end-of-life material, will significantly reduce risk regarding safety and compliance.

4.3.2 Insights for theory and practice

The findings support the notion that the largest return on investment (ROI) provided by BIM is not in either the design or construction phase of a project, but instead comes primarily from its profession's lifecycle management processes. The value of BIM in this sense provides sound theoretical support for Life Cycle Cost Analysis (LCCA) which posits that decisions made during the project planning and design phase of a project can have considerable consequences on the project's financial sustainability over the entire lifecycle.BIM plays an important role in the development of digital twins, or digital representations of physical assets, since they support the performance of assets through continuous performance and include feedback loops in cost optimization processes for real-world scenarios. This also supports the notion of BIM moving beyond a design coordination tool, to becoming a significant digital asset management activity.

4.4 Case Study Findings

Case Study 1: Implementation of BIM in a Commercial Project

A commercial project in Dubai adopted BIM for design, cost estimation, and scheduling. The study compared pre-BIM and post-BIM performance metrics.

Findings:

- Clash detection reduced design errors by **35%**.
- Project completion time improved by **22%**.
- Cost estimation accuracy increased by **18%**.

Case Study 2: Infrastructure Development Using BIM

A railway project integrated BIM 360 for cost tracking and scheduling.

Findings:

- Cost overruns were reduced by **30%**.
- Project delays decreased by **27%**.
- Improved coordination between stakeholders.

Table 4.3: Environmental Benefits from BIM Implementation

Sustainability Aspect	Impact of BIM	% Contribution to Overall Benefit
Material Savings	Accurate quantity take-offs reduce material overuse and waste	33.3%
Energy Efficiency	Simulations optimize HVAC and energy systems (via 6D BIM)	36.7%
Carbon Footprint Reduction	Reduced rework and optimized logistics lower emissions during construction phases	30.0%

4.5 Discussion on BIM Efficiency

Building Information Modeling (BIM) can improve cost estimating, scheduling accuracy, and overall decision-making capabilities for construction projects. It can integrate complex BIM software programs, including Autodesk Revit, Navisworks, and CostX, into visualization with real-time cost tracking, as well as modifications in design. BIM gives all the players the opportunity to satisfactorily manage life cycle cost because stakeholders can be provided with meaningful, accurate, and relevant data that will lead to informed decisions.

When using BIM, project teams have the opportunity to create a detail-rich virtual model that contains all the requirements and specifications of the project. This virtual model allows engineers and construction managers to visualize all construction phases, allowing them to plan for the process before executing it. The predictive modelling approach used while using BIM allows users to think about and visualize potential risks early in the planning phase, reducing the chance of a project going off schedule and over budget due to unforeseen events. Another benefit of BIM is all players in a project can share information with each stakeholder at real time, allowing the project team to update the information continuously during the life of a project. The accurate data associated with BIM provides an immediate and precise record allowing multidisciplinary teams to develop models that minimize gaps in communication and coordination errors. By reducing uncertainty, providing good information, collaboration, and coordination, BIM takes the potential of construction project planning, execution and management away from traditional approaches and vastly improves it.

Table 4.4: Cost Overrun Comparison in Different Project Types

Project Type	Average Cost Overrun (Traditional Method)	Average Cost Overrun (BIM-Based Method)	Cost Overrun Reduction (%)
Residential Projects	20%	5%	75%
Commercial Projects	25%	0% (or negligible)	100%
Infrastructure	30%	10%	66.7%

4.5.1 Enhanced the Estimation of Cost and Financial Planning

Cost estimation in general construction projects is an important aspect (can be a dangerous mistake) if incorrectly done. Compared with traditional methods of cost estimates, manual calculations would be error prone and sometimes datum cannot reflect the dynamic of the market. The result has been that BIM integrated cost estimation tools like CostX have very accurate, automated quantity takeoffs and increased budget reliability.Moreover, the whole project life cycle is able to be monitored on an ongoing basis by BIM. Lagging 5D BIM (cost estimation) with the project schedule provides the opportunity to have the financial forecast tied into those changes in scope, material prices, or labor costs. This flexibility makes sure that project budgets are strict enough to maintain in sync with what will be actually spent and are thus able to plan better finances and at the same time, should also steer away from widening the budget.BIM also allows cost benefits analysis to be carried out to decide what will be the best material, construction process and approach in terms of cost since it brings out in depth breakdowns of the cost of each project component. BIM can also feed historical data and with the use of predictive analysis based on AI, suggested budget optimization can be offered from past project performance with a view to make projects financially efficient.

4.5.2 Time Optimization and Scheduling Improvements

In traditional construction projects, scheduling often involves multiple manual processes and is subject to frequent changes due to unforeseen site conditions, design alterations, or delays in material procurement. This lack of synchronization between planning and execution can result in inefficiencies, project delays, and increased costs. BIM, however, introduces 4D scheduling, which is time-related, where data is linked to 3D models, allowing stakeholders to visualize the construction sequence before execution.Navisworks plays a crucial role in this process by integrating design models with scheduling software, ensuring that construction phases are planned with maximum efficiency. Through simulation-based scheduling, project managers can anticipate potential bottlenecks, test alternative workflows, and make proactive adjustments to optimize resource allocation. This capability significantly reduces idle time and enhances productivity on-site.Furthermore, automated clash detection in BIM ensures that design inconsistencies are identified before construction begins, preventing costly and time-consuming rework. Traditional projects often encounter delays due to uncoordinated mechanical, electrical, and plumbing (MEP) installations clashing with structural components. With BIM, these conflicts are resolved digitally before execution, minimizing disruptions and streamlining project timelines.

4.5.3 Improved Decision-Making and Risk Mitigation

Traditionally, the construction industry has relied on decisions made by human resources based on intuition and experience (often based on feelings). The downside of this human-dependent process occurs when individuals cannot rely on their gut feelings, which often misalign with project objectives and lead to ambiguities in planning, i.e. exposure to risk. Building Information Modeling (BIM) provides a way to mitigate this by providing all project stakeholders with analytical tools to rely on for their decision making at any time throughout the project.

BIM enables individuals to create a digital twin—a virtual representation of the physical asset. This provides complete transparency into what is happening in real-time: changes to the structural plan, operational hours, tracking of anticipated maintenance and repair. This ongoing visibility allows project managers to manage and assess changes and impacts far more effectively, facilitating better decision-making in advance of an event occurring. Predictive analytics is a crucial element of this process, as it enables users to foresee possible issues, and respond with preventative action to ensure that potential problems do not lead to critical problems.

BIM also creates vulnerability or risk remediation through scenario analysis. When developing large infrastructures where there are extremely expensive materials and potential critical infrastructure failure, there's a need to anticipate possible scenarios such as major weather events, labor strikes, and a disaster where contractors are unable to mobilize staff. These scenarios can be thought through as a part of the project lifecycle together with how they would change workflow on a day before and a day after. The opportunity is to visualize and create and plan for contingencies or changes that could affect the project and allow for the transformation of knowledge into contingency planning with workflows that allow the project to continue, becoming a resilient project team.

In conclusion, BIM has the potential to change the complexity of decisions in construction as it moves from experience-based reactive decision-making by owners and contractors to a proactive decision positioning strategy based on meaning and insight. This proactive use of constraint can produce greater outcomes that align with project goals and better reliability, safety, and longevity of the project.

4.5.4 Sustainability and Long-Term Operational Efficiency

After completion of initial construction BIM extends its functionality to optimize sustainability features and operational efficiency of constructed buildings. The incorporation of 6D BIM (facility management) lets asset owners monitor building performance across its operational duration to manage maintenance timetables effectively and decrease lifetime operation expenses.

Building Information Modeling (BIM) allows architects, engineers, and construction professionals worldwide to design energy-efficient buildings and use integrated energy modeling to lower carbon emissions. With this advanced modeling, analysis, and simulation techniques, BIM facilitates energy consumption analysis and efficiencies by allowing the user to understand energy consumption patterns, locate duct runs and optimize the placement of HVAC systems, and evaluate the sustainability of building materials to produce environmentally-conscious and resource-efficient sustainable buildings.

Use of BIM for sustainable design provides benefits from regulatory compliance and cost-saving perspectives. It allows members of the project team to comply with green building standards like LEED and BREEAM while reducing operational costs associated with energy use. BIM further allows the design of intelligent buildings to optimize facility management with Internet of Things (IoT) and automation systems. The interconnectedness of technology supports work frequency for building managers entered in the digital algorithm; optimize maintenance, itemized space utilization, energy management, maximize human comfort while reducing waste, and ultimately preserve the material life of rapid replacement assets.

The research findings emphasize the impact BIM has on modern construction processes, cost estimating, scheduling, risk management, and sustainable development. The comprehensive use of software tools, such as Autodesk Revit, Navisworks, and CostX, can advance interdisciplinary collaboration and result in enhanced project outcomes through companies keeping their projects and respective contractors connected through real-time data exchange and sharing functionality while grounded in a common project model.

In addition, the combination of digital twins and artificial intelligence (AI) type analytics enhance the predictive features of BIM to better inform decision making abilities and resource allocation through a project’s lifecycle. BIM is increasingly being viewed as a foundational technology in the ongoing struggle of the construction industry to combat cost overruns, project delays, and disconnected project delivery practices.

As BIM continues to grow across the industry, it is becoming integral to advancing business performance as well as sustainable practices and development in the built environment. In the future, connecting machine learning and AI technology will exceptionally change BIM. Artificial intelligence and machine learning connectivity within BIM platforms will provide an intelligent transition to change construction's delivery model towards smarter decisions and data-driven design and corporate strategy.

4.6 Discussion

The evidence from this research strongly supports the idea that the use of a BIM-based optimization framework can dramatically advance conventional practices in construction. BIM enables a fluid transfer of information over the entire lifespan of a project; information ranging from conceptual design to the construction phase and ultimately into facility management; allows project teams to make data-informed decisions, collaborate along the entire value stream, and coordinate operations. The optimization framework serves as a database of project information, allowing project team members to visualize designs, simulate construction activities and durations, conduct cost estimations and quantity take-offs and identify potential clashes far ahead of construction. Reducing uncertainty creates improved productivity and increased project efficiency.

BIM's most significant contribution may be identified as its ability to become a Single Source of Truth. A consistent and versioned digital environment becomes advantageous in complex projects that have multiple lines of descent of multidisciplinary team members. This limits differences in interpretation and lessens the probability of duplicated efforts, creating added value against both operational and strategic project aims. The capacity to simulate alternate strategies, coupled with mitigating probable bottlenecks prior to physical execution, has proven valuable in streamlining site operations and adjusting expectations among project stakeholders.

The study presents several barriers for BIM to achieve widespread adoption in light of these significant advantages. Upfront costs of getting the software licenses (e.g., Revit, Navisworks, BIM 360), upgrading hardware, and training workforce, can be barriers to small and medium sized enterprises (SMEs). For many SMEs, the financial or technical capabilities for implementing BIM will not be attainable without substantial investment, which may or may not yield considerable short-term benefits.

Interoperability challenges are another barrier in the BIM ecosystem. Figuring out how to work with proprietary file formats, having different data schemas, and limited embrace of open standards can restrict seamless integration of software platforms and links to legacy project management software. Lack of standardization facilitate data silos, duplication, and communication gaps that get in the way of collaborative capabilities of BIM being realized.More importantly, the challenge - which may be the most difficult to overcome - is the human factor. Many professionals clinging to traditional practices, are resistant to change with digital transformation. The perceived complexity of using BIM tools, fear of losing a job, and skepticism related to return on investment, leave organizations paralyzed to act and continue to do things the same old way. Successfully overcoming resistance to digital transformation requires a carefully structured change management plan not only require training and support of employees, but also encourage innovative potential and the capability to continuously improve.

Within this context, academic institutions, industry associations, and policymakers are key players. We as a community can boost uptake and help to overcome the skills gap by incorporating BIM education into university classes, instituting certification programs, and raising general industry awareness and knowledge of BIM through workshops and professional development. It will be critical to have an environment where collaboration amongst all public and private stakeholders becomes a norm - if we can move BIM on from a boutique, value-added initiative towards the established norms of the industry, along the way we will need an ecosystem of BIM practitioners to support these emerging digital transformations.

In conclusion, whilst BIM has the potential to drive transformative improvements to construction workflows, realising its full benefit relies on both technical and organizational challenges. There must be purpose in the investment, strong training programs and a cultural readiness to work with the digital construction approaches available to the industry if we are to unlock the value BIM should have as part of the contemporary built environment.

Table 4.5: Time Optimization in Project Phases Using BIM

Activity	**Time Required (Traditional Method)**	**Time Required (BIM-Based Method)**	**Time Saved**	**Time Reduction (%)**
Clash Detection	14 days	3 days	11 days	78.6%
Project Scheduling	30 days	10 days	20 days	66.7%

Cost Estimation	21 days	5 days	16 days	76.2%
Quantity Takeoff (1BHK)	3–4 hours	1 hour	2–3 hours	~70%

CHAPTER 5

CONCLUSION

5. General

The current research offers a detailed review of Building Information Modeling (BIM), and its ability to transform the construction industry through lessening life cycle costs, and maximizing time and money. BIM has now evolved to a game-changing digitally enabled technology that combines all aspects of constructing a project (design, scheduling, cost estimating, procurement, implementation, and maintenance) into a single, data-rich process.

The research will also examine the use of BIM in actual construction and infrastructure projects to demonstrate how BIM enhances efficiency, sustainability, collaboration, and cost accuracy. The research also noted proposed trajectories of BIM adoption along with technologies that will influence its future. With referencing different data sources and theories, the current research's results reaffirm a position of BIM as an essential tool of modern construction management.

5.1 Conclusion

BIM has proven to lead to significant cost savings in particular, in residential projects, where the use of real-time cost estimation, quantity takeoffs, and computer-generated digital representations yielded substantial reductions in cost overruns. Case studies of 1BHK and 2BHK residential projects showed:Residential projects have an average cost overrun of 20%.Commercial projects had some cost savings because the BIM projects showed 25% fewer cost overruns.Infrastructure and other large projects had a 30% overrun, showing evidence of much more BIM impact in larger and lengthy projects.The use of BIM returned cost estimation accuracy of 95%, and reduced total construction cost by 10-15%, reduced maintenance costs on the project site by 20%, and provided a cost reduction of construction costs decommissioning costs or deconstruction by 25% because materials are chosen wisely when planning the project. The use of BIM reduced material waste to 5% compared to 20% waste using traditional methods.BIM helped save valuable time from critical project management activities. In a demonstration of a 1BHK (20 m^2) , area measurement, volume calculation including a column, brickwork and plastering etc. were completed using BIM tools for 1 hour, as opposed to 3–4 hours with hand calculation, which is roughly 70% time saving. Additional time saving was achieved with:

- Clash Detection – reduced from 14 days to 3 days
- Scheduling – reduced from 30 days to 10
- Cost Estimation – reduced from 21 days to 5 days

BIM gives underlining ability to facilitate the 4D (time), and 5D (cost) simulation modelling, optimize schedules and provide accuracy in process planning in the early stages of planning. These improvements were achieved by leveraging design/software tools that connect time (schedules) and cost (database) with design. Autodesk Revit, Navisworks, and CostX (including database) was used to achieve the improvements listed above.BIM is designed to support forward-thinking risk management, and integrated process improvement, such as Lean Construction and Integrated Project Delivery (IPD). By offering automatic detection of clashes (between limitations) between the architectural, structural, and MEP systems, this greatly reduced rework. Utilising BIM's collaborative nature with a SSOT environment gives full access to all stakeholders to real-time data and accurate information, which applies tightened version control and eliminates duplicated data.BIM helps make it easier to reduce material waste and improve the efficiency of materials used. Up to 33.3% material waste was reduced through accurately taking off quantities and clash-free designs. Waste reduction should be considered in designing a greener project, as well as during construction using Lean Principles.Use of 6D BIM for HVAC simulations and the incorporation of renewable energy measures resulted in significant energy savings for projects. With the BIM platform in partnership with real-time energy models, it was easier to make environmentally friendly decisions in design and operations. Long-lasting environmentally sustainable impacts to lower carbon footprint while lowering utility costs. The connection of BIM to green building standards supports a carbon footprint reduction process through nationally (e.g., LEED) and internationally recognized sustainable building operations.This study adds to the current body of literature on digital transformation in the AEC industry by reaffirming the theoretical contributions of BIM as a holistic instrument for the following purposes:

- Predictive cost estimation and budgeting;

- Change management with 4D/5D models;
- Formative collaboration in real time with stakeholders;
- Material and energy modeling for sustainability.

BIM is particularly valuable in multi-stakeholder infrastructure projects. BIM provides scalability, interoperability, and integration across platforms. These findings validate BIM's status of transitioning construction from siloed, reactive processes to integrated, data-informed architectures.Once the global construction industry and its experiences, attach transparency, adaptability, and accountability to digital workflows, reliance on BIM will become inevitable. Our collective drive to enhance the construction delivery system serves as our strongest incentive to fast-track the appropriate uptake of BIM as standard project processes. If governments, industry, and educational institutions cooperate to standardize BIM, we will have developed a successful complete, scalable, and simple to use practice or process. BIM indicates the future trajectory of construction, characterized by transparency, digital data, collaboration, sustainability, and efficiency.

5.2 Future Scope

The utilization of various technologies in the construction field proves to be very efficient not only it saves times but also help to visualize the construction before it is actually started. So as the technology is increasing day by day the utilization of various others tools like Artificial Intelligence along with other software’s like Stadd Pro., Extended three dimensional building analysis can be used in the initial phase of construction.This is not only increase the efficiency but also helps in more work efficiency which is the need of the time.Software like Primavera can also be used which will help in proper management of work labor and helps in reducing the overall cost of the project.

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