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**Assessing the Impact of Building Information Modeling (BIM)
Implementation on Engineering Project Management Efficiency in Saudi
Arabian Construction Companies:
(An Empirical Study of Time, Cost, and Quality Performance).**

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بِسْمِ اللَّهِ الرَّحْمَنِ الرَّحِيمِ

Declaration

I hereby declare that this thesis, entitled “Assessing the Impact of Building Information Modeling (BIM) Implementation on Engineering Project Management Efficiency in Saudi Arabian Construction Companies: An Empirical Study of Time, Cost, and Quality Performance,” is my own original work and has been prepared for academic purposes in partial fulfillment of the requirements of the Master of Project Management program.

I confirm that the ideas, arguments, analysis, interpretations, and conclusions presented in this thesis are based on academic research, survey data, and properly acknowledged sources. All references, books, journal articles, reports, and other materials used in the preparation of this thesis have been cited and listed in accordance with academic referencing standards.

I further declare that this thesis has not been submitted, either in whole or in part, for the award of any other academic degree or qualification at any other university or institution. The survey data used in this study were collected for the purpose of this research, and the responses were analyzed collectively while maintaining the confidentiality and anonymity of the participants.

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Ethical Statement on the Use of Digital Tools

Digital tools may have been used only for language refinement, formatting support, grammar checking, and organization of ideas. The research topic, questionnaire design, data collection, SPSS analysis, interpretation of findings, conclusions, and final academic decisions remain the responsibility of the researcher. The researcher confirms that no data were fabricated, manipulated, or invented. All statistical results presented in this thesis should be supported by the original survey responses, raw Excel data, SPSS .sav file, and SPSS output tables attached in the evidence file or appendices.

Acknowledgement

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Dedication

I dedicate this work to my beloved parents, who have always been a constant source of support, inspiration, and encouragement throughout my life.

To my dear mother, whose love, care, and continuous encouragement have always been a source of motivation and strength, and to my father, who taught me the true meaning of perseverance, discipline, responsibility, and hard work.

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Abstract

This study assessed the impact of Building Information Modeling (BIM) implementation on engineering project management efficiency in Saudi Arabian construction companies, focusing on time performance, cost performance, quality performance, and overall project management efficiency. The study was based on a quantitative descriptive-analytical design. Data were collected through a structured questionnaire completed by 100 professionals working in the Saudi construction and engineering sector.

The questionnaire measured BIM implementation, time performance, cost performance, quality performance, project management efficiency, and BIM implementation challenges using a five-point Likert scale. The data were analyzed using descriptive statistics, reliability analysis, Pearson correlation, and regression analysis.

The findings showed that BIM implementation had a positive and statistically significant effect on time performance, cost performance, quality performance, and overall engineering project management efficiency. Quality performance recorded the highest mean among the performance dimensions. The results also indicated that BIM-related challenges remain important, especially those linked to training, organizational readiness, cost, interoperability, and integration with project management processes.

The study concludes that BIM can significantly improve engineering project management efficiency when it is effectively integrated into planning, scheduling, cost control, quality management, coordination, and decision-making. The study recommends strengthening BIM training, improving organizational readiness, developing clear BIM standards, and integrating BIM with 4D scheduling, 5D cost control, and quality assurance systems.

Keywords: Building Information Modeling, BIM Implementation, Project Management Efficiency, Time Performance, Cost Performance, Quality Performance, Saudi Construction Industry.

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Chapter One

1- Introduction: General Framework of the Study

1.1 Introduction

Construction has played a key role in economic development, infrastructure development, urbanization, and national development. Despite its strategic relevance, however, the construction industry is still struggling with numerous managerial and operational issues, particularly with respect to delays, cost overruns, lack of coordination, design errors, rework, and quality issues. These challenges have been intensely debated in the project management and construction literature, and the traditional construction project delivery process is often characterized as being document-based, fragmented, and reliant on disconnected communication channels among project stakeholders (Eastman et al., 2011; Flyvbjerg, 2014; McKinsey Global Institute, 2017).

In the field of engineering and construction, project management efficiency is often defined by the ability to complete a project on time, within budget, and within the desired quality standards. Time, cost, and quality are key measures of project performance and are closely linked to the “iron triangle” of project management (Atkinson, 1999; Project Management Institute [PMI], 2021). If any of these dimensions is not effectively managed, the whole performance of the project is affected in a negative way. The cost of the project can be higher if it takes longer to complete, cost overruns can reduce profits, and quality issues can result in rework, conflict, client dissatisfaction, and further operational risks.

In the era of modern engineering, the project management process is becoming more complicated, and the traditional project management method is not suitable in many cases. Owners, consultants, designers, engineers, contractors, subcontractors, suppliers, and regulatory bodies are all involved in large-scale construction projects. A significant amount of project information is created, shared, and relied upon by each of the stakeholders. If this information is not effectively shared, issues like inaccurate drawings, lack of coordination, duplicated work, delayed decisions, and construction conflicts can arise. This makes digital tools particularly important because they can enhance collaboration, information management, planning, monitoring, and decision-making (Borrmann et al., 2018; Sacks et al., 2018).

Building Information Modeling (BIM) is one of the most impactful digital technologies in the Architecture, Engineering, and Construction (AEC) industry today. BIM is more than just three-dimensional design; it is a digital process that allows the generation, management, sharing, and application of accurate information about a built asset over its life cycle (Eastman et al., 2011; ISO, 2018; Sacks et al., 2018). BIM gives project stakeholders access to the project in a virtual environment that can support the linking of geometric and non-geometric data to design, scheduling, cost estimation, construction planning, quality control, and facility management.

BIM is different from typical two-dimensional drawings because it allows the integration of projects in multiple dimensions. The 3D dimension can be used to visualize and coordinate design; 4D BIM can integrate the model with time and scheduling data; 5D BIM can incorporate quantities and cost information; and more dimensions are possible to connect with facility management, sustainability, safety, and lifecycle performance (Eastman et al., 2011; Sacks et al., 2018). This multidimensional structure makes BIM very relevant to project management, as it gives project managers a more accurate basis on which to plan and control project activities in a visual and data-based way.

Past research has revealed that BIM offers a number of benefits that can assist in making project performance better, such as improving visualization, reducing design conflicts, supporting clash detection, improving communication between the various stakeholders, minimizing rework, improving the estimation of project costs, and supporting better scheduling decisions (Azhar, 2011; Barlish & Sullivan, 2012; Bryde et al., 2013). The practical application of BIM, however, is not restricted to software availability, but also depends on the extent to which BIM is utilized in the project management process. If BIM is only applied for visualization of design products, its role in time, cost, quality, and overall project efficiency management might be limited (Khosrowshahi & Arayici, 2012; Succar, 2009).

The construction industry is rapidly changing in Saudi Arabia due to the implementation of major infrastructure projects, urbanization, smart city development, and national digital transformation initiatives. As the scale and complexity of construction work grows in the Kingdom, there is a rising demand for advanced project management solutions that can help enhance coordination, eliminate inefficiencies, and drive improved outcomes of construction delivery. According to studies conducted in the Saudi construction industry,

BIM use is growing and becoming more relevant; however, there are still some challenges that hinder the implementation of BIM, such as lack of training, limited awareness, shortage of skilled BIM personnel, interoperability issues, implementation cost, and organizational readiness (Alaboud & Alshahrani, 2023; Alhumayn et al., 2017; Sodangi et al., 2018).

Therefore, the aim of this study is to evaluate the influence of using BIM on engineering project management efficiency in construction companies in Saudi Arabia. The effect of BIM on three main performance dimensions, namely time performance, cost control and estimation accuracy, and project quality performance, is specifically examined. It also discusses the barriers that can hinder successful BIM application and offers some suggestions for improving the integration of BIM into project management.

1.2 Background of the Study

In engineering and construction projects, project management involves managing the project activities to ensure that they meet the predetermined goals. PMI (2021) claims that successful project management involves several domains and practices, such as planning, delivering the project, measuring the project, managing uncertainty, engaging stakeholders, and managing team performance. These practices are particularly critical in construction projects, since the project results depend on technical complexity, contractual arrangements, availability of resources, site conditions, regulatory requirements, and coordination of stakeholders.

In traditional construction project management, there are usually different documents, different schedules, manual cost estimates and disjointed communications. This disintegration leaves a gap between the design information and project implementation. For instance, drawings might be created prior to schedules, cost estimates might be drawn up without design models, and quality checking could be completed after construction mistakes are made. Project information systems are used to keep information separate, which can impact the accuracy of decisions and lead to delays, cost increase, and rework (Eastman et al., 2011; McKinsey Global Institute, 2017).

BIM has emerged as an approach to address these limitations. It is a single, digital representation of a facility with both physical and functional attributes. BIM's significance is that it links together project data via a shared model, enabling project stakeholders to "see the project" and identify conflicts, quantity take-off, construction sequence simulation, discipline coordination and better information flow (Azhar, 2011; Borrmann et al., 2018; Sacks et al., 2018). Consequently, BIM is no longer just a design technology, but an important project management tool as well.

BIM is closely connected with digital transformation of the construction industry. The industry is transitioning from paper to digital and data driven processes with more collaborative work spaces than ever. BIM can help with this change by facilitating the common data environment, standardizing information management, and facilitating more transparent project communication. The ISO 19650 is an international standard for the use of BIM throughout the lifecycle of built assets, it sets out the framework for managing the organization, digitization and exchange of project information (ISO, 2018). This confirms that BIM is a structured approach to information management as well as a modeling tool.

When it comes to time performance, BIM allows to incorporate project timetables and schedules into the digital model by means of 4D simulation. This enables project managers to see the construction sequence, recognize any conflicts in the construction schedule, and have a better understanding of options and track construction progress. BIM can help to enhance the clarity of schedules and minimize planning inaccuracies by connecting components of the model to activities that occur over time (Eastman et al., 2011; Bryde et al., 2013). When it comes to cost performance, BIM enables 5D cost modelling by correlating quantities, materials, and cost information with model objects. This can help to increase the accuracy of quantity take-off, aid cost estimation and enable project managers to know the cost implications of design changes (Azhar, 2011; Barlish & Sullivan, 2012).

BIM enhances design coordination, minimizes errors from clash detection, model checking, documentation control, and interdisciplinary collaboration, when it comes to quality performance. The capabilities can assist in identifying design incompleteness prior to the start of construction, thereby minimizing the risk of rework, and improving the quality of the project product (Azhar, 2011; Eastman et al., 2011). Hence, BIM is directly connected with the three main dimensions of project management efficiency: time, cost, and quality.

But the use of BIM does not guarantee improved project performance. Various organizational and technical considerations play a role in the benefits of BIM, and these are management support, staff capability, training, workflow integration, data standards, software interoperability and stakeholder commitment (Khosrowshahi & Arayici, 2012; Succar, 2009). These factors are especially significant in the construction industry in Saudi Arabia, as the adoption of BIM is still in its early stages and can differ widely among various companies, projects, and professional groups (Alaboud & Alshahrani, 2023; Alhumayn et al., 2017). Hence, it is essential to investigate the relationship between the use of BIM and the efficiency of engineering project management in the construction companies of Saudi Arabia in an empirical manner.

1.3 Statement of the Problem

Project delays, cost overruns, quality issues, design conflicts, and inadequate coordination among stakeholders are ongoing issues in the construction industry. These problems indicate significant inefficiencies in conventional engineering project management practices. Despite the proliferation of advanced digital technologies, many construction companies still experience workflows that are disjointed, isolated project information, and poor integration between design, scheduling, cost control, and quality management systems (Eastman et al., 2011; McKinsey Global Institute, 2017).

BIM is an effective solution to the challenge of enhancing the performance of projects on the basis of improved visualization, information integration, clash detection, scheduling simulation, cost estimation and collaborative decision-making. But many organizations have limited and inconsistent implementation of BIM. In some instances, BIM is only applied to the design visualization or for 3D models, where it is not fully utilized in project management processes such as time planning, cost management, quality assurance, progress monitoring, and performance evaluation (Khosrowshahi & Arayici, 2012; Succar, 2009).

Moreover, while various studies have recognized the advantages of BIM, there is a lack of in-depth empirical studies that consider the overall effects of BIM in engineering project management efficiency. Most of the current literature emphasizes on the benefits for the individual, like better visualization, less error, better cost estimation or shorter project

duration. But there are fewer researchers that have attempted to analysis the impact of BIM implementation on time performance, cost performance, quality performance and overall project management efficiency in a single research model (Barlish & Sullivan, 2012; Bryde et al., 2013).

The demand for effective integration of BIM in the construction industry is particularly significant in Saudi Arabia as a result of the large-scale construction projects, the complexity of engineering projects, and the focus on digital transformation. However, barriers including lack of training, limited expertise, high implementation costs, interoperability issues, organizational resistance, and lack of awareness of BIM managerial benefits continue to impact the implementation of BIM in construction companies in Saudi Arabia (Alaboud & Alshahrani, 2023; Alhumayn et al., 2017; Sodangi et al., 2018).

Therefore, the problem of the research is the lack of integration of BIM in engineering project management processes and the lack of empirical knowledge of its full effect on the project efficiency, especially in terms of time, cost, and quality performance of engineering projects in construction companies in Saudi Arabia.

1.4 Main Research Question

To what extent does Building Information Modeling (BIM) implementation affect engineering project management efficiency in Saudi Arabian construction companies?

1.5 Sub-Questions

What is the impact of BIM implementation on project time performance?

What is the impact of BIM implementation on cost control and cost estimation accuracy?

What is the impact of BIM implementation on project quality performance?

What are the main challenges that limit effective BIM implementation in engineering projects?

How can BIM be better integrated into project management practices to improve overall efficiency?

1.6 Research Objectives

General Objective

To assess the impact of BIM implementation on engineering project management efficiency in Saudi Arabian construction companies, particularly in relation to time, cost, and quality performance.

Specific Objectives

To evaluate the effect of BIM implementation on project time performance.

To examine the role of BIM in improving cost estimation and cost control.

To analyze the effect of BIM on project quality and reduction of errors and rework.

To identify the key challenges affecting BIM implementation in construction companies.

To propose recommendations for improving BIM integration into project management practices.

1.7 Importance of the Study

Scientific Importance

The academic significance of this study is that it contributes to the Building Information Modeling (BIM) and engineering project management literature. While BIM has been extensively studied as a technological and design tool, more studies are needed that examine BIM as a project management tool that can affect measurable project performance outcomes. This study helps provide a more holistic perspective on the correlation between digital construction technologies and project management effectiveness by analyzing the correlation between BIM implementation and time performance, cost control, quality performance, and project management effectiveness.

This study is also significant due to the research gap identified in the literature. There are many studies that have covered one aspect of BIM benefits such as visualization, coordination, cost estimation, clash detection, etc. The present study, however, focuses on BIM implementation using a wider performance-based perspective that represents the link between the independent variable (BIM implementation) and several dependent performance variables. This helps to build empirical knowledge and understanding of the impact of BIM on the overall engineering project management efficiency, not just as isolated outcomes (Azhar, 2011; Barlish & Sullivan, 2012; Bryde et al., 2013).

Furthermore, the research provides a theoretical perspective on BIM adoption by connecting BIM implementation with other concepts such as project performance, digital transformation, information integration, BIM maturity, and organizational readiness. The study can then serve as a reference for future researchers in the areas of digital construction, BIM implementation, construction project performance and development of project management in Saudi Arabia and similar contexts.

Practical Importance

This study has significant applications for industry professionals, including engineers, project managers, BIM specialists, contractors, consultants, and decision makers in the construction industry. The study can be used to analyze the benefits and drawbacks of implementing BIM in construction projects, as well as its potential to enhance planning, coordination, monitoring, and control processes. For construction firms looking to save time, manage budgets, ensure quality results, and avoid rework and mistakes, this is particularly important.

The study can also assist construction companies in Saudi Arabia to understand the challenges faced in practice to implement BIM. These obstacles include lack of training, high software and hardware costs, poor integration between BIM and project management, resistance to change, lack of standards, and shortage of skilled professionals. It is essential to understand these barriers as getting BIM right requires not only the technical tools but also organizational readiness, management support, staff development and clear implementation strategies (Alhumayn et al., 2017; Khosrowshahi & Arayici, 2012; Sodangi et al., 2018).

Moreover, the results of this study can inform decision making of the construction organizations who are considering BIM or implementing BIM as a practice. The study can help companies to understand the BIM relation with project management efficiency and achieve more effective integration of the BIM into project management, such as scheduling, cost and quality management and project control. This can help to improve the quality of project delivery, increase collaboration between stakeholders, minimize waste, and help drive the sector towards digitalization in Saudi.

1.8 Research Variables

The study is based on one independent variable and one main dependent variable with three major performance dimensions.

The independent variable is Building Information Modeling (BIM) implementation. In this study, BIM implementation refers to the extent to which construction companies use BIM tools, processes, and collaborative digital models to support project planning, coordination, scheduling, cost estimation, quality management, and information exchange. BIM implementation may include the use of 3D modeling, 4D scheduling, 5D cost modeling, clash detection, model-based coordination, and information-sharing platforms.

The dependent variable is engineering project management efficiency. In this study, project management efficiency refers to the ability of construction companies to manage engineering projects effectively through improved planning, coordination, resource use, decision-making, monitoring, and control. This efficiency is examined through three main dimensions: time performance, cost performance, and quality performance.

Time performance refers to the extent to which BIM supports project scheduling, delay reduction, progress monitoring, construction sequencing, and timely decision-making. Cost performance refers to the extent to which BIM improves cost estimation accuracy, quantity take-off, budget control, cost monitoring, and reduction of cost overruns. Quality performance refers to the extent to which BIM improves design accuracy, clash detection, documentation consistency, error reduction, rework reduction, and compliance with project requirements.

1.9 Research Hypotheses

The study hypotheses are formulated in accordance with the research questions, objectives, and conceptual framework. Since the study aims to test the relationship between BIM implementation and engineering project management efficiency, the hypotheses include one main hypothesis and a set of sub-hypotheses related to the major performance dimensions.

Main Null Hypothesis

H0: There is no statistically significant relationship between BIM implementation and engineering project management efficiency in Saudi Arabian construction companies.

Main Alternative Hypothesis

H1: There is a statistically significant relationship between BIM implementation and engineering project management efficiency in Saudi Arabian construction companies.

Sub-Hypotheses

H1a: BIM implementation has a statistically significant effect on project time performance.

H1b: BIM implementation has a statistically significant effect on cost control and cost estimation accuracy.

H1c: BIM implementation has a statistically significant effect on project quality performance.

H1d: BIM implementation has a statistically significant effect on overall engineering project management efficiency.

1.9.1 Conceptual Justification of the Research Hypotheses

The research hypotheses developed in this study are derived from the integrated theoretical framework and supported by previous empirical studies on Building Information Modeling (BIM) implementation and engineering project management. As discussed in Chapter Two, the Iron Triangle of Project Management, the Technology Acceptance Model (TAM), Diffusion of Innovation Theory, the BIM Maturity Perspective, and the Information Management Perspective collectively explain how BIM implementation can influence engineering project management efficiency. These theoretical perspectives suggest that

effective BIM implementation enhances project planning, coordination, information integration, communication, and decision-making, thereby contributing to improved project performance.

The main alternative hypothesis (H1) proposes that BIM implementation has a statistically significant relationship with engineering project management efficiency in Saudi Arabian construction companies. This hypothesis is theoretically justified because BIM provides an integrated digital environment that improves collaboration among project stakeholders, facilitates information sharing, supports informed decision-making, and enhances project planning and control. Previous empirical studies have consistently reported positive relationships between BIM implementation and project performance, indicating that organizations implementing BIM more effectively are more likely to achieve higher levels of engineering project management efficiency.

Hypothesis H1a proposes that BIM implementation has a statistically significant effect on project time performance. This expectation is supported by the capabilities of 4D BIM, which integrates construction schedules with digital models to improve activity sequencing, construction simulation, progress monitoring, and early identification of scheduling conflicts. These capabilities enable project managers to improve planning accuracy, reduce delays, and strengthen schedule control, thereby providing a sound theoretical basis for expecting improved time performance.

Hypothesis H1b proposes that BIM implementation has a statistically significant effect on cost control and cost estimation accuracy. The justification for this hypothesis is based on the ability of 5D BIM to integrate quantity take-off, cost estimation, budget forecasting, and cost monitoring within a unified digital environment. By improving the accuracy of quantity calculations, facilitating the evaluation of design changes, and supporting more effective budget management, BIM is expected to contribute to better cost performance and reduce the likelihood of cost overruns.

Hypothesis H1c proposes that BIM implementation has a statistically significant effect on project quality performance. This hypothesis is supported by previous studies demonstrating that BIM improves design coordination, clash detection, documentation accuracy, interdisciplinary collaboration, and quality control throughout the project lifecycle. By identifying design conflicts before construction begins and improving the consistency and reliability of project information, BIM is expected to reduce errors,

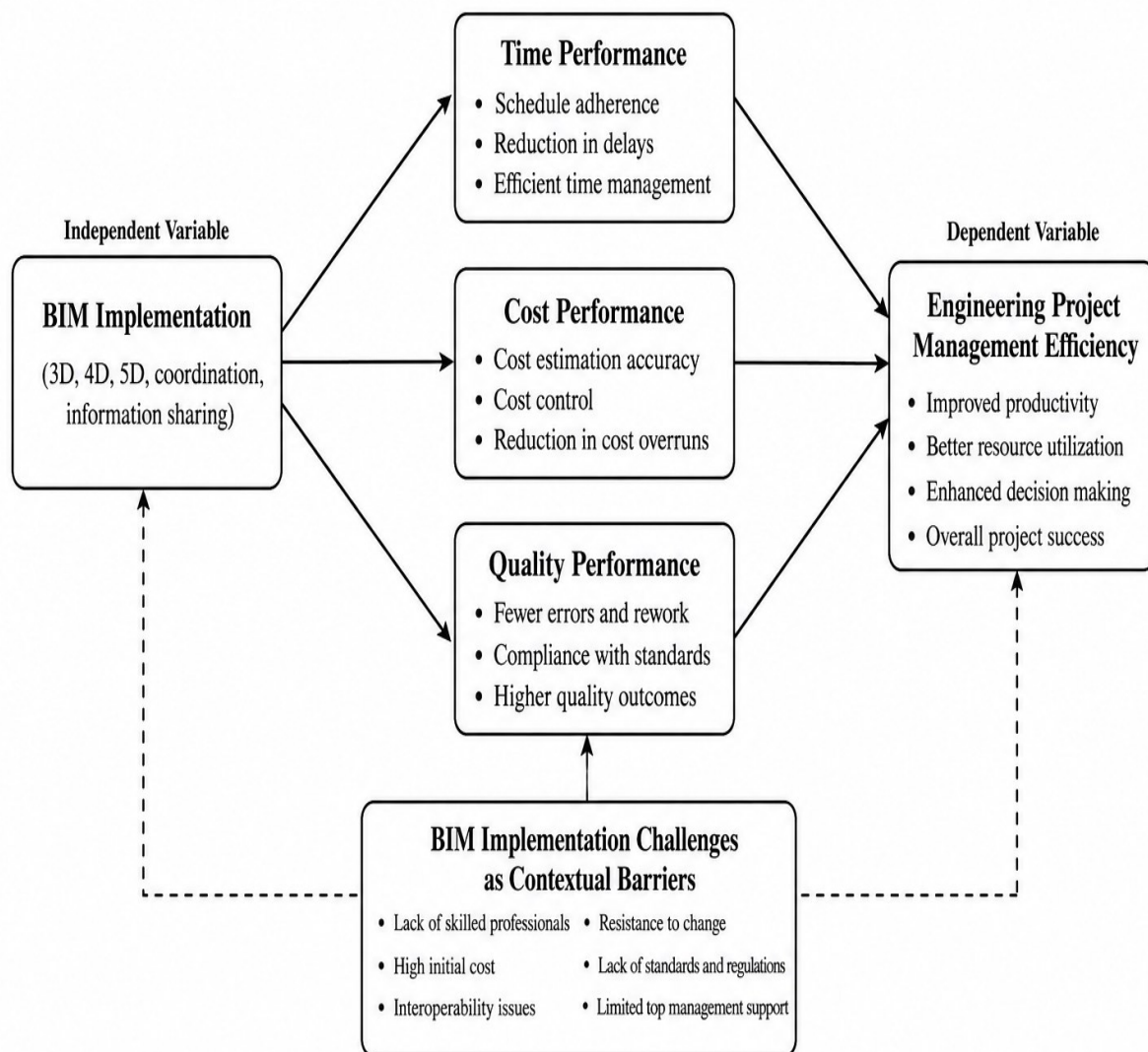
minimize rework, and enhance compliance with project specifications and quality standards.

Finally, Hypothesis H1d proposes that BIM implementation has a statistically significant effect on overall engineering project management efficiency. This hypothesis is conceptually justified because engineering project management efficiency is represented in this study through the combined dimensions of time performance, cost performance, and quality performance. Since BIM is theoretically expected to improve each of these performance dimensions through enhanced information management, organizational collaboration, and integrated project planning, effective BIM implementation is also expected to contribute positively to overall engineering project management efficiency.

Accordingly, the proposed hypotheses are firmly grounded in the integrated theoretical framework presented in this study and are supported by the existing body of empirical literature. They provide the conceptual basis for the statistical analyses conducted in Chapter Four to examine the impact of BIM implementation on engineering project management efficiency in Saudi Arabian construction companies

1.10 Conceptual Framework of the Study

Figure 1.1



Proposed Conceptual Framework Linking BIM Implementation to Engineering Project Management Efficiency

Source: Prepared by the researcher based on the reviewed literature.

Figure 1.1 presents the proposed conceptual framework of the study, illustrating the hypothesized relationship between Building Information Modeling (BIM) implementation and engineering project management efficiency in Saudi Arabian construction companies. The framework was developed based on the integrated theoretical foundation and the empirical evidence reviewed in the literature.

Within the framework, **BIM implementation** represents the **independent variable**, while **engineering project management efficiency** represents the **dependent variable**.

Engineering project management efficiency is operationalized through three interrelated performance dimensions: **time performance**, **cost performance**, and **quality performance**. These dimensions collectively provide a comprehensive measure of project management efficiency and reflect the traditional project performance criteria supported by the Iron Triangle of Project Management.

The framework proposes that effective BIM implementation positively influences each performance dimension. Specifically, BIM is expected to improve **time performance** through enhanced planning, 4D scheduling, progress monitoring, and coordination; **cost performance** through accurate quantity take-off, 5D cost modeling, budget control, and improved cost estimation; and **quality performance** through clash detection, design coordination, improved documentation, and reduced errors and rework. Improvements in these three dimensions are, in turn, expected to contribute to enhanced overall engineering project management efficiency.

The conceptual framework also provides the basis for the development of the study's research hypotheses and guides the empirical investigation presented in the subsequent chapters. It illustrates the theoretical assumptions underpinning the study and establishes a clear linkage between the independent variable, the dependent variable, and the proposed causal relationships to be examined through statistical analysis.

1.11 Scope and Limits of the Study

The scope and limits of the study define the boundaries within which the research will be conducted. These limits are important because they clarify the context, population, time period, and subject focus of the study.

Spatial Limits

The study will be applied to construction companies in Saudi Arabia. This spatial scope is selected because the Saudi construction sector is experiencing rapid development and increasing demand for digital transformation tools such as BIM.

Temporal Limits

The study will focus on data collected during the academic/research period of 2026. The results of the study will therefore reflect respondents' perceptions and organizational practices during this period.

Objective Limits

The study will focus only on BIM implementation and its impact on time performance, cost performance, quality performance, and overall engineering project management efficiency. Other possible BIM outcomes, such as sustainability, safety performance, facility management, and lifecycle operation, may be discussed theoretically but will not represent the primary empirical focus of this study.

Human Limits

The study population will include engineers, project managers, BIM professionals, consultants, contractors, and construction industry practitioners working in Saudi Arabian construction companies. These participants are considered appropriate because they are directly involved in engineering project delivery and are expected to have practical knowledge of BIM implementation and project management performance.

1.12 Definition of Key Terms

Building Information Modeling (BIM): BIM refers to a digital process for creating, managing, and exchanging information about a built asset throughout its lifecycle. It includes the development of intelligent digital models that combine geometric and non-geometric information to support design, construction, coordination, cost estimation, scheduling, and facility management (Eastman et al., 2011; ISO, 2018; Sacks et al., 2018).

BIM Implementation: BIM implementation refers to the practical use of BIM tools, workflows, standards, and collaborative processes within construction companies. In this study, it refers to the use of BIM to support project planning, scheduling, cost control, quality management, coordination, and information exchange.

Engineering Project Management Efficiency: Engineering project management efficiency refers to the ability to manage engineering projects effectively by achieving project objectives with optimal use of time, cost, resources, information, and stakeholder

coordination. In this study, it is measured through time performance, cost performance, and quality performance.

Time Performance: Time performance refers to the ability of a project to be planned, scheduled, monitored, and completed within the planned timeframe. In the context of BIM, time performance is associated with 4D scheduling, construction simulation, delay reduction, and improved progress monitoring.

Cost Performance: Cost performance refers to the ability to estimate, control, monitor, and manage project costs within the approved budget. In the context of BIM, cost performance is associated with 5D cost modeling, automated quantity take-off, cost estimation accuracy, budget control, and reduction of cost overruns.

Quality Performance: Quality performance refers to the extent to which project outputs meet required specifications, standards, and stakeholder expectations. In the context of BIM, quality performance is associated with clash detection, design accuracy, documentation consistency, reduction of errors, and reduction of rework.

Saudi Arabian Construction Companies: This term refers to companies operating in the construction and engineering sector in Saudi Arabia, including contractors, consultants, engineering firms, and organizations involved in project planning, design, execution, and management.

1.13 Structure of the Study

This study consists of five chapters organized in a logical sequence to address the research problem, theoretical background, methodology, statistical analysis, and final conclusions.

Chapter One presents the general framework of the study. It includes the introduction, background of the study, statement of the problem, research questions, research objectives, importance of the study, research variables, hypotheses, conceptual framework, scope and limits of the study, key definitions, and structure of the study.

Chapter Two presents the theoretical framework and literature review. It discusses the main concepts related to BIM, engineering project management, project management efficiency, BIM dimensions, BIM implementation, BIM and time performance, BIM and

cost performance, BIM and quality performance, challenges of BIM implementation, theoretical models supporting the study, previous studies, and the research gap.

Chapter Three presents the research methodology. It explains the research approach, research design, study population, sample, data sources, questionnaire design, measurement scale, validity and reliability procedures, data collection procedures, statistical analysis methods, and research model.

Chapter Four presents the statistical analysis and results. It includes the response rate, demographic characteristics of respondents, reliability analysis, descriptive analysis of study variables, correlation analysis, regression analysis, and hypotheses testing summary.

Chapter Five presents the discussion of results, recommendations, and conclusion. It discusses the findings in relation to the research questions, objectives, hypotheses, and previous studies. It also presents practical recommendations, academic recommendations, limitations of the study, suggestions for future research, and the final conclusion.

Chapter Two

Theoretical Framework and Literature Review

2.1 Introduction

This chapter introduces the theoretical background and literature review about Building Information Modeling (BIM) and Engineering project management efficiency. The objective of this chapter is to provide a comprehensive theoretical foundation for the study by reviewing the principal concepts, theoretical perspectives, empirical literature, and conceptual relationships relevant to Building Information Modeling (BIM) implementation and engineering project management efficiency.. The chapter discusses the relationship between BIM and the three primary dimensions of project performance—time, cost, and quality—as the present study examines the impact of BIM implementation on engineering project management efficiency in Saudi Arabian construction companies.

The chapter begins by discussing digital transformation in the construction industry and the increasing need for integrated information systems in project delivery. It then introduces the concept of engineering project management and project management efficiency, particularly highlighting time, cost and quality as important performance indicators. The chapter subsequently examines Building Information Modeling (BIM), including its concept, evolution, dimensions, implementation requirements, and role in improving engineering project management efficiency. The chapter also covers the impact of BIM on time management, cost management, and quality management of engineering projects. It also discusses some of the key challenges and barriers to effective BIM implementation including organizational readiness, technical capability, training, standardization, interoperability and cost.

In addition, this chapter introduces the theory and models used in the study, such as the Iron Triangle of Project Management, the Technology Acceptance and Innovation Adoption models, BIM maturity theory and information management principles. These theoretical models explain the mechanisms through which BIM implementation is expected to influence engineering project management efficiency and clarify why the benefits of BIM vary across organizations according to their level of adoption, implementation maturity, and information management capability. Lastly, the chapter summarizes the previous empirical studies conducted with the BIM and project performance, and highlights the

research gap, followed by a discussion on the contribution of the present study to the literature.

2.2 Digital Transformation in the Construction Industry

Digital transformation has become a major driver of change in the construction industry. In the past, construction was portrayed as a "disconnected and project-oriented industry" where information is passed around in the form of drawings, documents, spreadsheets, reports and various software systems. This separation often results in a lack of coordination, delayed decision making, design conflicts, inaccurate cost estimates and inefficient project control (Eastman et al., 2011; Sacks et al., 2018). Digital systems are increasingly required to enhance collaboration, integrate project information and facilitate evidence-based decision-making in engineering projects, especially as they grow in size and complexity.

Digital transformation in the construction industry encompasses the adoption of advanced digital technologies such as Building Information Modeling (BIM), cloud computing, artificial intelligence (AI), digital twins, the Internet of Things (IoT), automation, and data analytics. Among these technologies, BIM has emerged as one of the most influential innovations by supporting integrated information management and collaborative project delivery throughout the project lifecycle (Borrmann et al., 2018; Sacks et al., 2018). As the principal focus of this study, the concept, dimensions, and implementation of BIM are discussed comprehensively in Section 2.5.

Productivity challenges remain a significant concern in the construction industry because fragmented workflows, limited standardization, and inefficient information management continue to reduce project performance (McKinsey Global Institute, 2017). These challenges negatively affect engineering project management by limiting the availability of accurate, timely, and integrated information required for effective planning, monitoring, and decision-making. Digital transformation aims to address these issues through integrated digital processes and improved information management, while the specific contribution of BIM to project planning, scheduling, cost management, and coordination is examined in subsequent sections of this chapter.

Digital transformation also improves communication, collaboration, and information exchange among project participants by promoting integrated digital workflows and standardized information management practices. These improvements enhance coordination, transparency, and informed decision-making throughout the project lifecycle (Azhar, 2011; Gu & London, 2010). As one of the principal technologies supporting this transformation, BIM contributes significantly to these improvements; however, its specific role in engineering project management and project performance is examined in greater detail in Sections 2.3, 2.5, and 2.7.

With the massive amount of national infrastructure, urban development and construction projects in Saudi Arabia, digital transformation has become more significant. The Saudi construction sector is expected to provide complex projects that are under pressure to increase efficiency, quality and value. The research conducted in the last few years shows that the use of BIM in the construction industry in Saudi Arabia has gained more significance; however, there are several challenges that still hinder its implementation, including the lack of training, standards, and organizational readiness, which also have significant costs for the industry (Alaboud & Alshahrani, 2023; Alhumayn et al., 2017). Thus, studying BIM as a tool for a digital transformation in the construction industry in Saudi Arabia is academically and practically important.

2.3 Engineering Project Management

Engineering project management is the application of the knowledge, skills, tools, techniques and processes to plan, initiate, execute, monitor, control and close engineering projects successfully. The difficulty of construction and engineering projects lies in the fact that they have to meet technical requirements, they involve many parties, they have limited resources, they have contractual requirements, they are prone to risks, they have site related requirements, they have regulatory requirements, and they have performance targets. Project Management (PM) is therefore an essential requirement to ensure that projects are delivered within the approved scope, schedule, budget and quality requirements (Project Management Institute [PMI], 2021).

When it comes to building projects, project management has a number of interconnected operations. These functions cover scope, schedule, cost, quality, risk, procurement,

communication, stakeholder and integration. Project managers need to coordinate these functions and make decisions based on accurate information, and this is key to the success of any project (PMI, 2021). In contrast, construction project management has traditionally faced issues of disjointed information flow and poor information integration between design, planning, cost estimation and construction execution (Eastman et al., 2011).

One of the most important aspects of engineering project management is time management. This involves identifying project activities, scheduling the activities, forecasting activity durations, creating schedules, assigning resources, and tracking project advancement. Construction delays can cause loss of money, claims, disputes, and loss of stakeholder satisfaction. Similarly, cost management is essential since budgets, quantities, procurement, labor, equipment and change orders must be monitored throughout the construction project. Without proper cost control, budget problems and lower profitability arise. Quality management is the practice of ensuring that the outputs of the project are to the appropriate technical standard, meet client expectations and comply with the regulations in force. Defects, rework, extra costs, and schedule delays are all reasons that poor quality can result (Atkinson, 1999; PMI, 2021).

Project management functions are especially significant of integration in the construction. If the design changes, this can impact the schedule, cost estimate, procurement plan, construction sequence and quality requirements. If not caught early, the project can be delayed and cost overrun. BIM assists with this by linking design information to time, cost and coordination information. So, BIM has become more than just a design technology and is increasingly being seen as a project management tool (Bryde et al., 2013; Sacks et al., 2018).

2.4 Project Management Efficiency

Project management efficiency is defined by the ability to achieve project goals with optimal utilization of resources, time, cost, information, and coordination mechanisms. Efficiency in engineering projects is not just about getting things done quickly; it is also about doing them within agreed constraints, with quality, reduced waste, good communication, and effective decision-making. Efficiency is closely related to project

performance, as efficient project management leads to better project outcomes (Atkinson, 1999; PMI, 2021).

The traditional definition of a successful project is linked to the “Iron Triangle” of time, cost, and quality. While modern project management literature mentions other success criteria, including stakeholder satisfaction, sustainability, safety, strategic value, and long-term benefits, time, cost, and quality are still the main indicators of construction project performance (Atkinson, 1999; PMI, 2021). For this reason, time, cost, and quality are selected as the main dimensions of engineering project management efficiency in this study.

Time performance refers to the ability of the project to be planned and implemented in line with the agreed time frame. It involves aspects such as scheduling accuracy, progress monitoring, activity sequencing, reduction of delays, and timely decision-making. Cost performance is the capacity to estimate and control the cost of the project effectively. It includes quantity take-off, budget control, cost forecasting, change management, and reducing cost overruns. Quality performance is the extent to which the outputs from a project are in line with specifications and standards. This encompasses design accuracy, minimization of errors, clash detection, quality of documentation, compliance, and minimization of rework.

BIM has the potential to enhance project management efficiency by increasing the accuracy, availability, and integration of project information. BIM can be used to visualize construction sequences, reduce the risk of design conflicts, enable the generation of quantities, connect model elements to cost data, and improve interdisciplinary coordination (Eastman et al., 2011; Sacks et al., 2018). These capabilities enable more efficient decision-making and lower the risk of issues that are often related to time, cost, and quality.

BIM is not a guarantee of project efficiency, however. The degree of impact is dependent on its implementation, the level of maturity of the organization, collaboration with other stakeholders, and the level of BIM integration into the project management process (Succar, 2009). Thus, the theoretical link between BIM and project management efficiency should be tested empirically, particularly in the construction industry context in Saudi Arabia.

2.5 Building Information Modeling (BIM): Concept and Development

Building Information Modeling (BIM) is a digital process to create, manage, exchange and utilize information about a built asset over its lifecycle. BIM is the creation of intelligent digital models that integrate both geometric data (shape, size, location, etc.) and non-geometric data (material properties, quantities, costs, schedules, specifications, and maintenance data, etc.) (Eastman et al., 2011; Sacks et al., 2018). Thus BIM is not just a 3D view of a building, rather it is a process of structured information management that facilitates decision-making throughout the design, construction, operation and facility management processes.

Eastman et al. (2011) describe BIM as a modeling technology and a collection of processes that create, share and analyze building models. This definition emphasizes the BIM is not just a technology, but a process. BIM as a technology is the software tools used to create and manage digital models. BIM is a process, and it needs collaboration, sharing of information, standards, workflows and coordination of stakeholders. Likewise, ISO 19650-1 defines BIM as a part of a wider information management strategy for the built environment, including the organization, exchange, recording and management of information throughout the built asset's life cycle (International Organization for Standardization [ISO], 2018).

BIM can be seen as a change from two-dimensional drawings to integrated, object-based and data-rich modeling. Traditional drawings are static, and must be interpreted and coordinated manually. BIM models, however, are made up of intelligent objects which carry information and relationships. For instance, a wall in a BIM model can be a line or shape, and it can contain information on material, thickness, fire rating, cost, where it's located, and how it's connected to other parts of the building (Eastman et al., 2011; Sacks et al., 2018).

BIM has gone through a few phases. Initially, BIM was just used to visualize and coordinate designs in 3D. Later on, it grew to include clash detection, construction sequencing, cost estimation and facility management. Nowadays, BIM is increasingly associated with digital twins, cloud collaboration, automation, sustainability analysis, safety planning and asset information management (Borrmann et al., 2018). This progression has

made BIM relevant to project management as it enables the manager to link project information over various performance aspects.

The collaborative working aspect of BIM is also supported. On a BIM project, architects, structural engineers, mechanical engineers, electrical engineers, contractors, quantity surveyors, project managers and clients can collaborate on the same digital model or common data environment. This ensures that the risk of misinformation is minimized and the potential to identify issues prior to their occurrence on site is enhanced (Gu & London, 2010; ISO, 2018). This has led to BIM being one of the most significant technologies for enhancing the project management efficiency in modern construction.

2.6 BIM Dimensions

Figure 2-2

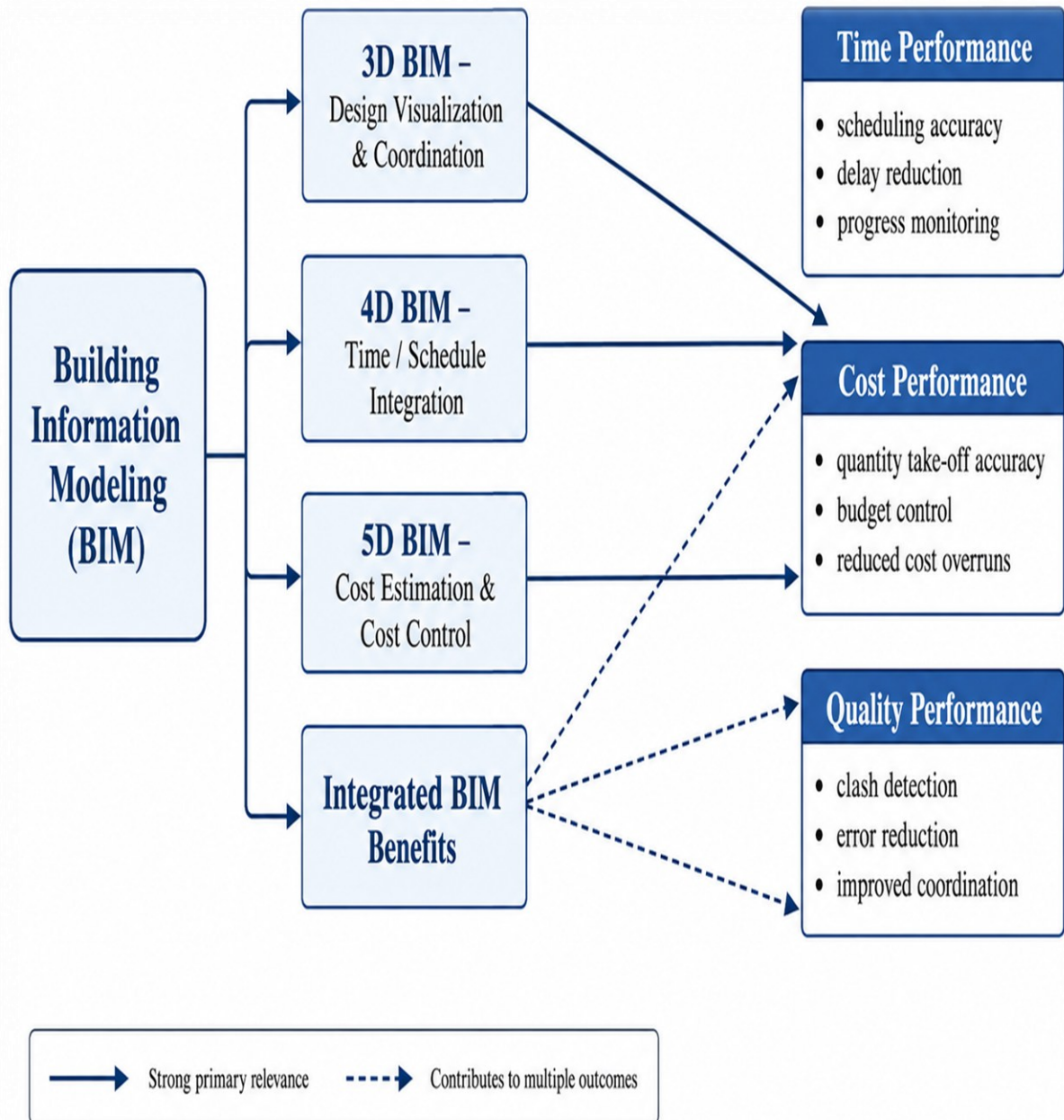


Figure 2.2: BIM Dimensions and Their Relevance to Time, Cost, and Quality Performance.

Source: Prepared by the researcher based on the reviewed literature.

Figure 2.2 illustrates the principal dimensions of Building Information Modeling (BIM) and their relevance to engineering project management performance. The figure demonstrates the progressive development of BIM from three-dimensional (3D) digital modeling to

advanced dimensions that support scheduling (4D), cost management (5D), sustainability (6D), and facility management (7D). Collectively, these dimensions highlight the evolution of BIM from a visualization tool to an integrated project management system that supports decision-making throughout the project lifecycle.

The figure is directly aligned with the objectives of the present study, as it demonstrates how different BIM dimensions contribute to improvements in the key performance indicators examined in this research. In particular, **4D BIM** supports project planning, scheduling, sequencing, and progress monitoring, thereby contributing to improved **time performance**. **5D BIM** enhances quantity take-off, cost estimation, budgeting, and financial control, leading to improved **cost performance**. Meanwhile, the integration of 3D modeling with coordination, clash detection, documentation accuracy, and information management contributes to improved **quality performance** by reducing design conflicts, construction errors, and project rework.

The figure also reinforces the theoretical argument that BIM implementation extends beyond technological adoption and functions as an integrated management approach that enhances collaboration, information sharing, coordination, and informed decision-making among project stakeholders. Consequently, the BIM dimensions presented in Figure 2.6 provide the conceptual basis for understanding how BIM implementation is expected to improve engineering project management efficiency within Saudi Arabian construction companies.

Accordingly, Figure 2.6 establishes an important conceptual link between the BIM capabilities discussed in the literature and the dependent variables investigated in this study. It supports the development of the research hypotheses by illustrating the mechanisms through which BIM implementation is expected to influence **time performance**, **cost performance**, and **quality performance**, which collectively represent **engineering project management efficiency**.

2.7 BIM Implementation in Construction Projects

The implementation of BIM technology and utilization of BIM technology in buildings and construction projects is called BIM implementation. The key to successful BIM

implementation is to do more than just install BIM software. It needs organizational readiness, skilled workforce, support of management, clear information requirements, standard procedures, model coordination procedures, and collaboration between project stakeholders (Khosrowshahi & Arayici, 2012; Succar, 2009).

Typically, there are multiple elements in the implementation of BIM. This includes technological infrastructure such as BIM software, hardware, cloud platforms, and data exchange tools. The second is the human aspect, which involves training, technical skills, BIM coordination knowledge and project management understanding. Process integration is the third aspect – integration of BIM into design coordination, scheduling, cost estimation, procurement, quality management and site execution. The fourth component is organizational governance, consisting of policies, standards, responsibilities, model ownership and protocols for sharing information (Gu & London, 2010; ISO, 2018).

Information management with BIM is stressed in ISO 19650. It offers principles to organize and share information in a structured manner throughout the life cycle of built assets. This is because the implementation of BIM is dependent on the quality and reliability of the information. Without adequate information, whether it is missing or inconsistent, the benefits of BIM could be diminished (ISO, 2018). So, the implementation of BIM is a Technical and Managerial process.

The implementation of BIM is also dependent on its maturity. BIM maturity is a concept defined by Succar (2009) as the ability of organizations and project teams to execute BIM-related processes. Low maturity BIM implementation could be as simple as 3D modeling, while higher maturity levels include collaboration, workflows, data sharing, and information management across the lifecycle. Organizations that are more mature in their use of BIM are more likely to have better project results – they are using BIM more strategically and systematically.

The implementation of BIM is still in its growth phase in Saudi Arabia. Alhumayn et al. (2017) identified some barriers that obstructs BIM implementation in Saudi Arabia: lack of training, lack of government legislation, BIM interoperability problems, BIM software/hardware costs, and lack of BIM knowledge. Alaboud and Alshahrani (2023) also found that recently, Saudi Arabia has paid more attention to the use of BIM; however, there are still organizational and technical issues that need to be addressed. The results confirm

the importance to study the implementation of BIM in Saudi construction companies in an empirical way.

2.8 BIM and Time Performance

Time performance is a central indicator of project management efficiency. Construction delays may arise from design errors, poor coordination, late information, inaccurate schedules, change orders, resource shortages, and site conflicts. BIM can improve time performance by supporting better planning, coordination, visualization, and progress monitoring (Eastman et al., 2011; Sacks et al., 2018).

One of the main ways BIM improves time performance is through 4D scheduling. By linking the 3D model with the project schedule, project teams can visualize the sequence of construction activities. This helps project managers identify conflicts in activity sequencing, evaluate alternative construction methods, and improve schedule communication among stakeholders (Zhang & Hu, 2011). 4D simulation also helps non-technical stakeholders understand the construction process, which can improve decision-making and reduce delays caused by misunderstandings.

BIM can also reduce delays by improving design coordination. Many construction delays occur when design conflicts are discovered during construction. For example, if mechanical and structural systems conflict on site, work may stop until the issue is resolved. BIM-based clash detection allows these conflicts to be identified earlier, before construction begins. This reduces rework and improves the likelihood that project activities will proceed according to schedule (Azhar, 2011; Eastman et al., 2011).

Another contribution of BIM to time performance is improved communication. In traditional project management, schedule updates and design changes may be communicated through separate documents, emails, and meetings. This can cause delays if stakeholders do not receive or understand updated information. BIM supports more integrated communication by providing a shared model and coordinated information environment. Bryde et al. (2013) found that BIM implementation produced reported benefits in project coordination and time-related performance across several projects.

BIM also supports progress monitoring. When BIM is integrated with construction planning and reporting, project managers can compare planned progress with actual progress. This improves project control because deviations can be identified earlier and corrective actions can be taken before delays become severe. Therefore, BIM can theoretically improve time performance by strengthening planning accuracy, coordination, communication, and monitoring.

However, the effect of BIM on time performance depends on implementation quality. If schedules are not properly linked to model elements, or if project teams do not update the model regularly, 4D BIM may not produce meaningful time benefits. Therefore, the relationship between BIM and time performance should be tested empirically rather than assumed automatically.

2.9 BIM and Cost Performance

Cost performance refers to the ability to estimate, monitor, and control project costs within the approved budget. Cost overruns are a common problem in construction projects and may result from inaccurate quantity take-off, design changes, rework, poor coordination, inflation, procurement problems, and weak cost control systems. BIM can support cost performance by improving quantity extraction, cost estimation, budget control, and change management (Eastman et al., 2011; Monteiro & Poças Martins, 2013).

The most direct relationship between BIM and cost performance appears through 5D BIM. In 5D BIM, cost data is linked to model components. This allows project teams to generate quantities more efficiently and improve the accuracy of cost estimates. When model elements are properly classified and developed, BIM-based quantity take-off can reduce manual errors and save time compared with traditional quantity measurement methods (Monteiro & Poças Martins, 2013).

BIM also supports cost control by improving the management of design changes. Design changes are one of the main causes of cost overruns in construction projects. Through BIM, the cost implications of design modifications can be assessed more quickly because changes in model elements can be connected to quantities and cost data. This allows project managers to make more informed decisions before approving changes (Eastman et al., 2011; Sacks et al., 2018).

Another important cost benefit of BIM is the reduction of rework. Rework increases project costs because it requires additional labor, materials, equipment, and time. BIM reduces rework by improving clash detection, design coordination, and documentation quality. Barlish and Sullivan (2012) found that BIM benefits can be measured through several indicators, including reduced rework, improved scheduling, and better cost-related outcomes. Similarly, Azhar (2011) emphasized that BIM can reduce errors and improve project performance when used effectively.

BIM may also improve procurement and resource planning. When project teams have more accurate quantities and clearer construction sequences, they can plan material procurement and resource allocation more effectively. This reduces waste and supports better financial control. However, the cost benefits of BIM may be reduced if the model is incomplete, if data is inaccurate, or if cost systems are not integrated with the BIM environment.

Therefore, BIM provides a strong theoretical basis for improving cost performance, but its actual impact depends on model accuracy, cost data integration, user skills, and organizational processes. This justifies the need to examine the effect of BIM implementation on cost control and cost estimation accuracy in Saudi Arabian construction companies.

2.10 BIM and Quality Performance

Quality performance refers to the extent to which construction project outputs meet required specifications, standards, and stakeholder expectations. Poor quality in construction projects may lead to defects, rework, safety risks, disputes, client dissatisfaction, and additional costs. Traditional quality management often relies on inspections after work has been completed, which means that errors may be detected late. BIM supports a more proactive approach to quality management by enabling early detection of design conflicts, improved documentation, and better coordination (Eastman et al., 2011; Sacks et al., 2018).

One of the most important quality-related benefits of BIM is clash detection. Clash detection allows project teams to identify conflicts between building systems before construction begins. This improves design quality because errors can be corrected during

the planning and coordination stage rather than during site execution. Azhar (2011) identified clash detection and error reduction as major benefits of BIM. These benefits are directly connected to quality performance because they reduce defects and improve the accuracy of project documentation.

BIM also improves quality by creating a more consistent information environment. In traditional projects, design information may be distributed across many drawings, documents, and revisions. Inconsistencies between documents can create confusion and errors. BIM reduces this problem by linking information to a coordinated model. When changes are made properly, they can be reflected across related views and documents, improving consistency and reducing the risk of outdated information (Eastman et al., 2011; ISO, 2018).

Another contribution of BIM to quality performance is improved stakeholder coordination. Quality problems often arise when project participants work separately and do not coordinate their designs or construction methods. BIM supports interdisciplinary coordination by allowing different disciplines to integrate their models and identify problems collectively. This improves the reliability of project information and supports better construction planning (Gu & London, 2010; Sacks et al., 2018).

BIM can also support quality assurance and quality control by providing visual and data-based tools for checking compliance with project requirements. Model checking can be used to assess whether certain design elements meet specified standards or rules. Although the effectiveness of model checking depends on the quality of the model and the rules applied, it shows how BIM can move quality management from a reactive inspection-based approach to a more proactive information-based approach (Borrmann et al., 2018).

Therefore, BIM is theoretically expected to improve quality performance by reducing errors, improving coordination, supporting clash detection, increasing documentation consistency, and reducing rework. These theoretical links support the hypothesis that BIM implementation has a statistically significant effect on project quality performance.

2.11 Challenges of BIM Implementation

Despite the potential benefits of BIM, its implementation is associated with several challenges. These challenges may be technical, organizational, financial, human, legal, or cultural. Understanding these barriers is important because the benefits of BIM depend on successful implementation. If barriers are not addressed, BIM may be used superficially and may not improve project management efficiency (Khosrowshahi & Arayici, 2012; Succar, 2009).

One of the major challenges is the high initial cost of BIM implementation. Construction companies may need to invest in software licenses, hardware upgrades, cloud platforms, training programs, and technical support. These costs may discourage small and medium-sized companies from adopting BIM, especially if they are uncertain about the return on investment (Khosrowshahi & Arayici, 2012; Migilinskas et al., 2013).

Another challenge is the lack of trained professionals. Effective BIM implementation requires technical and managerial skills, including modeling, coordination, information management, scheduling integration, cost integration, and BIM execution planning. Without skilled personnel, companies may not be able to use BIM effectively. Alhumayn et al. (2017) identified lack of BIM training and lack of BIM expertise as important barriers in Saudi Arabia. This suggests that training and capacity building are essential for successful BIM adoption.

Resistance to change is also a significant barrier. BIM changes traditional workflows, responsibilities, communication patterns, and decision-making processes. Employees and managers who are accustomed to conventional methods may resist BIM because they perceive it as complex, costly, or disruptive. Rogers' (2003) diffusion of innovations theory explains that adoption of new technologies depends on perceived advantage, compatibility, complexity, trialability, and observability. If construction professionals do not clearly perceive BIM's benefits or find it difficult to use, adoption may be slow.

Interoperability is another major challenge. Different stakeholders may use different software platforms, file formats, and modeling standards. If these systems do not exchange information effectively, data loss and coordination problems may occur. Interoperability issues can reduce the efficiency of BIM collaboration and limit the value of model-based project management (Eastman et al., 2011; Gu & London, 2010).

Lack of standards and legal frameworks may also affect BIM implementation. BIM requires clear rules regarding model ownership, responsibility, level of detail, information exchange, data security, and contractual obligations. Without clear standards, stakeholders may be uncertain about how to use and rely on BIM models. ISO 19650 provides a framework for information management, but organizations still need to adapt standards to their own projects and contractual environments (ISO, 2018).

In Saudi Arabia, research indicates that BIM adoption faces several barriers, including lack of client demand, lack of government legislation, high software and hardware costs, lack of training, interoperability issues, and limited awareness (Alhumayn et al., 2017). Alaboud and Alshahrani (2023) also highlight that BIM adoption in Saudi Arabia requires better understanding of the relationships between adoption barriers and stronger implementation strategies. These barriers show that BIM implementation is not only a technical issue but also an organizational and strategic challenge.

2.12 Theoretical Models Supporting the Study

The current study is supported by several theoretical perspectives that explain the relationship between BIM implementation and engineering project management efficiency. These perspectives include the Iron Triangle of project management, technology acceptance and innovation adoption theory, BIM maturity theory, and information management theory.

2.12.1 The Iron Triangle of Project Management

The Iron Triangle is one of the most widely used models for understanding project performance. It focuses on three main constraints: time, cost, and quality. According to this model, project success is strongly related to the ability to deliver the project within the planned schedule, approved budget, and required quality standards. Although Atkinson (1999) argued that project success should not be limited only to time, cost, and quality, these three dimensions remain central to project management practice and construction performance evaluation.

The Iron Triangle supports the current study because the dependent variable, engineering project management efficiency, is measured through time performance, cost performance,

and quality performance. BIM implementation is expected to influence these dimensions by improving scheduling, cost estimation, coordination, clash detection, and information management. Therefore, the Iron Triangle provides a theoretical foundation for selecting time, cost, and quality as the main performance indicators.

2.12.2 Technology Acceptance and Innovation Adoption Perspective

Technology acceptance theory explains why individuals and organizations adopt or reject new technologies. Davis (1989) proposed the Technology Acceptance Model (TAM), which suggests that perceived usefulness and perceived ease of use influence users' acceptance of information systems. In the context of BIM, perceived usefulness may refer to the belief that BIM improves project planning, coordination, cost control, and quality management. Perceived ease of use may refer to the extent to which construction professionals believe that BIM tools and workflows are understandable and manageable.

Rogers' (2003) diffusion of innovations theory also helps explain BIM adoption. According to this theory, innovation adoption depends on factors such as relative advantage, compatibility, complexity, trialability, and observability. BIM is more likely to be adopted when organizations believe it provides clear advantages, fits existing needs, is not too difficult to use, can be tested, and produces visible benefits. This theory is relevant because many BIM barriers are related to perceived complexity, lack of awareness, and uncertainty about benefits.

These technology adoption perspectives support the current study by explaining why BIM implementation may vary across construction companies. Even if BIM has strong theoretical benefits, organizations may not achieve those benefits if users do not accept the technology or if adoption barriers are not addressed.

2.12.3 BIM Maturity Perspective

BIM maturity refers to the level of development and capability an organization has in implementing BIM processes. Succar (2009) proposed a BIM framework that explains BIM as a set of technologies, processes, and policies. According to this view, BIM adoption develops through different levels of maturity, from basic modeling to integrated collaboration and lifecycle information management.

The BIM maturity perspective is important because it explains why some organizations achieve greater benefits from BIM than others. A company that uses BIM only for visualization may not achieve significant improvements in time, cost, or quality. In contrast, a company that integrates BIM with scheduling, cost control, coordination, and quality management is more likely to improve project management efficiency. Therefore, the impact of BIM depends not only on whether BIM is used, but also on how deeply it is implemented.

This perspective supports the current study because BIM implementation is treated as an independent variable that may affect project performance. The study assumes that stronger BIM implementation is associated with better time performance, cost performance, quality performance, and overall project management efficiency.

2.12.4 Information Management Perspective

BIM can also be understood through the information management perspective. Construction projects depend on large amounts of information, including drawings, schedules, specifications, quantities, contracts, reports, and change records. Poor information management can cause errors, delays, disputes, and inefficient decisions. BIM improves project information management by creating structured, coordinated, and shared digital information (ISO, 2018; Sacks et al., 2018).

ISO 19650 provides a formal framework for managing information using BIM. It emphasizes the importance of defining information requirements, organizing information delivery, exchanging information in a controlled manner, and ensuring that information is reliable and useful across the asset lifecycle (ISO, 2018). This perspective supports the current study because BIM is expected to improve project management efficiency by improving the quality, accessibility, and coordination of project information.

2.12.5 Integration of Theoretical Perspectives

The present study does not rely on a single theoretical perspective to explain the relationship between Building Information Modeling (BIM) implementation and engineering project management efficiency. Instead, it adopts an integrated theoretical framework that combines complementary theories to provide a comprehensive explanation of how BIM contributes to improved project outcomes. Each theoretical perspective explains a different aspect of BIM implementation, and together they offer a stronger

foundation for understanding the mechanisms through which BIM influences project management efficiency.

The **Iron Triangle of Project Management** provides the primary performance perspective for this study. It identifies **time, cost, and quality** as the fundamental dimensions of project success and serves as the basis for measuring the dependent variable, engineering project management efficiency. Since the objective of this research is to examine whether BIM implementation improves project performance, the Iron Triangle establishes the key performance outcomes that are evaluated throughout the study (Atkinson, 1999; Project Management Institute [PMI], 2021).

While the Iron Triangle explains **what constitutes successful project performance**, it does not explain **why organizations adopt BIM** or why BIM implementation differs across companies. This limitation is addressed by the **Technology Acceptance Model (TAM)** and **Diffusion of Innovation Theory**. According to Davis (1989), users are more likely to adopt BIM when they perceive it as useful and easy to use. Similarly, Rogers (2003) explains that organizational adoption of innovative technologies depends on perceived relative advantage, compatibility with existing practices, complexity, trialability, and observability. Together, these theories explain the behavioral and organizational factors that influence BIM adoption within construction companies.

However, technology adoption alone does not guarantee improved project performance. Organizations may adopt BIM at different levels of sophistication, leading to varying outcomes. The **BIM Maturity Perspective** proposed by Succar (2009) addresses this issue by emphasizing that BIM implementation progresses through different maturity levels. Organizations with higher BIM maturity integrate BIM into project planning, scheduling, cost management, coordination, and information sharing, whereas organizations with lower maturity may limit BIM use to three-dimensional modeling. Consequently, the benefits achieved from BIM implementation depend not only on adoption but also on the organization's capability to integrate BIM into its project management processes.

The **Information Management Perspective**, supported by ISO 19650 (International Organization for Standardization [ISO], 2018), further complements the previous theories by emphasizing that successful project management depends on the quality, consistency, accessibility, and reliability of project information. BIM facilitates structured information management by creating a common data environment that enables project stakeholders to

exchange accurate and coordinated information throughout the project lifecycle. Effective information management improves communication, supports informed decision-making, reduces errors, minimizes rework, and enhances coordination among project participants.

Collectively, these theoretical perspectives provide a comprehensive explanation of how BIM implementation can improve engineering project management efficiency. The Technology Acceptance Model and Diffusion of Innovation Theory explain the factors influencing BIM adoption, the BIM Maturity Perspective explains the depth and effectiveness of BIM implementation, the Information Management Perspective explains how BIM enhances project information quality and collaboration, and the Iron Triangle provides the framework for evaluating improvements in project performance through time, cost, and quality. Rather than functioning independently, these theories complement one another and establish a coherent conceptual foundation for examining the relationship between BIM implementation and engineering project management efficiency in Saudi Arabian construction companies.

Accordingly, the integrated theoretical framework adopted in this study supports the proposed conceptual model and provides the theoretical justification for the research hypotheses. It suggests that effective BIM implementation, supported by organizational readiness, user acceptance, implementation maturity, and high-quality information management, is expected to improve project planning, coordination, communication, decision-making, and ultimately enhance engineering project management efficiency through better time performance, cost performance, and quality performance.

2.12.6 Critical Comparison of the Supporting Theories

Although each of the theoretical perspectives adopted in this study contributes to understanding the relationship between Building Information Modeling (BIM) implementation and engineering project management efficiency, each theory has its own strengths and limitations. Therefore, relying on a single theoretical perspective would provide only a partial explanation of the complex factors influencing BIM implementation and project performance. For this reason, the present study adopts an integrated theoretical approach that combines complementary theories to provide a more comprehensive explanation of the research problem.

The Iron Triangle of Project Management is highly appropriate for this study because it provides a well-established framework for evaluating project performance through the three fundamental dimensions of time, cost, and quality. These dimensions form the basis for measuring the dependent variable, engineering project management efficiency, and are widely recognized as the traditional indicators of project success (Atkinson, 1999; Project Management Institute [PMI], 2021). However, while the Iron Triangle effectively measures project outcomes, it does not explain the organizational, technological, or behavioral factors that influence the adoption and implementation of innovative project management tools such as BIM. Consequently, it cannot independently explain why BIM implementation varies among construction organizations or why organizations achieve different performance outcomes.

The Technology Acceptance Model (TAM) complements the Iron Triangle by explaining the behavioral factors that influence individuals' willingness to adopt BIM technology. According to Davis (1989), users are more likely to accept and utilize BIM when they perceive it as useful and easy to use. TAM therefore provides valuable insight into individual technology acceptance within construction organizations. Nevertheless, its primary focus is on individual perceptions and behavioral intentions rather than organizational capability or project-level implementation. As a result, TAM alone cannot explain how differences in organizational readiness, management commitment, or implementation capability influence BIM success.

To overcome this limitation, Diffusion of Innovation Theory extends the analysis beyond individual users to the organizational level. Rogers (2003) argues that the adoption of innovative technologies depends on factors such as relative advantage, compatibility, complexity, trialability, and observability. This perspective explains how BIM adoption spreads throughout organizations and industries and why some organizations adopt BIM more rapidly than others. However, although Diffusion of Innovation Theory explains the adoption process, it does not fully explain how the depth and quality of BIM implementation influence project performance after adoption has occurred.

The BIM Maturity Perspective addresses this limitation by emphasizing that successful BIM implementation depends not only on technology adoption but also on the organization's capability to integrate BIM into its project management processes. According to Succar (2009), organizations progress through different levels of BIM

maturity, ranging from basic three-dimensional modeling to fully integrated lifecycle information management. Higher levels of BIM maturity are associated with stronger collaboration, standardized workflows, effective information sharing, and greater integration of BIM with project planning, scheduling, cost management, and quality management. Consequently, BIM maturity provides an important explanation for why organizations with similar levels of BIM adoption may achieve significantly different project outcomes.

The Information Management Perspective further strengthens the theoretical foundation by explaining the operational mechanisms through which BIM contributes to project management efficiency. Construction projects depend heavily on accurate, timely, and coordinated information. Poor information management frequently results in communication failures, design conflicts, project delays, cost overruns, and quality deficiencies. The Information Management Perspective, supported by ISO 19650 (International Organization for Standardization [ISO], 2018), explains how BIM improves information quality by establishing structured information management processes and a common data environment that facilitates collaboration, transparency, and informed decision-making throughout the project lifecycle. This perspective therefore provides the direct operational link between BIM implementation and improvements in project performance.

A comparison of these theoretical perspectives demonstrates that each theory addresses a different dimension of the research problem. The Iron Triangle explains how project performance is evaluated, the Technology Acceptance Model explains individual acceptance of BIM technology, Diffusion of Innovation Theory explains organizational adoption processes, the BIM Maturity Perspective explains implementation capability and organizational development, and the Information Management Perspective explains how improved information management enhances project coordination and decision-making. Individually, each theory provides valuable insights; however, none is sufficient to explain the complex relationship between BIM implementation and engineering project management efficiency in its entirety.

Accordingly, this study adopts an integrated theoretical framework because it provides a more comprehensive explanation of the research phenomenon than any single theory alone. The combination of these complementary theoretical perspectives strengthens the

conceptual framework, provides robust theoretical justification for the proposed hypotheses, and establishes a coherent foundation for examining the impact of BIM implementation on engineering project management efficiency in Saudi Arabian construction companies.

2.13 Previous Studies

Previous academic studies have examined BIM from several perspectives, including BIM benefits, project performance, implementation barriers, BIM maturity, information management, and adoption in specific countries. This section reviews key studies that are directly relevant to the present research.

Azhar (2011) examined BIM trends, benefits, risks, and challenges. The study emphasized that BIM improves visualization, coordination, clash detection, and project performance. Azhar also highlighted that BIM can reduce errors and rework, but successful implementation requires training, organizational readiness, and clear understanding of risks. This study is relevant because it provides a foundation for linking BIM with time, cost, and quality improvements.

Eastman et al. (2011) provided one of the most comprehensive references on BIM technologies and processes. Their work explains BIM as a modeling technology and set of processes that support project visualization, coordination, analysis, and lifecycle information management. The book is highly relevant to the current study because it explains the theoretical basis of 3D, 4D, and 5D BIM and their relationship to project management.

Barlish and Sullivan (2012) developed a case study approach to measuring BIM benefits. Their study showed that BIM benefits can be evaluated through practical performance indicators such as cost savings, schedule improvements, and reduction of rework. This study is important because it supports the idea that BIM benefits should be measured empirically rather than discussed only theoretically.

Bryde et al. (2013) investigated the project benefits of BIM through a study of construction projects. Their findings indicated that BIM contributes to improved coordination, communication, and project performance, including benefits related to time and cost. This

study is directly relevant to the present research because it connects BIM implementation with measurable project benefits.

Succar (2009) developed a BIM framework for industry stakeholders. The study explained BIM through fields, stages, and maturity concepts. This framework is important because it shows that BIM implementation is not a single activity but a process that develops through maturity levels. The current study benefits from this perspective because it examines BIM implementation as a variable that may influence project management efficiency.

Khosrowshahi and Arayici (2012) proposed a roadmap for BIM implementation in the UK construction industry. Their study highlighted the importance of strategic planning, training, industry readiness, and process transformation. The study is relevant because it shows that BIM implementation requires organizational change, not only technology adoption.

Gu and London (2010) examined BIM adoption in the AEC industry and discussed the role of BIM in improving collaboration and coordination. Their study is relevant because it emphasizes that BIM adoption depends on both technological capability and industry-level collaboration. This supports the argument that BIM implementation in construction companies requires coordination among multiple stakeholders.

Volk et al. (2014) reviewed BIM for existing buildings and identified future needs related to modeling, information management, and lifecycle applications. Although their focus is existing buildings, the study is relevant because it highlights the importance of BIM for facility management and lifecycle information, which supports the broader theoretical understanding of BIM beyond design and construction.

In the Saudi context, Alhumayn et al. (2017) investigated barriers and strategies for implementing BIM in Saudi Arabia. Their study found that BIM adoption is limited by barriers such as lack of training, lack of government legislation, cost of software and hardware, interoperability issues, and lack of expertise. This study is highly relevant because the current research is applied to Saudi Arabian construction companies.

Alaboud and Alshahrani (2023) examined BIM adoption in the Saudi construction industry using interpretive structural modelling. Their study is relevant because it provides recent evidence that BIM adoption in Saudi Arabia is connected to broader digital transformation but still faces organizational and technical barriers. This supports the need for more

empirical research on BIM implementation and project performance in Saudi construction companies.

Alghuried (2023) examined the benefits and barriers of BIM implementation in sustainable practice within the Saudi construction industry. The study is relevant because it confirms the continuing importance of understanding both BIM benefits and BIM barriers in the Saudi context. It also supports the view that BIM implementation should be examined in relation to practical outcomes rather than treated only as a technological trend.

Collectively, these studies demonstrate that Building Information Modeling (BIM) consistently contributes to improved engineering project performance by enhancing design coordination, project communication, scheduling accuracy, cost estimation, clash detection, and information management. Despite these widely recognized benefits, the literature also indicates that the extent of BIM's positive impact varies considerably across organizations. This variation is largely influenced by factors such as organizational readiness, BIM maturity, employee competencies, management support, interoperability, and the degree to which BIM is integrated into project management processes. Furthermore, although previous studies have extensively investigated individual BIM benefits, relatively few have examined BIM implementation as a comprehensive project management approach that simultaneously influences time performance, cost performance, quality performance, and overall project management efficiency, particularly within the Saudi Arabian construction industry. Consequently, the present study seeks to address this gap by providing an integrated empirical assessment of BIM implementation and its influence on engineering project management efficiency.

2.14. Synthesis of Previous Studies

Collectively, the reviewed studies demonstrate that Building Information Modeling (BIM) has become a significant digital innovation for improving engineering project management and construction project performance. Across different countries, project environments, and research methodologies, the literature consistently indicates that BIM enhances project coordination, information sharing, communication, visualization, clash detection, scheduling accuracy, cost estimation, and overall decision-making. These improvements contribute to better project outcomes by reducing design conflicts, minimizing rework,

supporting interdisciplinary collaboration, and strengthening project planning and control throughout the project lifecycle.

Despite this broad agreement regarding the benefits of BIM, the literature also suggests that the magnitude of these benefits varies considerably among organizations and projects. Previous studies indicate that successful BIM implementation depends not only on the availability of BIM technologies but also on organizational readiness, management commitment, employee competencies, implementation maturity, standardized information management practices, and effective integration of BIM into project management processes. Consequently, BIM adoption alone does not guarantee improved project performance; rather, the effectiveness of BIM depends on the quality and maturity of its implementation within the organizational environment.

Furthermore, the review of previous studies reveals that many researchers have investigated individual aspects of BIM implementation, such as design visualization, clash detection, scheduling improvement, cost estimation, or quality enhancement. However, relatively few studies have examined BIM implementation as an integrated project management approach that simultaneously influences time performance, cost performance, quality performance, and overall engineering project management efficiency within a unified conceptual framework. This observation is particularly evident in the context of Saudi Arabian construction companies, where empirical evidence remains comparatively limited despite the growing emphasis on digital transformation and BIM adoption under Saudi Vision 2030.

Accordingly, the existing literature demonstrates substantial evidence supporting the benefits of BIM while simultaneously highlighting important gaps concerning integrated performance evaluation and context-specific empirical investigation. These observations provide a strong theoretical and empirical foundation for the present study and lead directly to the identification of the research gap discussed in the following section.

2.15 Summary of Previous Studies

Table 2.1: Summary of Previous Studies Related to BIM and Project Management

Author(s)	Year	Focus of Study	Method / Approach	Key Findings	Relevance to Current Study
Succar	2009	BIM framework and maturity	Conceptual framework	BIM implementation depends on technology, process, policy, and maturity stages	Supports BIM maturity perspective
Gu and London	2010	BIM adoption in the AEC industry	Literature and industry analysis	BIM improves collaboration but adoption depends on organizational and industry readiness	Supports BIM adoption discussion
Eastman et al.	2011	BIM technologies and processes	Academic handbook	BIM supports visualization, coordination, 4D scheduling, 5D cost, and lifecycle management	Provides core BIM definitions and dimensions
Azhar	2011	BIM benefits, risks, and challenges	Literature-based analysis	BIM improves visualization, clash detection, coordination, and reduces rework	Supports BIM impact on quality and efficiency
Barlish and Sullivan	2012	Measuring BIM benefits	Case study approach	BIM benefits can be measured through cost,	Supports empirical measurement

				schedule, and rework indicators	of BIM benefits
Khosrowshahi and Arayici	2012	BIM implementation roadmap	Industry analysis	BIM implementation requires training, strategy, and organizational transformation	Supports BIM implementation challenges
Bryde et al.	2013	Project benefits of BIM	Empirical project analysis	BIM improves communication, coordination, time, and cost performance	Supports hypotheses on BIM and performance
Migilinskas et al.	2013	BIM benefits and implementation obstacles	Literature and practical analysis	BIM offers benefits but faces organizational and technical challenges	Supports discussion of BIM barriers
Volk et al.	2014	BIM for existing buildings	Literature review	BIM supports lifecycle information and facility management but requires reliable data	Supports 6D BIM and lifecycle perspective
Alhumayn et al.	2017	BIM barriers in Saudi Arabia	Questionnaire survey	Lack of training, cost, legislation, interoperability, and expertise limit BIM adoption	Supports Saudi context

Sacks et al.	2018	BIM technologies and practice	Academic handbook	BIM supports collaboration, standards, project delivery, and information management	Supports theoretical explanation of BIM
Alaboud and Alshahrani	2023	BIM adoption in Saudi construction	Interpretive structural modelling	BIM adoption in Saudi Arabia is increasing but still faces barriers	Supports current research context
Alghuried	2023	BIM benefits and barriers in Saudi Arabia	Empirical analysis	BIM has benefits for sustainable practice, but barriers still affect implementation	Supports practical relevance in Saudi Arabia

Source: Prepared by the researcher based on the literature review and methodology design.

Table 2.1 summarizes the major studies related to **Building Information Modeling (BIM)** and **engineering project management**. Collectively, these studies demonstrate the evolution of BIM from a three-dimensional visualization tool into an integrated project management approach that supports collaboration, information management, scheduling, cost control, quality assurance, and lifecycle management. Despite differences in research objectives, methodologies, and geographical contexts, the reviewed studies consistently conclude that BIM enhances project performance by improving coordination, communication, decision-making, and resource management.

A comparison of the literature reveals complementary research perspectives. Early studies, including **Succar (2009)**, **Eastman et al. (2011)**, and **Sacks et al. (2018)**, established the theoretical foundations, maturity models, and technological capabilities of BIM. In contrast, empirical studies by **Azhar (2011)**, **Barlish and Sullivan (2012)**, and **Bryde et al. (2013)** demonstrated measurable improvements in project time, cost, quality, and coordination following BIM implementation. Other researchers, such as **Gu and London (2010)**,

Khosrowshahi and Arayici (2012), Migilinskas et al. (2013), and Alhumayn et al. (2017), emphasized that successful BIM implementation depends on organizational readiness, management commitment, staff competency, and effective implementation strategies. More recent Saudi Arabian studies by **Alaboud and Alshahrani (2023)** and **Alghuried (2023)** confirm that BIM adoption is expanding but continues to face technical, organizational, and regulatory challenges.

Although the reviewed studies consistently highlight the benefits of BIM, most focus on individual aspects such as technology adoption, implementation barriers, organizational maturity, or isolated project performance indicators. Limited research has examined the integrated effect of BIM implementation on **engineering project management efficiency** through the combined assessment of **time performance, cost performance, and quality performance**, particularly within the context of **Saudi Arabian construction companies**. This represents an important gap in the existing literature.

Accordingly, the present study extends previous research by integrating established theoretical perspectives with empirical investigation through a unified conceptual framework. It examines **BIM implementation** as the independent variable and evaluates its influence on **engineering project management efficiency** across the three interrelated performance dimensions of **time, cost, and quality**. By focusing on Saudi Arabian construction companies and employing a quantitative research approach, the study contributes new empirical evidence that supports both academic knowledge and practical decision-making regarding BIM implementation in the Saudi construction industry.

2.16 Research Gap

The literature shows that BIM has been widely studied as a digital technology capable of improving construction project performance. Previous studies have confirmed that BIM can improve visualization, coordination, clash detection, cost estimation, scheduling, communication, and quality management (Azhar, 2011; Barlish & Sullivan, 2012; Bryde et al., 2013; Eastman et al., 2011). However, several gaps remain.

First, many previous studies focus on specific BIM benefits separately, such as cost reduction, schedule improvement, design coordination, or clash detection. While these

studies are valuable, they do not always provide an integrated understanding of how BIM affects overall engineering project management efficiency through time, cost, and quality together. The current study addresses this gap by examining BIM implementation in relation to time performance, cost performance, quality performance, and overall project management efficiency within one research model.

Second, much of the literature discusses BIM from a technical or design perspective. Although BIM began as a modeling and visualization tool, its current value extends to project management, information management, scheduling, cost control, and quality assurance. Therefore, there is a need for more research that treats BIM as a project management tool rather than only as a design technology (Sacks et al., 2018; Succar, 2009).

Third, while international studies have examined BIM benefits and implementation barriers, the Saudi construction context still requires further empirical investigation. Saudi Arabia has a rapidly developing construction sector, but BIM adoption continues to face organizational, technical, regulatory, and human-resource challenges (Alaboud & Alshahrani, 2023; Alhumayn et al., 2017). Therefore, more research is needed to examine whether BIM implementation contributes to project management efficiency in Saudi Arabian construction companies.

Fourth, previous studies show that BIM benefits depend on the level of implementation maturity. Companies that use BIM only for visualization may not achieve the same performance improvements as companies that integrate BIM with scheduling, cost control, quality management, and information exchange. Therefore, the present study contributes by examining BIM implementation as an independent variable that affects measurable performance dimensions.

Accordingly, the research gap can be summarized as the limited empirical understanding of the integrated impact of BIM implementation on engineering project management efficiency, particularly through time, cost, and quality performance, within Saudi Arabian construction companies.

2.17 Chapter Summary

This chapter presented the theoretical framework and literature review for the study. It explained that digital transformation has become essential in the construction industry because traditional project management methods often suffer from fragmentation, poor coordination, and limited information integration. The chapter also discussed engineering project management and project management efficiency, emphasizing time, cost, and quality as core indicators of project performance.

The chapter then provided a detailed explanation of BIM, including its concept, development, dimensions, implementation requirements, and relevance to project management. It explained how 3D BIM supports visualization and coordination, how 4D BIM supports scheduling and time planning, how 5D BIM supports cost estimation and cost control, and how 6D BIM supports lifecycle and facility management. The chapter also discussed the relationship between BIM and time performance, cost performance, and quality performance.

In addition, the chapter reviewed major barriers to BIM implementation, including high initial cost, lack of training, resistance to change, interoperability problems, lack of standards, and limited organizational readiness. The chapter also presented theoretical models supporting the study, including the Iron Triangle, technology acceptance and innovation adoption theories, BIM maturity perspective, and information management perspective.

Finally, the chapter reviewed previous studies and identified the research gap. The literature indicates that although BIM has many potential benefits, there remains a need for empirical research that examines its integrated impact on engineering project management efficiency through time, cost, and quality performance in Saudi Arabian construction companies. This research gap provides the foundation for the methodology presented in the next chapter.

Chapter Three

Research Methodology

3.1 Introduction

This chapter presents the methodological procedures adopted to examine the impact of Building Information Modeling (BIM) implementation on engineering project management efficiency in Saudi Arabian construction companies. The chapter explains the research approach, research design, population, sample, sampling method, data sources, questionnaire structure, measurement scale, validity and reliability procedures, data collection process, ethical considerations, statistical analysis methods, and research model. It also clarifies how the hypotheses of the study will be tested statistically.

Research methodology is a fundamental part of any academic study because it determines how the research problem will be investigated, how data will be collected, and how conclusions will be drawn. According to Creswell and Creswell (2018), the research methodology should be consistent with the nature of the research problem, the research questions, and the type of data required to answer those questions. Since the current study aims to measure the relationship between BIM implementation and engineering project management efficiency, a quantitative survey-based methodology is considered appropriate.

The present study focuses on measurable relationships between variables. The independent variable is BIM implementation, while the dependent variable is engineering project management efficiency, measured through time performance, cost performance, quality performance, and overall project management efficiency. Therefore, the study requires numerical data that can be analyzed statistically. For this reason, a structured questionnaire will be used to collect primary data from 100 participants working in the Saudi construction and engineering sector. The collected data will be analyzed using the Statistical Package for the Social Sciences (SPSS), which is widely used in social science, business, management, and applied research for descriptive and inferential statistical analysis (Field, 2018; Pallant, 2020).

3.2 Research Approach

This study adopts a quantitative research approach. Quantitative research is appropriate when the researcher aims to measure variables, examine relationships, test hypotheses, and generalize findings based on numerical evidence (Creswell & Creswell, 2018; Saunders et al., 2019). In quantitative studies, data are usually collected through structured instruments such as questionnaires and analyzed using statistical techniques.

The quantitative approach is suitable for this study because the research seeks to assess the effect of BIM implementation on project management efficiency using measurable indicators. These indicators include project time performance, cost control and cost estimation accuracy, project quality performance, and overall project management efficiency. Each of these dimensions can be measured through questionnaire statements using a Likert scale, allowing respondents' perceptions to be converted into numerical values for statistical analysis.

In addition, the quantitative approach allows the researcher to test the research hypotheses objectively. The study does not only describe BIM implementation but also examines whether statistically significant relationships exist between BIM implementation and the dependent performance dimensions. Therefore, the quantitative approach provides a systematic and evidence-based method for examining the research problem.

3.3 Research Design

The study uses a descriptive-analytical research design. A descriptive research design is used to describe the characteristics, perceptions, and responses of the study participants, while the analytical aspect is used to examine relationships between variables and test hypotheses (Saunders et al., 2019; Sekaran & Bougie, 2016).

The descriptive part of the study will describe the demographic characteristics of the respondents, such as gender, age, educational qualification, job position, years of experience, company type, and BIM experience. It will also describe the level of BIM implementation, time performance, cost performance, quality performance, overall project management efficiency, and BIM implementation challenges using frequencies, percentages, means, and standard deviations.

The analytical part of the study will examine the statistical relationships between BIM implementation and the dependent variables. Pearson correlation will be used to examine

the strength and direction of relationships between the study variables, while regression analysis will be used to test the effect of BIM implementation on time performance, cost performance, quality performance, and overall engineering project management efficiency. This design is appropriate because the study aims to move beyond description and provide statistical evidence regarding the impact of BIM on project management efficiency.

The study is also cross-sectional in nature because data will be collected from respondents at one point in time. Cross-sectional surveys are commonly used in management and construction research when the objective is to examine current perceptions, practices, and relationships between variables within a defined population (Bryman, 2016; Saunders et al., 2019).

3.4 Population of the Study

The population of the study consists of professionals working in construction and engineering companies in Saudi Arabia. The study targets individuals who are directly or indirectly involved in engineering project management, BIM implementation, design coordination, construction planning, cost control, quality management, or project execution.

The target population includes engineers, project managers, BIM specialists, consultants, contractors, quantity surveyors, site engineers, planning engineers, cost control engineers, and other construction professionals. These participants are considered appropriate because they are expected to have practical knowledge of construction project management and may have experience with BIM tools, BIM-based coordination, or digital project delivery.

The selection of this population is consistent with the aim of the study, which is to assess the impact of BIM implementation on engineering project management efficiency in Saudi Arabian construction companies. Since the research focuses on time, cost, quality, and overall project management efficiency, it is important to collect data from professionals who understand how construction projects are planned, monitored, controlled, and delivered.

3.5 Sample of the Study

The sample of this study will consist of **100 participants** from Saudi Arabian construction and engineering companies. The sample size is considered suitable for a master's-level quantitative survey because it allows the researcher to conduct descriptive statistics, reliability analysis, correlation analysis, and regression analysis with an acceptable level of statistical stability. Hair et al. (2019) explain that sample size should be appropriate to the research model, the number of variables, and the type of statistical analysis used. Therefore, in this study, the sample size is sufficient to examine the relationship between BIM implementation and the main dimensions of project performance.

The sample size of 100 respondents is also considered acceptable because the study targets a specialized professional group with direct knowledge of BIM implementation and engineering project management. The respondents will include engineers, project managers, BIM specialists, consultants, contractors, cost control professionals, planners, and quality management practitioners. Therefore, the study focuses on informed professional responses rather than responses from the general population.

The study will use a **purposive sampling technique**. This technique is suitable when the researcher needs to select participants who possess specific knowledge or experience relevant to the research topic (Saunders et al., 2019). In this study, participants must be professionals working in the construction or engineering sector and should have awareness of project management practices, BIM implementation, or construction project performance. This sampling approach is appropriate because the study requires knowledgeable responses from professionals directly related to the research area.

The inclusion criteria for participants are as follows: participants should be working in the construction or engineering sector in Saudi Arabia; they should have a professional role related to engineering projects, project management, BIM, construction, consultancy, cost control, planning, or quality management; and they should be willing to complete the questionnaire voluntarily. Participants who do not work in the construction or engineering sector will be excluded because their responses may not be relevant to the objectives of the study.

3.6 Data Sources

The study will use both primary and secondary data sources. Using more than one type of data source strengthens the research because it allows the researcher to connect empirical findings with existing academic literature (Creswell & Creswell, 2018).

3.6.1 Primary Data

Primary data will be collected through a structured questionnaire distributed to 100 participants. The questionnaire will measure respondents' perceptions of BIM implementation and its impact on time performance, cost performance, quality performance, and overall engineering project management efficiency. It will also collect data about the challenges that may limit effective BIM implementation in construction projects.

The questionnaire is appropriate for this study because it allows data to be collected from a relatively large number of respondents in a standardized format. Survey questionnaires are widely used in quantitative research because they allow the researcher to measure attitudes, perceptions, and experiences numerically (Fowler, 2014). In this study, the questionnaire will be self-administered and distributed electronically to facilitate access to construction professionals in different companies and locations.

3.6.2 Secondary Data

Secondary data will be collected from academic books, peer-reviewed journal articles, conference papers, professional reports, BIM standards, and previous studies related to BIM, project management, construction performance, digital transformation, and research methodology. The secondary sources will help build the theoretical framework, support the development of questionnaire items, and compare the findings of the current study with previous literature.

Important secondary sources include academic references on BIM such as Eastman et al. (2011), Sacks et al. (2018), Azhar (2011), Bryde et al. (2013), Barlish and Sullivan (2012), and Succar (2009). Methodological references such as Creswell and Creswell (2018), Saunders et al. (2019), Field (2018), Pallant (2020), and Hair et al. (2019) will also be used to support the research design and data analysis procedures.

3.7 Research Instrument: Questionnaire

The main research instrument in this study is a structured questionnaire. The questionnaire will be designed to collect standardized responses from the participants and measure the study variables using closed-ended statements. A structured questionnaire is suitable for quantitative research because it allows responses to be coded numerically and analyzed statistically (Bryman, 2016; Sekaran & Bougie, 2016).

The questionnaire will be developed based on the research objectives, research questions, study variables, theoretical framework, and previous studies on BIM and project management efficiency. The questionnaire will include several sections. The first section will collect demographic information. The following sections will measure BIM implementation, time performance, cost performance, quality performance, overall project management efficiency, and BIM implementation challenges.

The questionnaire structure is presented in Table 1.

Table 3.2: Questionnaire Structure

Section	Dimension	Purpose
Section A	Demographic information	To describe the characteristics of respondents
Section B	BIM implementation	To measure the extent of BIM use, integration, collaboration, and organizational support
Section C	Time performance	To measure scheduling accuracy, delay reduction, progress monitoring, and time planning
Section D	Cost performance	To measure cost estimation accuracy, budget control, quantity take-off, and cost variation reduction
Section E	Quality performance	To measure clash detection, design accuracy, error reduction, rework reduction, and documentation quality
Section F	Overall project management efficiency	To measure coordination, decision-making, communication, monitoring, and project performance improvement
Section G	BIM implementation challenges	To identify technical, financial, organizational, and human-resource barriers

Source: Prepared by the researcher based on the literature review and methodology design.

Table 3.2 presents the structure of the research questionnaire, which was developed from the study's conceptual framework, research objectives, and the reviewed literature. The questionnaire consists of seven sections covering respondents' demographic characteristics, **Building Information Modeling (BIM) implementation, time performance, cost performance, quality performance, overall engineering project management efficiency, and BIM implementation challenges.**

The questionnaire was designed to operationalize the study variables by measuring **BIM implementation** as the independent variable and **engineering project management efficiency** as the dependent variable through its three performance dimensions: **time, cost, and quality.** The inclusion of demographic information and BIM implementation challenges provides additional contextual data for interpreting the findings and identifying factors that may influence BIM adoption within Saudi Arabian construction companies.

Overall, the questionnaire structure ensures comprehensive coverage of the research variables and aligns with the study's conceptual framework, research objectives, and hypotheses. It provides a reliable basis for collecting empirical data to examine the impact of **BIM implementation** on **engineering project management efficiency** in the Saudi construction industry.

3.8 Measurement Scale

The questionnaire will use a five-point Likert scale. The Likert scale is one of the most widely used measurement scales in survey research because it allows respondents to express their level of agreement with a set of statements (Likert, 1932). In this study, the Likert scale will be used to measure participants' perceptions of BIM implementation and project management efficiency.

The scale will be coded as follows:

Table 3.3: Five-Point Likert Scale Coding

Scale Value	Response
1	Strongly Disagree
2	Disagree
3	Neutral
4	Agree
5	Strongly Agree

Source: Prepared by the researcher based on the literature review and methodology design.

The use of a five-point Likert scale is appropriate because it is simple, clear, and easy for respondents to understand. It also allows the researcher to calculate means and standard deviations for each item and dimension. The interpretation of mean scores will be as follows:

Table 3.4 : Interpretation of Mean Scores

Mean Range	Interpretation
1.00–1.80	Very Low
1.81–2.60	Low
2.61–3.40	Moderate
3.41–4.20	High
4.21–5.00	Very High

Source: Prepared by the researcher based on the literature review and methodology design.

This interpretation will help classify the respondents' perceptions regarding the level of BIM implementation, project time performance, cost performance, quality performance, overall efficiency, and implementation challenges.

3.9 Operationalization of Study Variables

Operationalization refers to the process of translating theoretical concepts into measurable indicators. Since this study examines the impact of BIM implementation on engineering project management efficiency, each variable must be measured through clear questionnaire items.

The independent variable is BIM implementation. This variable will be measured through indicators such as BIM use in project planning, BIM use in design coordination, BIM-based information sharing, management support for BIM, BIM training, and integration of BIM with project management activities.

The dependent variable is engineering project management efficiency. This variable will be measured through four related dimensions: time performance, cost performance, quality performance, and overall project management efficiency. Time performance will be measured through scheduling accuracy, delay reduction, progress monitoring, and construction sequencing. Cost performance will be measured through cost estimation accuracy, budget control, quantity take-off, and cost variation reduction. Quality performance will be measured through clash detection, design accuracy, reduction of errors, reduction of rework, and documentation quality. Overall project management efficiency will be measured through coordination, communication, decision-making, monitoring, control, and project delivery improvement.

The operationalization of variables is shown in Table 2.

Table 3.5: Operationalization of Study Variables

Variable Type	Variable / Dimension	Indicators
Independent Variable	BIM Implementation	BIM use, BIM tools, model coordination, information sharing, management support, training, integration with project management
Dependent Variable	Time Performance	Scheduling accuracy, delay reduction, progress monitoring, construction sequencing, timely decisions

Dependent Variable	Cost Performance	Cost estimation accuracy, quantity take-off, budget control, cost monitoring, reduction of cost overruns
Dependent Variable	Quality Performance	Clash detection, design accuracy, documentation consistency, reduction of errors, reduction of rework
Dependent Variable	Overall Project Management Efficiency	Coordination, communication, decision-making, project control, performance improvement
Additional Dimension	BIM Implementation Challenges	Cost, training, skilled professionals, resistance to change, interoperability, standardization

Source: Prepared by the researcher based on the literature review and methodology design.

Table 3.5 presents the operationalization of the study variables by translating the conceptual constructs into measurable indicators suitable for empirical investigation. The operationalization process establishes a clear relationship between the theoretical framework, the conceptual framework, the research hypotheses, and the data collection instrument, thereby ensuring that each variable can be objectively measured and statistically analyzed.

The study identifies **Building Information Modeling (BIM) implementation** as the independent variable, measured through indicators reflecting the extent of BIM utilization, model coordination, information sharing, management support, staff training, and integration with project management practices. These indicators represent both the technological and organizational dimensions of BIM implementation discussed in the reviewed literature.

The dependent variable, **engineering project management efficiency**, is represented through four complementary performance dimensions: **time performance**, **cost performance**, **quality performance**, and **overall project management efficiency**. Time performance is assessed through scheduling accuracy, progress monitoring, construction sequencing, and delay reduction. Cost performance is evaluated using indicators related to quantity take-off, cost estimation accuracy, budget control, and cost monitoring. Quality performance focuses on design accuracy, clash detection, documentation consistency, and the reduction of construction errors and rework. In addition, overall project management

efficiency is reflected through improved coordination, communication, project control, decision-making, and overall project performance.

The table also includes **BIM implementation challenges** as an additional analytical dimension to identify the principal organizational, technical, and managerial barriers that may influence BIM adoption in Saudi Arabian construction companies. Although these challenges are not treated as the primary explanatory variable in the hypothesis-testing model, they provide valuable contextual evidence that supports the interpretation of the empirical findings.

Accordingly, Table 3.5 provides the methodological foundation for the empirical phase of this research. It establishes a direct linkage between the study variables, the questionnaire items, and the statistical analyses conducted in Chapter Four, including descriptive statistics, reliability analysis, correlation analysis, and regression analysis. Consequently, the operationalization of the variables ensures consistency between the theoretical framework, the conceptual framework, and the empirical investigation undertaken to assess the impact of BIM implementation on engineering project management efficiency in Saudi Arabian construction companies.

3.10 Validity of the Study Instrument

Validity refers to the extent to which a research instrument measures what it is intended to measure (Creswell & Creswell, 2018). In this study, validity will be addressed through content validity and face validity.

Content validity will be ensured by developing the questionnaire items based on the theoretical framework, previous studies, and the research objectives. The questionnaire will be designed to cover all major dimensions of the study, including BIM implementation, time performance, cost performance, quality performance, overall project management efficiency, and BIM implementation challenges. This helps ensure that the questionnaire adequately represents the constructs being measured.

Face validity will be ensured by submitting the questionnaire to academic supervisors and/or specialists in project management, construction management, and BIM. Their feedback will be used to improve the clarity, wording, relevance, and logical order of the

questionnaire items. This step is important because unclear or ambiguous items may affect the quality of responses and reduce the accuracy of the findings.

The questionnaire will also be reviewed to ensure that the language is clear, the questions are understandable, the response options are appropriate, and the instrument is not excessively long. This is important because survey quality can be affected by respondent fatigue, unclear wording, and poorly structured questions (Fowler, 2014).

3.11 Reliability of the Study Instrument

Reliability refers to the consistency and stability of a research instrument. A reliable questionnaire should produce consistent results when measuring the same construct under similar conditions (Sekaran & Bougie, 2016). In this study, reliability will be tested using Cronbach's Alpha.

Cronbach's Alpha is one of the most commonly used statistical measures for assessing the internal consistency of multi-item scales. It indicates whether the items used to measure a particular construct are sufficiently related to each other. According to Nunnally and Bernstein (1994), a Cronbach's Alpha value of 0.70 or above is generally considered acceptable for research purposes. Tavakol and Dennick (2011) also explain that Cronbach's Alpha is useful for evaluating whether questionnaire items measure the same underlying construct.

In this study, Cronbach's Alpha will be calculated for each major dimension of the questionnaire, including BIM implementation, time performance, cost performance, quality performance, overall project management efficiency, and BIM implementation challenges. If the Alpha value for a dimension is acceptable, the items in that dimension will be considered internally consistent and suitable for further statistical analysis.

The reliability test will be conducted using SPSS before proceeding to correlation and regression analysis. This step is necessary to ensure that the questionnaire provides dependable measurements of the study variables.

3.12 Data Collection Procedures

Figure 3. 3

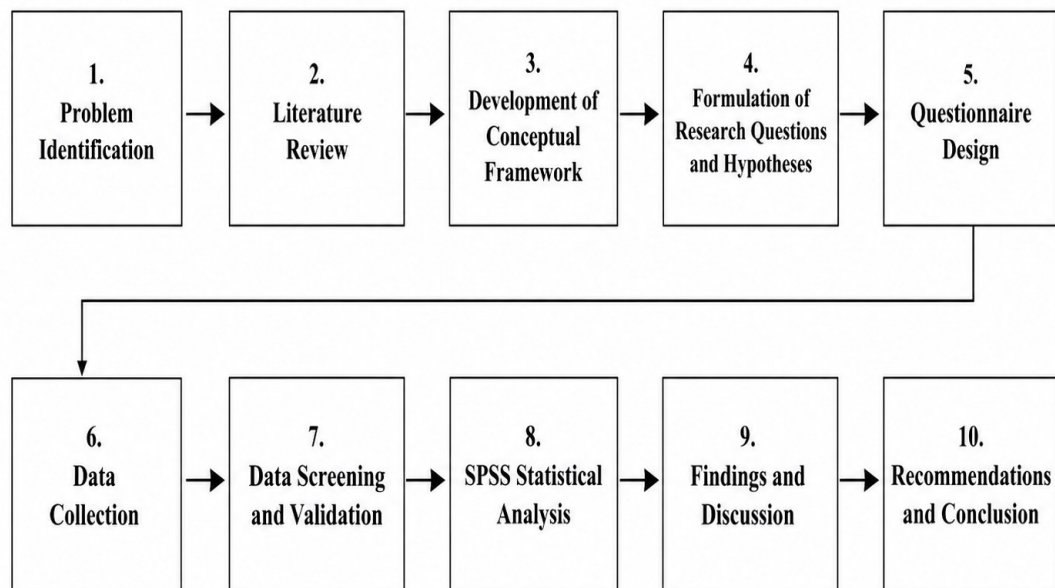


Figure.3.3: Research Process Followed in the Study

Source: Prepared by the researcher based on survey results and thesis framework.

Figure 3.3 illustrates the systematic research process adopted in the present study, beginning with the development of the research framework and ending with the statistical analysis and interpretation of the collected data. The process was designed to ensure methodological consistency between the research objectives, theoretical framework, conceptual framework, questionnaire development, data collection, and empirical analysis.

The study population comprised professionals working in **Saudi Arabian construction and engineering companies**, including project managers, project engineers, BIM engineers, consultants, construction managers, and other professionals directly involved in engineering project management and BIM implementation. These participants were selected because they possess the practical knowledge and professional experience required to evaluate the influence of BIM implementation on engineering project management efficiency.

A structured questionnaire was developed based on the reviewed literature, research objectives, conceptual framework, and study hypotheses. The questionnaire was distributed electronically to facilitate access to qualified respondents across different organizations and geographical locations within Saudi Arabia. Electronic distribution enhanced the efficiency

of data collection while maintaining participant anonymity and confidentiality in accordance with accepted research ethics.

The study targeted **100 valid responses**, which were considered sufficient to perform the planned statistical analyses. Following data collection, all returned questionnaires were carefully screened for completeness, consistency, and eligibility. Responses containing substantial missing data, duplicate submissions, or evidence of inconsistent answering patterns were excluded from the analysis. Consequently, only valid and complete questionnaires were retained for statistical processing.

The documentation of the sample selection process, including the study population, target sample, distributed questionnaires, returned questionnaires, rejected responses, and final valid sample, enhances the transparency and credibility of the research methodology. This systematic procedure reduces the potential for data bias and strengthens the validity and reliability of the empirical findings.

Accordingly, Figure 3.6 demonstrates the logical progression of the research methodology and establishes a clear linkage between the study population, sample selection, data collection procedures, questionnaire administration, data screening, and the subsequent statistical analyses conducted using SPSS. The figure therefore provides the methodological foundation for examining the impact of Building Information Modeling (BIM) implementation on engineering project management efficiency in Saudi Arabian construction companies.

3.13 Ethical Considerations

Ethical considerations are essential in research involving human participants. The study will follow the principles of voluntary participation, informed consent, confidentiality, anonymity, and responsible use of data.

Participants will be informed that their participation is voluntary and that they have the right to withdraw at any time without any negative consequences. They will also be informed that the data will be used only for academic research purposes. No personal identifying information will be required in the questionnaire, and the responses will be analyzed collectively rather than individually.

Confidentiality will be maintained by ensuring that the collected data are stored securely and accessed only for research purposes. The results will be reported in aggregate form, such as frequencies, percentages, means, correlations, and regression results. This means that no individual respondent or company will be identified in the research report.

The study will also avoid leading or biased questions. The questionnaire statements will be written in a neutral academic style to allow participants to express their real perceptions. This helps improve the ethical quality and scientific credibility of the research.

3.14 Statistical Methods Analysis

The collected data will be analyzed using the Statistical Package for the Social Sciences (SPSS). SPSS is widely used in quantitative research because it allows researchers to organize data, conduct descriptive analysis, test reliability, examine relationships between variables, and perform regression analysis (Field, 2018; Pallant, 2020).

The statistical analysis will include both descriptive and inferential statistics.

Descriptive statistics will be used to summarize the demographic characteristics of the respondents and describe their responses to the questionnaire items. Frequencies and percentages will be used for categorical variables such as gender, age group, education level, job position, years of experience, company type, and BIM experience. Means and standard deviations will be used to describe the level of agreement with questionnaire items and dimensions.

Reliability analysis will be conducted using Cronbach's Alpha to test the internal consistency of the questionnaire dimensions. This test will determine whether the items within each dimension are reliable and suitable for further analysis.

Pearson correlation analysis will be used to examine the relationship between BIM implementation and the dependent variables. Correlation analysis helps determine the strength and direction of the relationship between variables. A positive correlation would indicate that higher BIM implementation is associated with higher project management performance.

Simple linear regression analysis will be used to test the effect of BIM implementation on each dependent variable separately. This includes the effect of BIM implementation on

time performance, cost performance, quality performance, and overall project management efficiency.

Multiple regression analysis may also be used to examine the combined influence of time performance, cost performance, and quality performance on overall project management efficiency. Regression analysis is appropriate when the researcher seeks to assess the predictive effect of one or more independent variables on a dependent variable (Field, 2018; Hair et al., 2019).

The significance level for hypothesis testing will be set at 0.05. This means that a relationship or effect will be considered statistically significant if the p-value is less than or equal to 0.05.

The statistical analysis methods are summarized in Table 5.

Table 3.6: Statistical Analysis Methods Used in the Study

Statistical Method	Purpose
Frequencies and percentages	To describe demographic characteristics
Mean and standard deviation	To describe responses to questionnaire items and dimensions
Cronbach's Alpha	To test the reliability of questionnaire dimensions
Pearson correlation	To examine relationships between BIM implementation and performance dimensions
Simple linear regression	To test the effect of BIM implementation on each dependent variable
Multiple regression	To test the combined effect of performance dimensions on overall project management efficiency
Significance test	To accept or reject hypotheses at the 0.05 significance level

Source: *Prepared by the researcher based on the literature review and methodology design.*

Table 3.7 presents the statistical methods employed to analyze the data collected in this study and demonstrates their alignment with the research objectives, hypotheses, and conceptual framework. The selected statistical techniques were chosen to ensure that the

research questions could be addressed systematically and that the proposed relationships between Building Information Modeling (BIM) implementation and engineering project management efficiency could be examined using appropriate quantitative methods.

Descriptive statistical techniques, including **frequencies, percentages, means, and standard deviations**, were used to summarize the demographic characteristics of the respondents and to describe their perceptions of BIM implementation, time performance, cost performance, quality performance, and overall project management efficiency. These analyses provide an overall understanding of the sample characteristics and the distribution of responses across the study variables.

The reliability of the questionnaire was evaluated using **Cronbach's Alpha**, ensuring that the measurement scales consistently assess the intended research constructs. Establishing internal consistency enhances the credibility of the questionnaire and supports the validity of the subsequent statistical analyses.

To examine the relationships among the study variables, **Pearson correlation analysis** was employed to determine the strength and direction of the associations between BIM implementation and the performance dimensions. Subsequently, **simple linear regression analysis** was conducted to evaluate the individual effect of BIM implementation on each dependent variable, namely **time performance, cost performance, and quality performance**, thereby directly testing the corresponding research hypotheses.

Furthermore, **multiple regression analysis** was used to examine the combined contribution of the performance dimensions to **overall engineering project management efficiency**, providing a comprehensive assessment of how improvements in time, cost, and quality collectively influence project management outcomes. Finally, hypothesis testing was performed using a **5% significance level ($\alpha = 0.05$)**, which represents the conventional threshold for determining statistical significance in quantitative research.

Accordingly, the statistical methods presented in Table 3.7 establish a direct connection between the conceptual framework, operationalized study variables, research hypotheses, and empirical analysis. Collectively, these techniques provide a rigorous analytical framework for evaluating the impact of BIM implementation on engineering project management efficiency in Saudi Arabian construction companies and ensure that the study findings are supported by reliable and statistically valid evidence.

3.15 Hypotheses Testing Procedures

The hypotheses of the study will be tested using correlation and regression analysis. The main purpose of hypothesis testing is to determine whether BIM implementation has a statistically significant relationship with engineering project management efficiency and whether it has a statistically significant effect on time, cost, quality, and overall project performance.

The main null hypothesis is:

H0: There is no statistically significant relationship between BIM implementation and engineering project management efficiency in Saudi Arabian construction companies.

The main alternative hypothesis is:

H1: There is a statistically significant relationship between BIM implementation and engineering project management efficiency in Saudi Arabian construction companies.

The sub-hypotheses are:

H1a: BIM implementation has a statistically significant effect on project time performance.

H1b: BIM implementation has a statistically significant effect on cost control and cost estimation accuracy.

H1c: BIM implementation has a statistically significant effect on project quality performance.

H1d: BIM implementation has a statistically significant effect on overall engineering project management efficiency.

For each hypothesis, the p-value will be compared with the significance level of 0.05. If the p-value is less than or equal to 0.05, the null hypothesis will be rejected, and the alternative hypothesis will be supported. If the p-value is greater than 0.05, the null hypothesis will not be rejected.

The regression results will also be interpreted using the regression coefficient, R value, R² value, F-test, and significance value. The regression coefficient will show the direction and strength of the effect, while R² will indicate the percentage of variance in the dependent variable explained by BIM implementation. The F-test will show whether the regression model is statistically significant.

3.16 Chapter Summary

This chapter presents the research methodology adopted in the study. The study uses a quantitative approach and a descriptive-analytical research design to examine the impact of BIM implementation on engineering project management efficiency. A structured questionnaire will be used to collect primary data from 100 participants working in Saudi Arabian construction and engineering companies.

The chapter explained the study population, sample, sampling technique, data sources, questionnaire structure, measurement scale, operationalization of variables, validity, reliability, data collection procedures, ethical considerations, statistical analysis methods, hypotheses testing procedures, and research model. The collected data will be analyzed using SPSS. The statistical methods will include frequencies, percentages, means, standard deviations, Cronbach's Alpha, Pearson correlation, simple linear regression, and multiple regression.

The methodology is designed to provide reliable and valid evidence regarding the relationship between BIM implementation and project management efficiency. The next chapter will present the statistical analysis and results based on the questionnaire responses.

Chapter Four

Statistical Analysis and Results

4.1 Introduction

This chapter presents the statistical analysis of the survey data collected from 100 participants working in the Saudi construction and engineering sector. The analysis is organized around data screening, respondent demographics, reliability testing, descriptive statistics, Pearson correlation, simple linear regression, an optional multiple regression model, and hypotheses testing.

The purpose of the chapter is not only to report numerical results, but also to interpret what the results indicate about the impact of BIM implementation on time performance, cost performance, quality performance, and overall engineering project management efficiency.

4.2 Data Screening and Response Rate

The final dataset consisted of 100 valid survey responses. The workbook was inspected at the item level and the calculated scale-score formulas were reviewed. The analysis confirmed that all Likert-scale responses were coded from 1 to 5, which is consistent with the five-point scale used in the questionnaire. No missing values were identified, and therefore no imputation or case deletion was required.

Table 4.7: Data Screening and Validation Summary

Data Screening Criterion		Result
Number of valid responses	100	
Missing values	0 missing cells; 0 rows affected	
Likert coding range	1 to 5	
Out-of-range Likert values	0	
Scale scores	Recomputed from item-level responses and verified against workbook formulas	
Statistical significance level	alpha = 0.05	

Source: Prepared by the researcher based on survey results.

Table 4.7 summarizes the data screening and validation procedures undertaken before conducting the statistical analyses. Data screening is a critical step in quantitative research because it ensures that the collected data are complete, accurately coded, and suitable for reliable statistical analysis. Performing these procedures before hypothesis testing enhances the validity, reliability, and overall credibility of the research findings.

The results indicate that all **100 valid questionnaires** were retained for analysis, with no missing values or incomplete responses identified. Furthermore, all responses were correctly coded within the predefined **five-point Likert scale (1–5)**, and no out-of-range values were detected, confirming the accuracy and consistency of the data entry process. The composite scale scores were recalculated from the individual questionnaire items and verified against the workbook formulas to ensure the integrity and accuracy of the measurement scales used in the study.

The study adopted a statistical significance level of $\alpha = 0.05$, which is the conventional criterion for evaluating statistical significance in quantitative research. This threshold provides the basis for testing the proposed research hypotheses and determining whether the relationships between **Building Information Modeling (BIM) implementation** and the dimensions of **engineering project management efficiency**—namely **time performance, cost performance, quality performance, and overall project management efficiency**—are statistically significant.

Overall, the data screening results confirm that the dataset satisfies the quality requirements for quantitative analysis and provides a reliable foundation for the subsequent descriptive statistics, reliability analysis, Pearson correlation analysis, and regression analyses presented in this chapter. Consequently, the validated dataset strengthens the credibility of the empirical investigation and supports the study's objective of assessing the impact of BIM implementation on engineering project management efficiency in Saudi Arabian construction companies.

4.3 Demographic Characteristics of Respondents

The demographic profile indicates that the sample included professionals from different roles and organization types. This diversity strengthens the relevance of the results because BIM implementation affects design coordination, planning, cost control, construction execution, and quality management across multiple professional groups.

Table 4.8: Demographic Characteristics of Respondents

Variable	Category	Frequency	Percentage
Gender	Male	79	79.0%
Gender	Female	18	18.0%
Gender	Prefer not to say	3	3.0%
Age	25–34 years	41	41.0%
Age	35–44 years	27	27.0%
Age	45–54 years	19	19.0%
Age	Less than 25 years	8	8.0%
Age	55 years or above	5	5.0%
Educational Qualification	Bachelor’s degree	64	64.0%
Educational Qualification	Master’s degree	21	21.0%
Educational Qualification	Diploma	10	10.0%
Educational Qualification	Other	3	3.0%
Educational Qualification	Doctorate degree	2	2.0%
Current Job Position	Civil Engineer	20	20.0%
Current Job Position	BIM Specialist / BIM Coordinator	15	15.0%
Current Job Position	Project Manager	14	14.0%
Current Job Position	Cost Control Engineer / Quantity Surveyor	10	10.0%

Current Job Position	Planning Engineer	10	10.0%
Current Job Position	Architectural Engineer	9	9.0%
Current Job Position	Quality Engineer / Quality Manager	8	8.0%
Current Job Position	Mechanical / Electrical Engineer	6	6.0%
Current Job Position	Contractor	5	5.0%
Current Job Position	Consultant	2	2.0%
Current Job Position	Other	1	1.0%
Type of Organization	Contracting company	38	38.0%
Type of Organization	Consulting firm	21	21.0%
Type of Organization	Project management company	14	14.0%
Type of Organization	Engineering design office	13	13.0%
Type of Organization	Government or semi-government organization	12	12.0%
Type of Organization	Real estate / development company	2	2.0%
Years of Professional Experience	6–10 years	25	25.0%
Years of Professional Experience	Less than 3 years	22	22.0%
Years of Professional Experience	3–5 years	21	21.0%
Years of Professional Experience	11–15 years	19	19.0%
Years of Professional Experience	More than 15 years	13	13.0%
Level of Experience with BIM	Advanced user	28	28.0%
Level of Experience with BIM	Intermediate user	26	26.0%
Level of Experience with BIM	Basic awareness only	16	16.0%

Level of Experience with BIM	Beginner user	15	15.0%
Level of Experience with BIM	Expert / BIM manager level	10	10.0%
Level of Experience with BIM	No experience	5	5.0%
BIM Usage Frequency	Often	38	38.0%
BIM Usage Frequency	Sometimes	27	27.0%
BIM Usage Frequency	Always	15	15.0%
BIM Usage Frequency	Rarely	12	12.0%
BIM Usage Frequency	Never	8	8.0%

Source: Prepared by the researcher based on survey results.

Table 4.8 presents the demographic characteristics of the respondents who participated in the study. The findings indicate that the sample comprises professionals with diverse demographic and occupational backgrounds, providing an appropriate representation of individuals involved in engineering project management and Building Information Modeling (BIM) implementation within the Saudi Arabian construction industry.

The sample was predominantly male (79.0%), reflecting the workforce composition commonly observed in the construction sector in Saudi Arabia. Most respondents were between **25 and 44 years of age (68.0%)**, indicating that the majority were in their active professional careers and were likely to possess current industry knowledge and practical experience. In terms of educational qualifications, **85.0%** of the respondents held either a **Bachelor's or Master's degree**, demonstrating a high level of academic preparation and supporting the credibility of their responses regarding BIM implementation and project management practices.

The occupational profile further strengthens the quality of the sample, as it includes project managers, civil engineers, BIM specialists, planning engineers, cost control engineers, quality engineers, consultants, and contractors. This diversity ensures that the study captures perspectives from the principal stakeholders involved in engineering project planning, coordination, execution, and control. Moreover, the largest proportion of respondents was employed by **contracting companies (38.0%)**, followed by **consulting**

firms (21.0%), reflecting the organizations where BIM implementation is most actively applied during the project lifecycle.

The respondents also demonstrated substantial professional and technical experience. Nearly **57.0%** reported **six or more years of professional experience**, while **54.0%** identified themselves as **advanced, intermediate, or expert BIM users**. Furthermore, **80.0%** indicated that they use BIM either **always, often, or sometimes**, confirming that the majority possess practical experience with BIM implementation. This level of exposure enhances the reliability of the responses and ensures that participants were capable of evaluating BIM practices and their influence on project performance.

Overall, the demographic profile confirms that the study sample is well suited to address the research objectives. The respondents possess the educational background, professional experience, organizational diversity, and practical BIM knowledge required to provide informed assessments of the relationship between **Building Information Modeling (BIM) implementation** and **engineering project management efficiency**. Consequently, the characteristics of the sample strengthen the validity of the empirical findings and support the subsequent analyses examining the effects of BIM implementation on **time performance, cost performance, quality performance, and overall engineering project management efficiency** in Saudi Arabian construction companies.

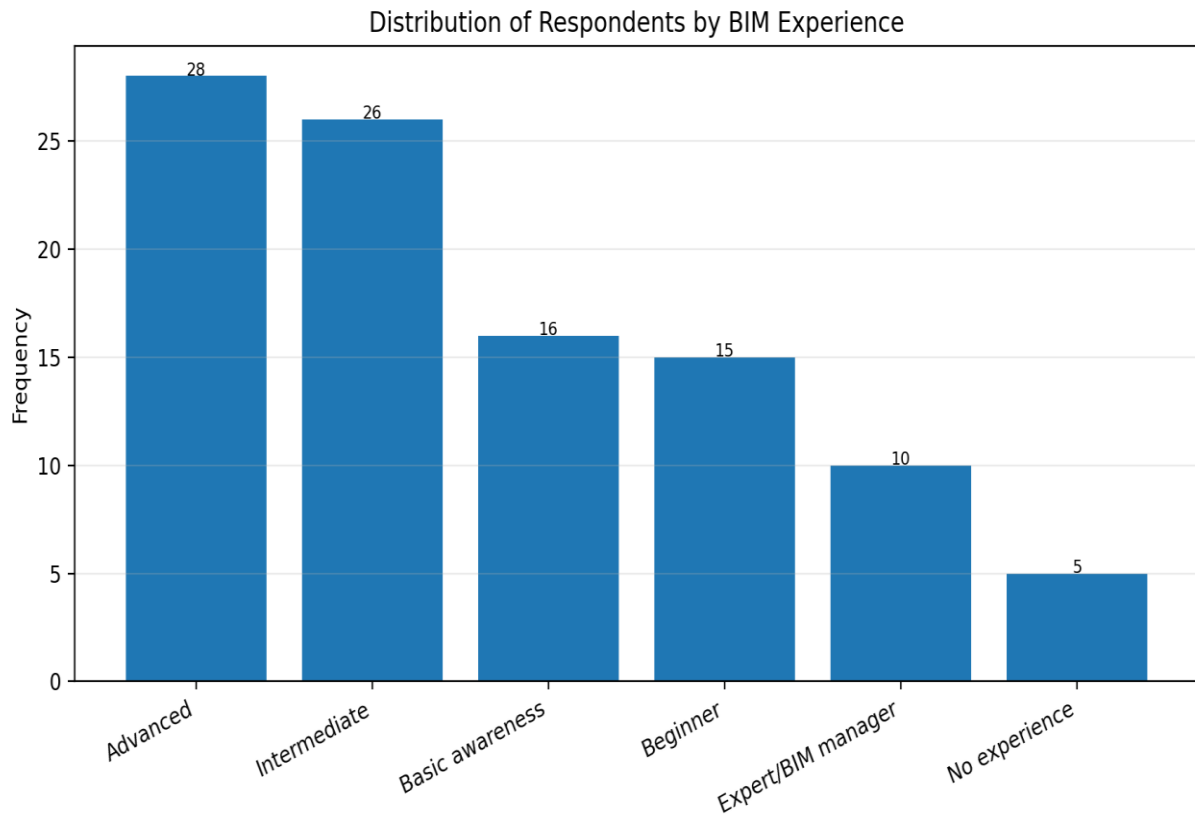


Figure 4.4: Distribution of Respondents by BIM Experience

Source: Prepared by the researcher based on survey results and thesis framework.

Figure 4.4 illustrates the respondents' level of experience with Building Information Modeling (BIM). The findings indicate that most participants possess **advanced, intermediate, or expert** BIM experience, while relatively few reported only basic awareness or no experience. This demonstrates that the sample has sufficient practical knowledge to evaluate BIM implementation in engineering projects. Consequently, the respondents provide a reliable basis for examining the relationship between **BIM implementation** and **engineering project management efficiency**, including **time performance, cost performance, quality performance, and overall project management efficiency**.

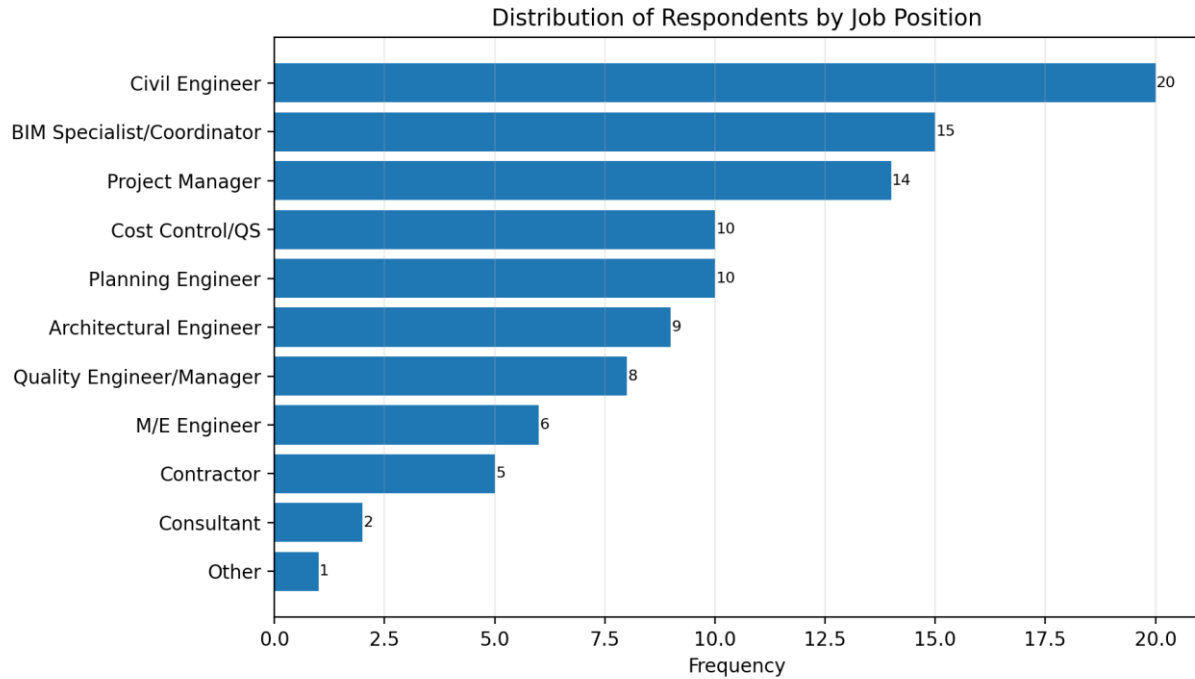


Figure 4.5: Distribution of Respondents by Job Position

Source: Prepared by the researcher based on survey results and thesis framework

Figure 4.5 illustrates the respondents' current job positions, representing a diverse range of engineering and project management professionals involved in Saudi Arabian construction projects. This diversity enhances the representativeness of the sample and provides a reliable basis for evaluating the impact of **Building Information Modeling (BIM) implementation on engineering project management efficiency**, including **time performance, cost performance, quality performance, and overall project management efficiency**.

4.4 Reliability Analysis

Cronbach's Alpha was used to examine the internal consistency reliability of the questionnaire constructs. Values of alpha at or above .70 are generally considered acceptable for social science research, values above .80 are considered good, and values above .90 are considered excellent (Nunnally & Bernstein, 1994; Field, 2018; Pallant, 2020).

Table 4.9: Reliability Analysis Using Cronbach's Alpha

Construct	Number of Items	Cronbach's Alpha	Interpretation
BIM Implementation	10	0.954	Excellent
Time Performance	10	0.926	Excellent
Cost Performance	10	0.928	Excellent
Quality Performance	10	0.932	Excellent
Overall Project Management Efficiency	10	0.930	Excellent
BIM Implementation Challenges	10	0.772	Acceptable

Source: Prepared by the researcher based on survey results.

Table 4.9 presents the reliability analysis of the study constructs using **Cronbach's Alpha**, which was employed to assess the internal consistency of the questionnaire. The results indicate that all research constructs achieved satisfactory reliability coefficients, confirming that the measurement instrument is both reliable and suitable for empirical analysis.

The constructs of **BIM Implementation ($\alpha = 0.954$)**, **Time Performance ($\alpha = 0.926$)**, **Cost Performance ($\alpha = 0.928$)**, **Quality Performance ($\alpha = 0.932$)**, and **Overall Project Management Efficiency ($\alpha = 0.930$)** all demonstrated **excellent internal consistency**, indicating that the questionnaire items consistently measure their respective constructs. Although the **BIM Implementation Challenges** construct recorded a lower reliability coefficient ($\alpha = 0.772$), it remains within the acceptable range recommended for social science research, confirming its suitability for descriptive analysis.

Overall, these findings demonstrate that the questionnaire provides reliable measurements of the study variables and supports the validity of the subsequent statistical analyses. The high reliability coefficients strengthen confidence in the empirical examination of the relationship between **Building Information Modeling (BIM) implementation** and **engineering project management efficiency**, particularly its dimensions of **time performance, cost performance, quality performance, and overall project management efficiency**. Consequently, the reliability results provide a robust methodological foundation for testing the study's research hypotheses and achieving its research objectives.

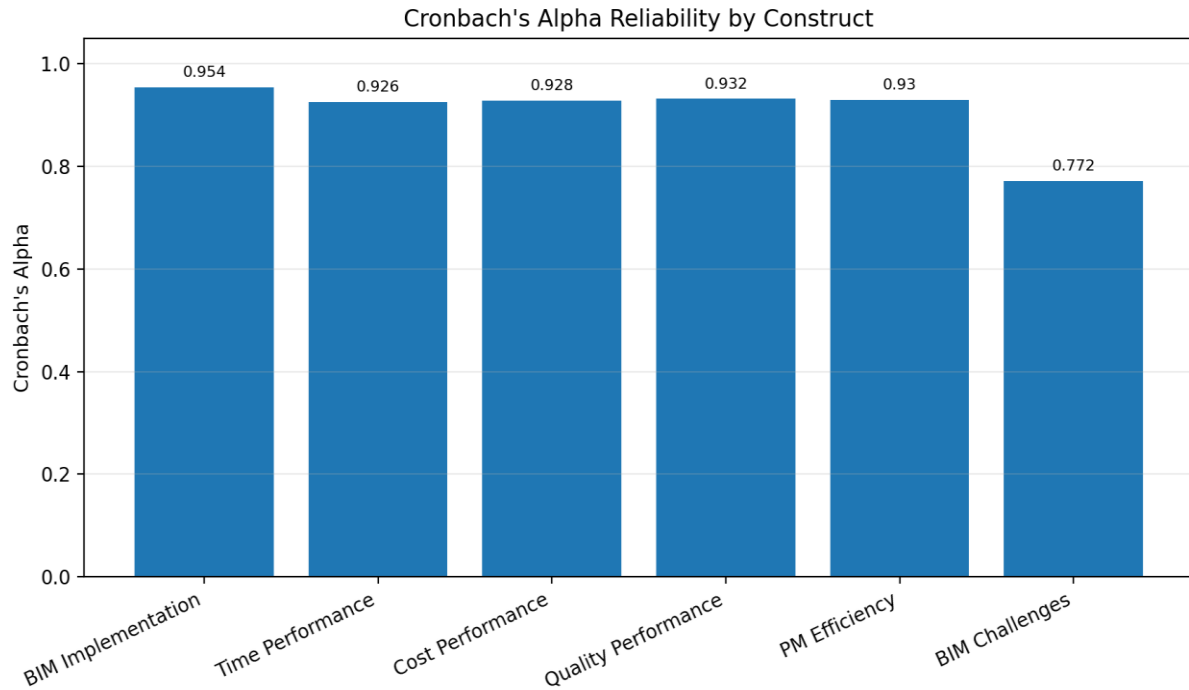


Figure 4.6: Reliability Coefficients of Study Variables

Source: Prepared by the researcher based on survey results and thesis framework

Figure 4.6 illustrates the reliability coefficients of the study variables measured using **Cronbach's Alpha**. The results indicate **excellent internal consistency** for **BIM Implementation, Time Performance, Cost Performance, Quality Performance, and Overall Project Management Efficiency**, while **BIM Implementation Challenges** demonstrated **acceptable reliability**. These findings confirm that the questionnaire reliably measures the intended research constructs and provides a sound methodological basis for the subsequent correlation, regression, and hypothesis-testing analyses. Consequently, the high reliability coefficients strengthen confidence in the empirical investigation of the relationship between **Building Information Modeling (BIM) implementation** and **engineering project management efficiency** in Saudi Arabian construction companies.

4.5 Descriptive Analysis of Study Variables

The descriptive statistics summarize the central tendency and dispersion of the major study variables. The interpretation followed the five-level scale adopted in the methodology chapter, where mean scores from 3.41 to 4.20 indicate a high level.

Table 4.10: Descriptive Statistics for Major Study Variables

Variable	Mean	Standard Deviation	Minimum	Maximum	Inter- pretation
BIM Implementation	3.431	0.880	1.400	4.900	High
Time Performance	3.809	0.673	1.700	4.900	High
Cost Performance	3.617	0.706	1.800	4.800	High
Quality Performance	3.945	0.699	2.300	5.000	High
Overall Project Management Efficiency	3.851	0.677	1.900	4.900	High
BIM Implementation Challenges	3.774	0.414	2.800	4.700	High

Source: Prepared by the researcher based on survey results.

Table 4.10 presents the descriptive statistics for the major study variables. The results indicate that all variables achieved **high mean scores**, suggesting positive respondent perceptions of **Building Information Modeling (BIM) implementation, time performance, cost performance, quality performance, overall project management efficiency, and BIM implementation challenges**. Among the performance dimensions, **Quality Performance** recorded the highest mean, indicating that respondents perceived BIM to have its greatest impact on improving project quality.

The relatively moderate standard deviations indicate a reasonable level of agreement among respondents, suggesting consistency in their perceptions across the study variables. Although respondents acknowledged the benefits of BIM implementation, the high mean for **BIM implementation challenges** also indicates that organizational, technical, and managerial barriers continue to influence BIM adoption within Saudi Arabian construction companies.

Overall, these descriptive findings provide preliminary support for the study's conceptual framework by indicating positive perceptions of BIM implementation and its association with engineering project management efficiency. They establish a sound foundation for the

subsequent correlation and regression analyses, which examine the statistical relationships between **BIM implementation** and the dimensions of **time performance**, **cost performance**, **quality performance**, and **overall project management efficiency**.

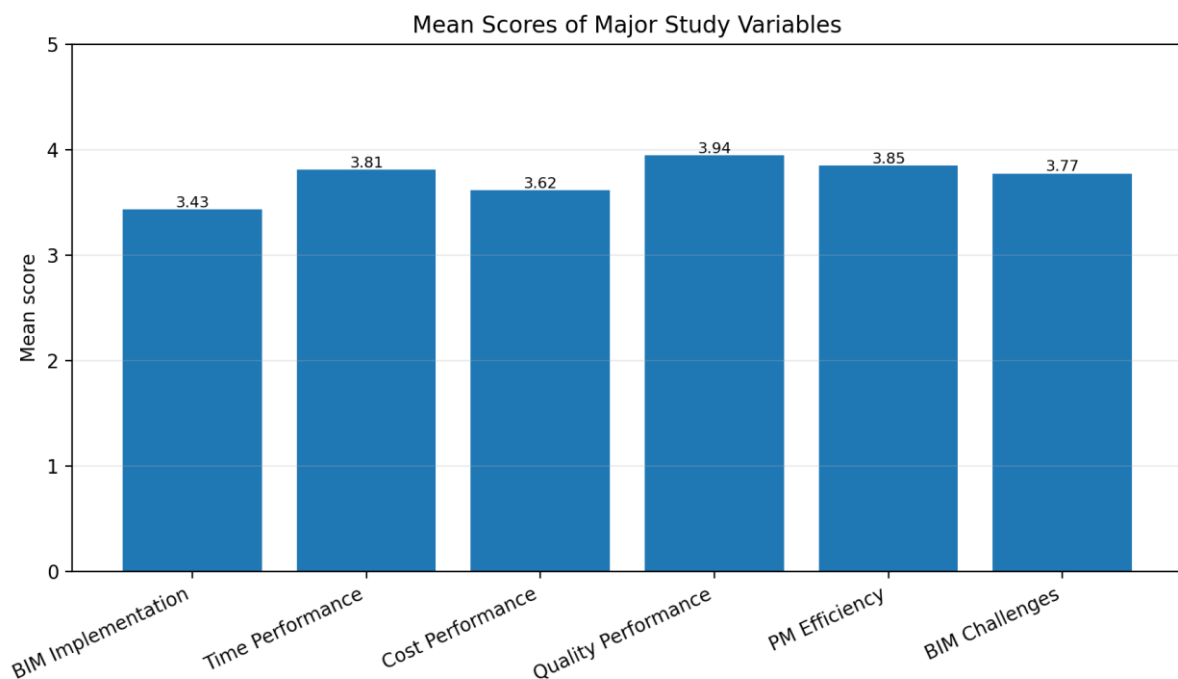


Figure 4.7: Mean Scores of Major Study Variables

Source: Prepared by the researcher based on survey results and thesis framework.

Figure 4.7 presents the mean scores of the major study variables. The highest mean score was recorded for **Quality Performance** ($M = 3.945$), followed by **Overall Project Management Efficiency** ($M = 3.851$) and **Time Performance** ($M = 3.809$). **BIM Implementation** also achieved a high mean score ($M = 3.431$), indicating a positive level of BIM adoption among the participating organizations.

The findings suggest that respondents perceive BIM implementation as having the greatest contribution to improving **quality-related aspects** of engineering projects, particularly design accuracy, coordination, documentation, and the reduction of errors and rework. The high mean scores for **time performance**, **cost performance**, and **overall project management efficiency** further support the study's conceptual framework, which proposes that effective BIM implementation contributes to enhanced engineering project management performance. Consequently, these descriptive results provide preliminary

empirical evidence in support of the study objectives and establish a foundation for the subsequent correlation, regression, and hypothesis-testing analyses examining the impact of **Building Information Modeling (BIM) implementation on engineering project management efficiency** in Saudi Arabian construction companies.

4.5 Descriptive Analysis of BIM Implementation

Table 4.11: Item-Level Descriptive Statistics for BIM Implementation

Item	Statement	Mean	Std. Dev.	Rank	Interpretation
BIM1	BIM is used in my organization or projects to support engineering design and coordination.	3.500	1.040	3	High
BIM2	BIM models are used to improve communication among project stakeholders.	3.410	1.065	6	High
BIM3	BIM is integrated into project planning and management activities, not only design visualization.	3.370	0.991	9	Moderate
BIM4	BIM tools are used to detect clashes and conflicts before construction begins.	3.660	1.017	1	High
BIM5	BIM supports better information sharing among engineers, consultants, contractors, and project managers.	3.440	1.008	4	High
BIM6	Management in my organization supports the adoption and use of BIM.	3.410	1.083	7	High
BIM7	Employees receive sufficient training to use BIM tools and processes effectively.	3.180	1.086	10	Moderate
BIM8	BIM is used to support decision-making during different stages of the project.	3.380	1.090	8	Moderate

BIM9	BIM improves coordination between architectural, structural, mechanical, and electrical disciplines.	3.530	1.114	2	High
BIM10	BIM implementation in my organization contributes to better project control and monitoring.	3.430	0.946	5	High

Source: Prepared by the researcher based on survey results.

Table 4.11 indicates a **high level of BIM implementation** among the surveyed organizations. The highest-rated practice was the use of **BIM for clash detection** before construction (BIM4, M = 3.660), while **employee training** (BIM7, M = 3.180) received the lowest rating, highlighting the need to strengthen organizational capability and staff development. Overall, the findings are consistent with the reviewed literature and provide preliminary support for the study's conceptual framework, demonstrating that effective **BIM implementation** contributes to **engineering project management efficiency**, particularly in terms of **time performance, cost performance, quality performance**, and **overall project management efficiency**.

4.7 Descriptive Analysis of Time Performance

Table 4.12: Item-Level Descriptive Statistics for Time Performance

Item	Statement	Mean	Std. Dev.	Rank	Inter-pretation
TP1	BIM improves the accuracy of project scheduling and time planning.	3.790	0.856	6	High
TP2	BIM helps project teams visualize construction sequences more clearly.	3.870	0.872	3	High
TP3	BIM supports early identification of scheduling conflicts before they affect site work.	3.750	0.892	8	High
TP4	BIM contributes to reducing delays in engineering and construction projects.	3.650	0.857	10	High

TP5	BIM improves progress monitoring during project execution.	3.880	0.913	2	High
TP6	BIM helps project managers compare planned progress with actual progress.	3.780	0.871	7	High
TP7	BIM supports faster decision-making when time-related problems occur.	3.820	0.833	5	High
TP8	BIM improves coordination between project activities and construction phases.	3.720	0.817	9	High
TP9	BIM reduces time wasted due to design conflicts or unclear project information.	3.960	0.909	1	High
TP10	Overall, BIM improves project time performance.	3.870	0.849	4	High

Source: Prepared by the researcher based on survey results.

Table 4.12 indicates that respondents perceived **Building Information Modeling (BIM)** as making a significant contribution to **project time performance**, with all items achieving **high mean scores**. The highest-rated item was **reducing time wasted due to design conflicts and unclear project information** (TP9, $M = 3.960$), while **reducing project delays** (TP4, $M = 3.650$) received the lowest, although still high, rating. These findings suggest that BIM enhances scheduling, construction sequencing, progress monitoring, coordination, and time-related decision-making. The results are consistent with the reviewed literature and provide preliminary empirical support for the study's conceptual framework, indicating that effective **BIM implementation** contributes positively to **engineering project management efficiency**, particularly through improved **time performance**. These findings also establish a foundation for the subsequent correlation, regression, and hypothesis-testing analyses.

4.8 Descriptive Analysis of Cost Performance

Table 4.13: Item-Level Descriptive Statistics for Cost Performance

Item	Statement	Mean	Std. Dev.	Rank	Interpretation
CP1	BIM improves the accuracy of quantity take-off.	3.760	0.900	1	High
CP2	BIM supports more accurate cost estimation during project planning.	3.680	0.815	3	High
CP3	BIM helps project teams understand the cost impact of design changes.	3.580	0.867	7	High
CP4	BIM contributes to better budget control during project execution.	3.610	0.840	5	High
CP5	BIM reduces unexpected project costs caused by errors or rework.	3.530	1.010	9	High
CP6	BIM improves the monitoring of project cost performance.	3.610	0.840	6	High
CP7	BIM supports better resource planning and material estimation.	3.750	0.936	2	High
CP8	BIM helps reduce cost overruns in engineering and construction projects.	3.430	0.998	10	High
CP9	BIM improves coordination between technical design and cost control teams.	3.570	0.913	8	High
CP10	Overall, BIM improves project cost performance.	3.650	0.936	4	High

Source: Prepared by the researcher based on survey results.

Table 4.13 indicates that respondents perceived **Building Information Modeling (BIM)** as making a positive contribution to **project cost performance**, with all items achieving **high mean scores**. The highest-rated item was **improving the accuracy of quantity take-off** (CP1, M = 3.760), while **reducing project cost overruns** (CP8, M = 3.430) received the lowest, although still high, rating. These findings suggest that BIM is perceived to be particularly effective in supporting cost estimation, quantity measurement, resource planning, and budget control, whereas cost overruns may also be influenced by external

managerial and market-related factors. Overall, the results are consistent with the reviewed literature and provide preliminary support for the study's conceptual framework, indicating that **BIM implementation** is positively associated with **cost performance** as a key dimension of **engineering project management efficiency**. These findings provide a foundation for the subsequent correlation, regression, and hypothesis-testing analyses.

4.9 Descriptive Analysis of Quality Performance

Table 4.14: Item-Level Descriptive Statistics for Quality Performance

Item	Statement	Mean	Std. Dev.	Rank	Interpretation
QP1	BIM improves the accuracy of engineering design information.	3.930	0.913	7	High
QP2	BIM helps detect design errors before construction begins.	4.060	0.827	1	High
QP3	BIM reduces clashes between different engineering disciplines.	3.980	0.853	3	High
QP4	BIM contributes to reducing rework during construction.	3.920	0.825	8	High
QP5	BIM improves the consistency and quality of project documentation.	3.940	0.908	5	High
QP6	BIM supports better compliance with project specifications and requirements.	3.800	0.932	10	High
QP7	BIM improves coordination between design teams and construction teams.	4.020	0.921	2	High
QP8	BIM helps project teams identify quality-related risks at an early stage.	3.940	0.941	6	High
QP9	BIM contributes to improving the final quality of construction outputs.	3.960	0.828	4	High

QP10	Overall, BIM improves project quality performance.	3.900	0.927	9	High
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Source: Prepared by the researcher based on survey results.

Table 4.14 indicates that respondents perceived **Building Information Modeling (BIM)** as making a significant contribution to **project quality performance**, with all items achieving **high mean scores**. The highest-rated item was **detecting design errors before construction begins** (QP2, M = 4.060), followed by **improving coordination between design and construction teams** (QP7, M = 4.020). These findings suggest that BIM is particularly effective in enhancing design accuracy, interdisciplinary coordination, early risk identification, and reducing construction errors and rework. The results are consistent with the reviewed literature and provide preliminary support for the study's conceptual framework, indicating that **BIM implementation** contributes positively to **quality performance** as a key dimension of **engineering project management efficiency**. These findings establish a basis for the subsequent correlation, regression, and hypothesis-testing analyses.

4.10 Descriptive Analysis of Overall Project Management Efficiency

Table 4.15: Item-Level Descriptive Statistics for Overall Project Management Efficiency

Item	Statement	Mean	Std. Dev.	Rank	Interpretation
PME1	BIM improves overall coordination among project stakeholders.	4.000	0.816	1	High
PME2	BIM supports more effective project planning and control.	3.930	0.902	2	High
PME3	BIM improves communication between project teams.	3.840	0.813	7	High

PME4	BIM enhances the quality of project management decisions.	3.880	0.868	4	High
PME5	BIM reduces uncertainty during project execution.	3.720	0.792	10	High
PME6	BIM supports better integration between design, planning, cost, and quality management.	3.850	0.947	6	High
PME7	BIM helps project managers monitor project performance more effectively.	3.790	0.891	8	High
PME8	BIM contributes to reducing project risks related to time, cost, and quality.	3.750	0.770	9	High
PME9	BIM improves the overall efficiency of engineering project management.	3.890	0.886	3	High
PME10	BIM should be further integrated into project management practices in Saudi construction companies.	3.860	0.943	5	High

Source: Prepared by the researcher based on survey results.

able 4.15 indicates that respondents perceived **Building Information Modeling (BIM)** as making a positive contribution to **overall engineering project management efficiency**, with all items receiving **high mean scores**. The highest-rated item was **improving coordination among project stakeholders** (PME1, M = 4.000), while **reducing uncertainty during project execution** (PME5, M = 3.720) received the lowest, although still high, rating. Overall, the findings support the study's conceptual framework, indicating that **BIM implementation** enhances **engineering project management efficiency** and provide a basis for the subsequent correlation, regression, and hypothesis-testing analyses.

4.11 Descriptive Analysis of BIM Implementation Challenges

Table 4.16: Item-Level Descriptive Statistics for BIM Implementation Challenges

Item	Statement	Mean	Std. Dev.	Rank	Interpretation
CH1	The high cost of BIM software and hardware limits BIM implementation.	3.810	0.692	5	High
CH2	Lack of trained professionals is a major barrier to effective BIM implementation.	3.910	0.712	2	High
CH3	Resistance to organizational change limits the adoption of BIM.	3.690	0.662	8	High
CH4	Lack of management support reduces the effectiveness of BIM implementation.	3.570	0.782	10	High
CH5	Lack of clear BIM standards and procedures affects BIM use in projects.	3.840	0.788	4	High
CH6	Interoperability problems between different software platforms limit BIM effectiveness.	3.860	0.711	3	High
CH7	Limited awareness of BIM benefits reduces its adoption in construction companies.	3.760	0.754	6	High
CH8	Weak integration between BIM and project management processes limits BIM benefits.	3.700	0.745	7	High
CH9	Insufficient training programs make BIM implementation more difficult.	3.930	0.714	1	High
CH10	The absence of clear contractual or regulatory requirements limits BIM adoption.	3.670	0.667	9	High

Source: Prepared by the researcher based on survey results.

Table 4.16 indicates that respondents perceived several **significant challenges** affecting the implementation of **Building Information Modeling (BIM)**, with all items receiving **high mean scores**. The highest-rated challenges were **insufficient training programs** (CH9, M = 3.930) and the **lack of trained professionals** (CH2, M = 3.910), while **lack of management support** (CH4, M = 3.570) received the lowest, although still high, rating. These findings suggest that human resource capability, organizational readiness,

interoperability, and the availability of BIM standards remain the principal barriers to effective BIM adoption. The results are consistent with the reviewed literature and provide important contextual evidence for interpreting the relationship between **BIM implementation** and **engineering project management efficiency**. They indicate that addressing these implementation challenges may enhance BIM adoption and improve **time performance, cost performance, quality performance, and overall engineering project management efficiency** in Saudi Arabian construction companies.

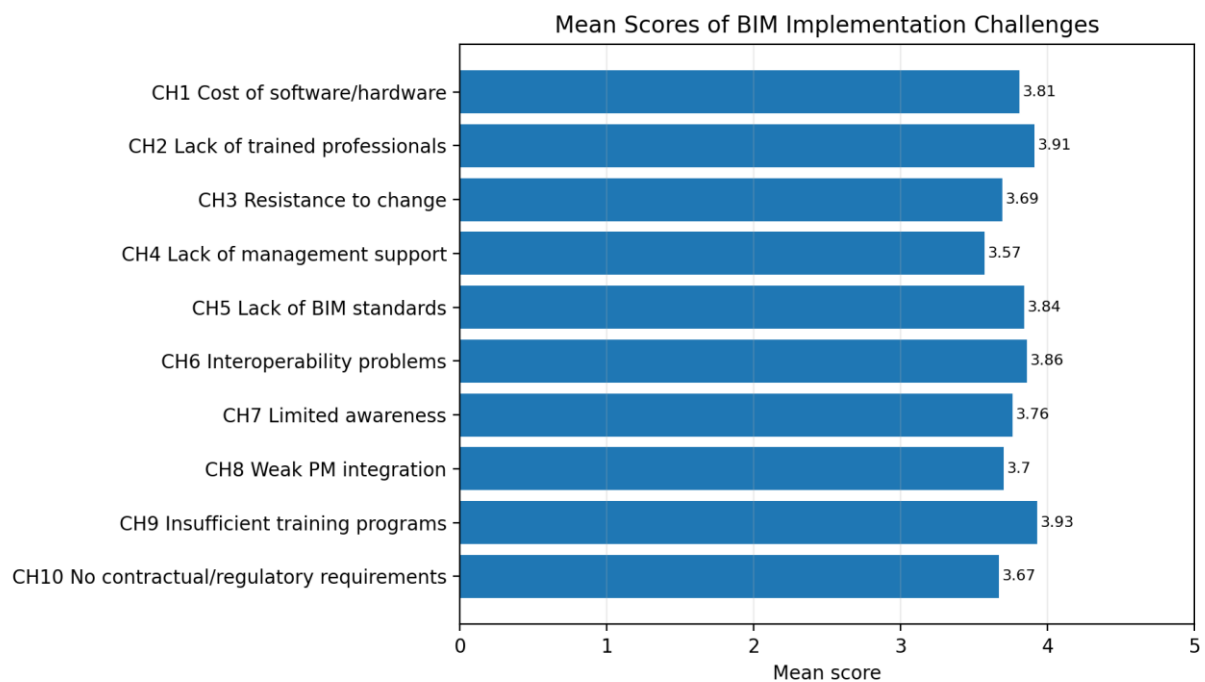


Figure 4.8: Mean Scores of BIM Implementation Challenges

Source: Prepared by the researcher based on survey results and thesis framework.

Figure 4.8 presents the mean scores of the **BIM implementation challenges**. The figure indicates that all identified challenges received **high mean scores**, with **insufficient training programs** and the **lack of trained professionals** emerging as the most significant barriers to effective BIM implementation. These findings suggest that human resource development, organizational readiness, interoperability, and standardized BIM practices remain critical factors influencing BIM adoption in Saudi Arabian construction companies. The results are consistent with the reviewed literature and provide important contextual evidence for interpreting the relationship between **Building Information Modeling (BIM) implementation** and **engineering project management efficiency**. Addressing these challenges is expected to enhance BIM implementation and support improvements in **time**

performance, cost performance, quality performance, and overall project management efficiency.

4.12 Correlation Analysis

Pearson correlation analysis was conducted to examine the direction and strength of relationships among the major study variables. The results show statistically significant positive relationships among BIM implementation and the project performance dimensions, while BIM challenges were negatively related to implementation and performance.

Table 4.17: Pearson Correlation Matrix for Major Study Variables

Variable	BIM Implemen tation	Time Performan ce	Cost Performanc e	Quality Performance	PM Efficiency	BIM Challenges
BIM Implementati on	1.000	0.916	0.898	0.917	0.927	-0.695
Time Performance	0.916	1.000	0.837	0.857	0.845	-0.655
Cost Performance	0.898	0.837	1.000	0.865	0.820	-0.640
Quality Performance	0.917	0.857	0.865	1.000	0.869	-0.635
PM Efficiency	0.927	0.845	0.820	0.869	1.000	-0.638
BIM Challenges	-0.695	-0.655	-0.640	-0.635	-0.638	1.000

Source: Prepared by the researcher based on survey results.

Table 4.19 presents the **Pearson correlation matrix** for the major study variables. The results reveal **strong positive correlations** between **Building Information Modeling (BIM) implementation** and **time performance** ($r = 0.916$), **cost performance** ($r = 0.898$),

quality performance ($r = 0.917$), and overall engineering project management efficiency ($r = 0.927$). These findings indicate that higher levels of BIM implementation are associated with improved project management performance across all measured dimensions. In contrast, **BIM implementation challenges** exhibited **moderate negative correlations** with BIM implementation and the performance variables, suggesting that greater implementation barriers are associated with lower levels of BIM adoption and reduced project management performance.

Overall, the correlation analysis provides preliminary empirical support for the study's conceptual framework and research hypotheses by demonstrating statistically meaningful associations between **BIM implementation** and the dimensions of **engineering project management efficiency**. These results provide the foundation for the subsequent regression analyses, which further examine the extent to which BIM implementation predicts **time performance, cost performance, quality performance, and overall engineering project management efficiency** in Saudi Arabian construction companies.

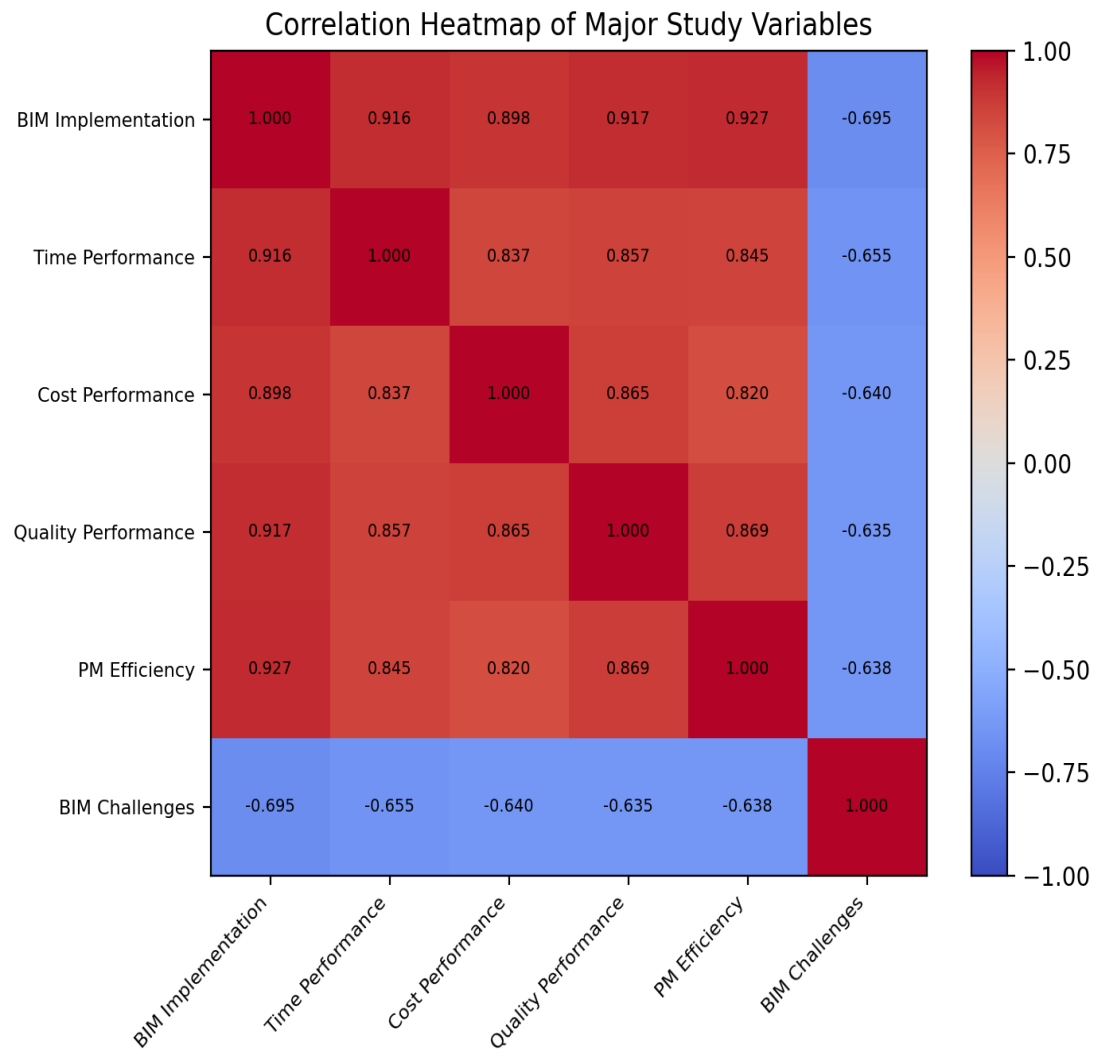


Figure 4.9: Correlation Heatmap of Major Study Variables

Source: Prepared by the researcher based on survey results and thesis framework.

Figure 4.9 presents a visual summary of the Pearson correlation coefficients among the major study variables. The heatmap illustrates **strong, positive, and statistically significant** relationships between **Building Information Modeling (BIM) implementation** and **Time Performance** ($r = 0.916$), **Cost Performance** ($r = 0.898$), **Quality Performance** ($r = 0.917$), and **Overall Engineering Project Management Efficiency** ($r = 0.927$) ($p < 0.001$). In contrast, **BIM Implementation Challenges** show **moderate negative correlations** with BIM implementation and the project performance variables, indicating that greater implementation barriers are associated with lower levels of BIM adoption and project management performance.

Overall, the heatmap provides visual support for the study's conceptual framework by demonstrating significant associations between **BIM implementation** and the dimensions of **engineering project management efficiency**. These findings provide preliminary empirical support for the study hypotheses and establish a foundation for the subsequent regression analyses, which evaluate the predictive effect of BIM implementation on **time performance, cost performance, quality performance, and overall engineering project management efficiency** in Saudi Arabian construction companies.

4.13 Regression Analysis and Hypotheses Testing

Simple linear regression was used to test the effect of BIM Implementation on each dependent variable. The regression models were evaluated using R, R Square, adjusted R Square, F statistics, unstandardized coefficients, standardized beta values, t statistics, and p-values at the 0.05 significance level.

Table 4.18: Simple Linear Regression Results for the Study Hypotheses

Model	Dependent Variable	R	R Square	Adj. R Square	F	p-value	B	Beta	t	Sig.
Model 1	Time Performance	0.916	0.839	0.837	509.293	< .001	0.700	0.916	22.568	< .001
Model 2	Cost Performance	0.898	0.806	0.804	406.898	< .001	0.721	0.898	20.172	< .001
Model 3	Quality Performance	0.917	0.841	0.839	517.650	< .001	0.729	0.917	22.752	< .001
Model 4	Overall Project Management Efficiency	0.927	0.860	0.859	602.156	< .001	0.714	0.927	24.539	< .001

Source: Prepared by the researcher based on survey results.

Table 4.18 presents the results of the simple linear regression analyses conducted to test the study hypotheses. The findings indicate that **Building Information Modeling (BIM)**

implementation has a **positive and statistically significant** effect on **Time Performance, Cost Performance, Quality Performance, and Overall Engineering Project Management Efficiency** ($p < 0.001$). The high R^2 values (0.806–0.860) demonstrate that BIM implementation explains a substantial proportion of the variation in each dependent variable, with the strongest explanatory power observed for **Overall Engineering Project Management Efficiency** ($R^2 = 0.860$).

The positive standardized regression coefficients (**Beta = 0.898–0.927**) indicate strong positive relationships between BIM implementation and all performance dimensions, while the significant **F** and **t** statistics confirm the robustness of the regression models. Overall, these findings provide strong empirical support for the study's conceptual framework and confirm the acceptance of the proposed research hypotheses, demonstrating that **BIM implementation** significantly contributes to improvements in **time performance, cost performance, quality performance, and overall engineering project management efficiency** in Saudi Arabian construction companies.

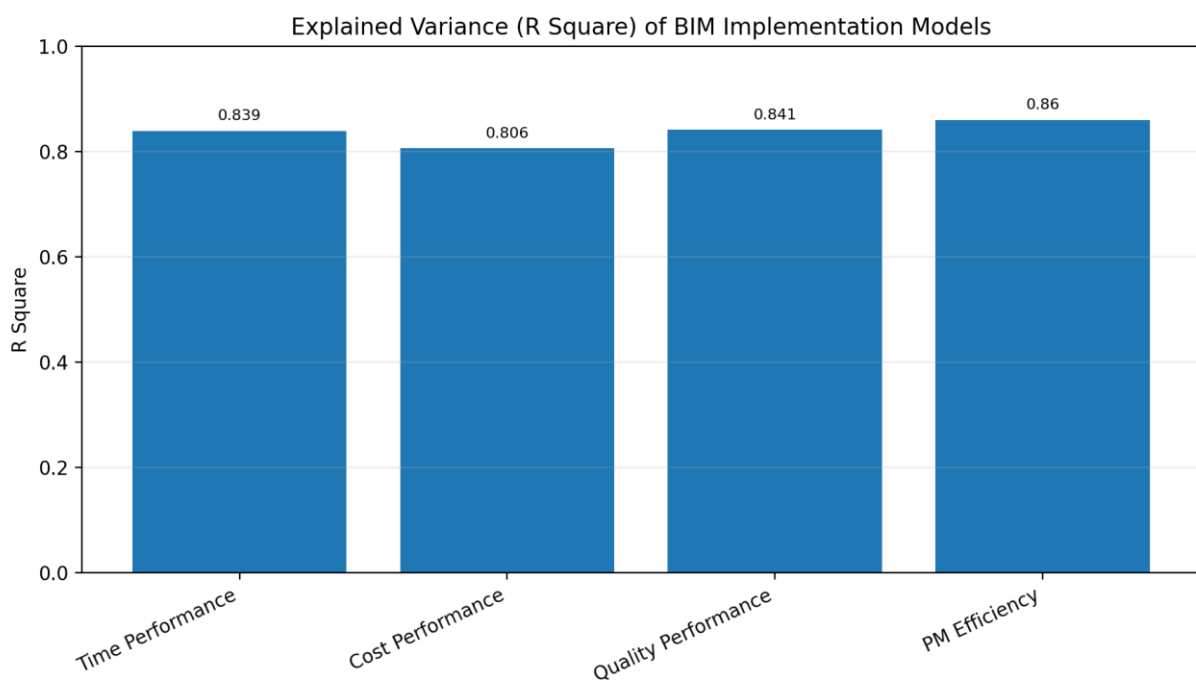


Figure 4.10: Regression R Square Values for BIM Implementation Effects

Source: Prepared by the researcher based on survey results and thesis framework.

Figure 4.10 illustrates the **R^2 values** obtained from the simple linear regression models, showing the proportion of variance in each dependent variable explained by **Building**

Information Modeling (BIM) implementation. The figure demonstrates that BIM implementation explains a substantial proportion of the variation in **Time Performance, Cost Performance, Quality Performance, and Overall Engineering Project Management Efficiency**, with **Overall Engineering Project Management Efficiency** recording the highest explanatory power ($R^2 = 0.860$). These findings provide strong empirical support for the study's conceptual framework and research hypotheses, indicating that **BIM implementation** is a significant predictor of engineering project management efficiency in Saudi Arabian construction companies. The figure also reinforces the regression results presented in Table 4.20 and highlights the practical importance of BIM adoption in improving project performance.

4.13.1 Effect of BIM Implementation on Time Performance

The regression model was statistically significant, $F = 509.293$, $p < .001$. BIM Implementation explained 83.9% of the variance in time performance. The unstandardized coefficient was positive ($B = 0.700$), and the standardized beta coefficient was strong ($Beta = 0.916$). Therefore, the hypothesis related to time performance is supported.

4.13.2 Effect of BIM Implementation on Cost Performance

The regression model was statistically significant, $F = 406.898$, $p < .001$. BIM Implementation explained 80.6% of the variance in cost performance. The unstandardized coefficient was positive ($B = 0.721$), and the standardized beta coefficient was strong ($Beta = 0.898$). Therefore, the hypothesis related to cost performance is supported.

4.13.3 Effect of BIM Implementation on Quality Performance

The regression model was statistically significant, $F = 517.650$, $p < .001$. BIM Implementation explained 84.1% of the variance in quality performance. The unstandardized coefficient was positive ($B = 0.729$), and the standardized beta coefficient was strong ($Beta = 0.917$). Therefore, the hypothesis related to quality performance is supported.

4.13.4 Effect of BIM Implementation on Overall Project Management Efficiency

The regression model was statistically significant, $F = 602.156$, $p < .001$. BIM Implementation explained 86.0% of the variance in overall project management efficiency. The unstandardized coefficient was positive ($B = 0.714$), and the standardized beta

coefficient was strong (Beta = 0.927). Therefore, the hypothesis related to overall project management efficiency is supported.

4.13.5 Multiple Regression Predicting Overall Project Management Efficiency

An additional multiple regression model was conducted to determine which performance dimension contributed most strongly to Overall Project Management Efficiency when Time Performance, Cost Performance, and Quality Performance were entered simultaneously. The model was statistically significant, $F = 126.464$, $p < .001$, and explained 79.8% of the variance in overall project management efficiency.

Table 4.19: Multiple Regression Predicting Overall Project Management Efficiency

Predictor	B	Std. Error	Beta	t	p-value
Intercept	0.323	0.185		1.749	0.084
Time Performance	0.328	0.097	0.325	3.393	0.001
Cost Performance	0.144	0.094	0.150	1.525	0.131
Quality Performance	0.446	0.101	0.460	4.404	< .001

Source: Prepared by the researcher based on survey results

Table 4.19 presents the results of the multiple regression analysis examining the combined effects of **Time Performance**, **Cost Performance**, and **Quality Performance** on **Overall Engineering Project Management Efficiency**. The findings indicate that **Quality Performance** was the strongest and most significant predictor ($\beta = 0.460$, $p < 0.001$), followed by **Time Performance** ($\beta = 0.325$, $p = 0.001$). Although **Cost Performance** showed a positive coefficient, its effect was not statistically significant ($\beta = 0.150$, $p = 0.131$) after controlling for the other performance dimensions.

These findings suggest that improvements in **quality** and **time performance** contribute most strongly to enhancing overall engineering project management efficiency. The results are consistent with the study's conceptual framework, highlighting that the benefits of **Building Information Modeling (BIM) implementation** are primarily realized through improvements in project quality and scheduling performance. Consequently, the multiple

regression analysis provides further empirical support for the study's research objectives and reinforces the conclusion that BIM implementation enhances **engineering project management efficiency** in Saudi Arabian construction companies.

4.14 Hypotheses Testing Summary

Table 4.20: Summary of Hypotheses Testing Results

Hypothesis	Statistical Test	p-value	Result	Decision	Inter-pretation
H1a: BIM implementation has a statistically significant effect on project time performance.	Simple linear regression	< .001	Statistically significant	Supported	BIM implementation significantly predicts time performance.
H1b: BIM implementation has a statistically significant effect on cost control and cost estimation accuracy.	Simple linear regression	< .001	Statistically significant	Supported	BIM implementation significantly predicts cost performance.
H1c: BIM implementation has a statistically significant effect on project quality performance.	Simple linear regression	< .001	Statistically significant	Supported	BIM implementation significantly predicts quality performance.
H1d: BIM implementation has a statistically significant effect on overall engineering project management efficiency.	Simple linear regression	< .001	Statistically significant	Supported	BIM implementation significantly predicts overall project management efficiency.

Source: Prepared by the researcher based on survey results.

Table 4.20 summarizes the results of the hypothesis testing conducted using **simple linear regression**. The findings indicate that all four research hypotheses (**H1a–H1d**) were **supported**, with statistically significant positive effects of **Building Information Modeling (BIM) implementation** on **Time Performance, Cost Performance, Quality Performance, and Overall Engineering Project Management Efficiency** ($p < 0.001$). These results confirm the study's conceptual framework and demonstrate that BIM implementation is a significant predictor of engineering project management performance. Overall, the hypothesis-testing results achieve the study's research objectives and provide strong empirical evidence that effective BIM implementation contributes to improved engineering project management efficiency in Saudi Arabian construction companies.

4.15 Chapter Summary

This chapter confirmed that the survey data were valid, complete, and suitable for statistical analysis. Reliability analysis showed acceptable to excellent internal consistency across the constructs. Descriptive statistics indicated high levels of BIM implementation, performance outcomes, and perceived implementation challenges. Correlation analysis showed strong positive relationships between BIM implementation and the three performance dimensions, as well as overall engineering project management efficiency. Regression analysis supported all study hypotheses, confirming that BIM implementation significantly predicts time, cost, quality, and overall project management efficiency. The next chapter discusses these findings in relation to the research questions, theoretical framework, previous studies, practical recommendations, and future research directions.

Chapter Five

Discussion of Results, Recommendations, and Conclusion

5.1 Introduction

This chapter discusses the findings of the study in relation to the research objectives, research questions, hypotheses, theoretical framework, and previous studies. The chapter also presents practical and academic recommendations, a proposed framework for BIM integration into project management, study limitations, suggestions for future research, and the final conclusion.

5.2 Discussion of Findings Related to BIM Implementation

The descriptive results showed that BIM Implementation reached a high level ($M = 3.431$). This finding indicates that BIM is no longer viewed by many Saudi construction and engineering professionals as a limited visualization tool; rather, it is increasingly connected to design coordination, clash detection, information sharing, decision-making, and project control. However, the lowest BIM implementation item related to employee training, which suggests that implementation maturity is uneven. This result is consistent with the BIM maturity perspective, which argues that digital tools create value only when organizational processes, standards, and human capabilities develop alongside technology (Succar, 2009; Sacks et al., 2018).

The Saudi construction sector is undergoing rapid digital transformation, especially through large infrastructure and development programs. The result therefore suggests a favorable environment for BIM adoption, but it also confirms that effective implementation requires more than software acquisition. Internal standards, management support, model-based collaboration, and continuous skills development remain essential for moving from partial BIM use toward integrated BIM-enabled project management.

5.3 Discussion of Findings Related to BIM and Time Performance

The regression analysis supported H1a and showed that BIM Implementation has a statistically significant effect on Time Performance ($\text{Beta} = 0.916$, $R \text{ Square} = 0.839$, $p <$

.001). This means that higher levels of BIM implementation are associated with stronger scheduling, sequencing, progress monitoring, and time-control outcomes. The descriptive results also showed that respondents most strongly associated BIM with reducing time wasted due to design conflicts and unclear project information.

These findings align with Bryde et al. (2013), who found that BIM can generate project benefits related to time, coordination, and process improvement. They are also consistent with Eastman et al. (2011) and Sacks et al. (2018), who emphasized the role of 4D BIM in linking digital models with construction schedules. Similarly, Zhang and Hu (2011) demonstrated that BIM and 4D methods can support conflict analysis and construction management. The current result adds empirical evidence from the Saudi construction context, showing that BIM's time-related value is strongest when it reduces uncertainty and improves coordination before problems reach the site.

5.4 Discussion of Findings Related to BIM and Cost Performance

H1b was also supported. BIM Implementation had a statistically significant positive effect on Cost Performance (Beta = 0.898, R Square = 0.806, $p < .001$). Respondents particularly recognized BIM's contribution to improving quantity take-off accuracy and cost estimation. This indicates that 5D BIM can strengthen the link between model information, quantities, cost planning, and budget control.

The result is consistent with Barlish and Sullivan (2012), who argued that BIM benefits can be measured through cost, schedule, and rework indicators. It also supports Azhar (2011), Eastman et al. (2011), and Monteiro and Poças Martins (2013), who highlighted BIM's role in automated quantities, cost estimation, and cost-related decision-making. Nevertheless, the lowest cost item was the reduction of cost overruns, indicating that BIM improves cost control but cannot eliminate overruns without strong procurement, contract management, change control, and organizational governance.

5.5 Discussion of Findings Related to BIM and Quality Performance

The results supported H1c and showed that BIM Implementation significantly predicts Quality Performance (Beta = 0.917, R Square = 0.841, $p < .001$). Quality Performance also

recorded the highest mean among the major dependent dimensions ($M = 3.945$). This indicates that respondents perceived BIM as especially effective in improving design accuracy, clash detection, documentation consistency, and rework reduction.

This result agrees with Azhar (2011), Eastman et al. (2011), Sacks et al. (2018), and Gu and London (2010), who emphasized BIM's contribution to coordination, error reduction, and interdisciplinary collaboration. In practical terms, quality improvements appear to be one of the clearest benefits of BIM because they are visible through clash detection, model review, and the early correction of design conflicts. The finding suggests that quality management should be treated as a core BIM objective in Saudi construction companies rather than as a secondary benefit.

5.6 Discussion of Findings Related to Overall Project Management Efficiency

H1d was supported. BIM Implementation had a statistically significant effect on Overall Engineering Project Management Efficiency ($\text{Beta} = 0.927$, $R^2 = 0.860$, $p < .001$). This was the strongest simple regression model, indicating that BIM implementation explains a substantial proportion of variation in perceived overall project management efficiency.

The finding supports the argument of Bryde et al. (2013) that BIM benefits extend beyond individual technical tasks to broader project performance. It also aligns with Succar (2009), who viewed BIM maturity as a combination of technology, process, and policy development. From a project management perspective, the result is consistent with PMI (2021) and Atkinson (1999), because BIM contributes to the classic time-cost-quality dimensions while also improving communication, coordination, information management, and decision quality. The optional multiple regression further showed that quality performance and time performance were the strongest unique contributors to overall efficiency, which suggests that BIM-enabled project management should prioritize model-based quality assurance and schedule integration.

5.7 Discussion of BIM Implementation Challenges

The challenge scale also reached a high level ($M = 3.774$). The highest-ranked challenges were insufficient training programs make BIM implementation more difficult. ($M = 3.930$), lack of trained professionals is a major barrier to effective BIM implementation. ($M = 3.910$), interoperability problems between software platforms ($M = 3.860$), and lack of clear BIM standards and procedures ($M = 3.840$). These barriers indicate that BIM implementation is constrained mainly by human capability, technical integration, and organizational governance.

This finding is consistent with Alhumayn et al. (2017), who identified training, standards, and organizational barriers as important obstacles in Saudi Arabia. It also aligns with Alaboud and Alshahrani (2023), Alghuried (2023), Khosrowshahi and Arayici (2012), and Migilinskas et al. (2013), who noted that BIM adoption depends on skills, collaboration, interoperability, clear procedures, and institutional support. The negative correlation between challenges and BIM implementation further confirms that barriers reduce the ability of organizations to obtain BIM's full project management benefits.

5.8 Answers to Research Questions

Table 5.21: Answers to the Research Questions

Research Question	Answer Based on Findings
What is the impact of BIM implementation on project time performance?	BIM implementation has a statistically significant positive effect on time performance ($\text{Beta} = 0.916$, $p < .001$). BIM improves scheduling, sequencing, progress monitoring, and time-related coordination.
What is the impact of BIM implementation on cost control and cost estimation accuracy?	BIM implementation has a statistically significant positive effect on cost performance ($\text{Beta} = 0.898$, $p < .001$), especially through quantity take-off accuracy, cost estimation, and cost monitoring.
What is the impact of BIM implementation on project quality performance?	BIM implementation has a statistically significant positive effect on quality performance ($\text{Beta} = 0.917$, $p < .001$). The strongest perceived benefits relate to design-error detection, clash reduction, and documentation quality.

What are the main challenges that limit effective BIM implementation?	The main challenges are insufficient training programs, lack of trained professionals, interoperability problems, lack of clear BIM standards and procedures, and high software/hardware costs.
How can BIM be better integrated into project management practices?	BIM should be integrated into scheduling, cost control, quality assurance, coordination meetings, common data environments, project monitoring, and decision-making processes rather than being restricted to design visualization.

Source: Prepared by the researcher based on survey results.

Table 5.21 summarizes the answers to the study's research questions based on the empirical findings. The results confirm that **Building Information Modeling (BIM) implementation** has significant positive effects on **time performance, cost performance, quality performance, and overall engineering project management efficiency**. The findings also identify key implementation challenges, including inadequate training, limited professional expertise, interoperability issues, and the absence of clear BIM standards. Furthermore, the study highlights that maximizing BIM benefits requires its integration into project planning, scheduling, cost control, quality management, coordination, and decision-making processes. Overall, these findings directly address the research questions, achieve the study's objectives, validate the conceptual framework, and provide practical evidence supporting the adoption of BIM to enhance engineering project management efficiency in Saudi Arabian construction companies.

5.9 Theoretical Implications

The findings support the Iron Triangle of project management because BIM implementation significantly improved time, cost, and quality dimensions. However, the results also confirm Atkinson's (1999) argument that project success should not be limited to these three dimensions only; BIM also contributes to broader efficiency through coordination, communication, decision quality, and risk reduction.

The findings also support the BIM maturity perspective because the benefits of BIM were stronger when BIM was integrated into project management activities. From the technology

adoption perspective, the high implementation level indicates perceived usefulness, while the challenge results show that ease of use, training, organizational readiness, and management support remain critical. From the information management perspective, the study confirms that BIM improves efficiency by creating a shared digital information environment for design, scheduling, cost, quality, and decision-making.

5.10 Practical Recommendations

Table 5.22: Practical Recommendations for Saudi Construction Companies

Recommendation	Practical Application
Integrate BIM into project management	Use BIM as a management platform for planning, coordination, monitoring, and decision-making, not only as a design visualization tool.
Use 4D BIM for scheduling	Link BIM models with project schedules to visualize sequencing, identify schedule conflicts, and monitor progress.
Use 5D BIM for cost control	Connect model quantities with cost databases to improve estimation accuracy, budget control, and change-impact analysis.
Strengthen BIM-based quality control	Use clash detection, model checking, and coordinated documentation reviews as standard quality assurance procedures.
Provide continuous BIM training	Develop regular training programs for engineers, project managers, quantity surveyors, planners, and quality teams.
Develop internal BIM standards	Establish clear modeling standards, naming conventions, model exchange procedures, and BIM execution plans.
Improve interoperability	Adopt common data exchange protocols and select software workflows that reduce information loss between platforms.
Increase top management support	Link BIM adoption to strategic performance goals, digital transformation, and measurable project benefits.
Use a common data environment	Centralize project information, model versions, approvals, and communication to reduce fragmentation.

Source: Prepared by the researcher based on survey findings and literature review.

Table 5.22 presents the practical recommendations developed from the study's empirical findings. The recommendations focus on strengthening **Building Information Modeling (BIM) implementation** through improved integration with project management processes, enhanced training, standardized BIM practices, greater interoperability, and stronger organizational support. These recommendations directly address the implementation challenges identified in the study and are consistent with the research findings demonstrating the positive effects of BIM on **time performance, cost performance, quality performance, and overall engineering project management efficiency**. Consequently, they provide practical guidance for Saudi construction companies seeking to improve project performance, support digital transformation, and maximize the benefits of BIM implementation.

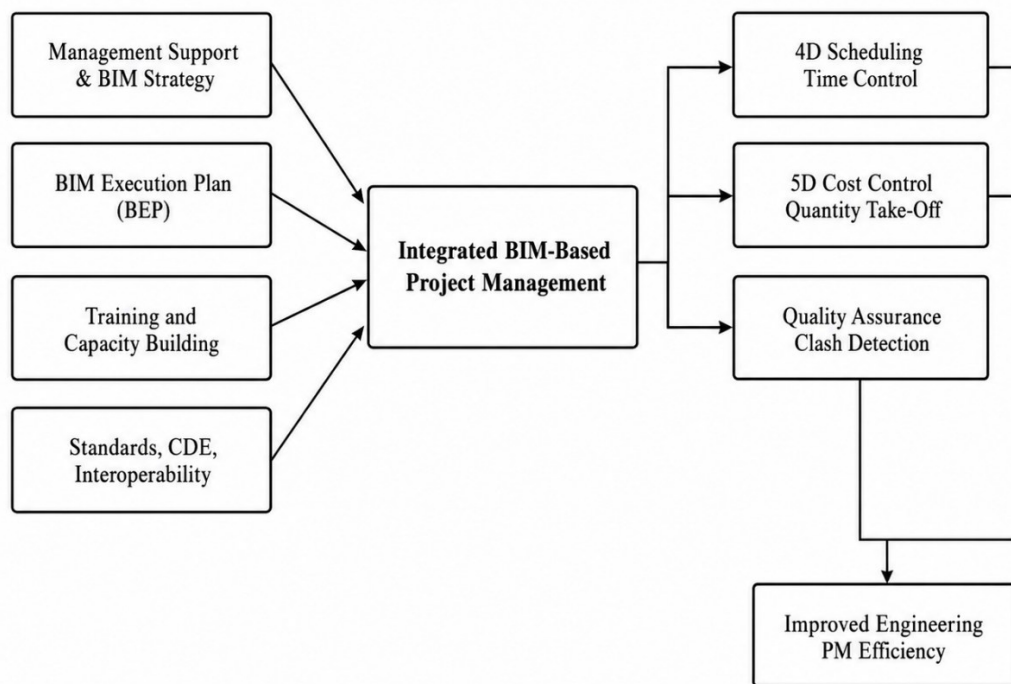
5.11 Academic Recommendations

Future researchers should expand the sample size beyond 100 participants and include broader representation from owners, contractors, consultants, government organizations, and project management firms. Comparative studies between Saudi Arabia and other Gulf countries would also help identify regional similarities and differences in BIM maturity and implementation barriers.

Qualitative interviews with BIM managers and senior project managers are recommended to explore the reasons behind training, interoperability, and standards-related challenges. Longitudinal studies would also be useful for measuring how BIM maturity evolves over time.

5.12 Proposed Framework for BIM Integration

Figure 5.11. Proposed framework for BIM Integration into Engineering Project management.



Proposed Framework for Integrating BIM into Engineering Project Management Practices

Source: Prepared by the researcher based on survey results and thesis framework.

Figure 5.11 presents the **proposed framework for integrating Building Information Modeling (BIM) into engineering project management practices**, developed from the study's empirical findings and supported by the reviewed literature. The framework combines key elements of successful BIM implementation, including organizational readiness, training, BIM standards, 4D scheduling, 5D cost management, quality assurance, collaboration, performance monitoring, and continuous improvement.

The proposed framework directly reflects the study's findings, which demonstrated that **BIM implementation** has significant positive effects on **time performance, cost performance, quality performance, and overall engineering project management efficiency**, while also highlighting the importance of addressing implementation challenges such as training, interoperability, and organizational readiness. Consequently, the framework provides a practical roadmap for Saudi construction companies to strengthen BIM adoption, improve project management practices, and support digital transformation. As the principal practical outcome of this research, it translates the study's conceptual

framework and empirical evidence into actionable guidance for enhancing engineering project management efficiency.

Table 5.23: Proposed Framework for BIM Integration into Project Management

Stage	Framework Component	Purpose
1	Organizational readiness assessment	Assess current BIM skills, software, workflows, management support, and data maturity.
2	BIM strategy and objectives	Define clear BIM objectives linked to time, cost, quality, coordination, and decision-making.
3	BIM standards and execution plan	Develop modeling standards, roles, deliverables, information exchange requirements, and BIM execution plans.
4	Staff training and capacity building	Provide continuous training for technical and project management staff.
5	4D scheduling integration	Connect BIM models with schedules for sequencing, progress control, and delay prevention.
6	5D cost control integration	Use model-based quantities and cost data for estimation, budgeting, and change control.
7	Quality assurance and clash detection	Use model checking, clash detection, and design reviews to improve quality and reduce rework.
8	Common data environment	Manage models, documents, approvals, and communications through an integrated digital environment.
9	Performance monitoring	Measure BIM outcomes using time, cost, quality, coordination, and efficiency indicators.
10	Continuous improvement	Review lessons learned and improve BIM maturity across projects.

Source: Prepared by the researcher based on survey results and the reviewed literature.

Table 5.23 presents the proposed framework for integrating **Building Information Modeling (BIM)** into engineering project management. Developed from the study's empirical findings and the reviewed literature, the framework provides a structured approach to strengthening BIM implementation through organizational readiness, BIM standards, training, 4D scheduling, 5D cost management, quality assurance, performance monitoring, and continuous improvement. The framework directly addresses the implementation challenges identified in the study and supports the achievement of the research objectives by providing practical guidance for improving **time performance, cost performance, quality performance, and overall engineering project management efficiency** in Saudi Arabian construction companies.

5.13 Limitations of the Study

The study has several limitations. First, the sample size was limited to 100 participants, which is suitable for the statistical techniques used but may not represent the entire Saudi construction industry. Second, the study focused on Saudi construction companies and related engineering organizations, so the results should be generalized to other contexts with caution. Third, the study relied on survey-based self-reported data, which may reflect respondents' perceptions rather than objective project records. Fourth, the research used a cross-sectional design, meaning that it measured perceptions at one point in time. Finally, the study focused mainly on time, cost, quality, and overall project management efficiency, while other BIM outcomes such as sustainability, safety, risk management, and facility management were outside its main scope.

5.14 Suggestions for Future Research

Future studies should collect larger datasets and compare BIM adoption across regions, project types, and organization sizes. Researchers should also combine quantitative surveys with qualitative interviews to understand how organizational culture, contracts, procurement methods, and leadership affect BIM outcomes. Longitudinal research is recommended to examine whether BIM benefits increase as organizations move from basic adoption to higher maturity levels. Future studies may also use structural equation modeling to test direct and indirect relationships among BIM implementation, challenges, performance dimensions, and project success.

5.15 Conclusion

This thesis assessed the impact of Building Information Modeling implementation on engineering project management efficiency in Saudi Arabian construction companies using a quantitative survey of 100 participants. The study examined BIM implementation as the independent variable and time performance, cost performance, quality performance, and overall engineering project management efficiency as dependent dimensions, while also analyzing BIM implementation challenges.

The results confirmed that BIM implementation has statistically significant positive effects on project time performance, cost performance, quality performance, and overall engineering project management efficiency. Quality performance recorded the highest descriptive mean and was the strongest unique contributor to overall efficiency in the multiple regression model. The findings also showed that training limitations, lack of trained professionals, interoperability problems, and unclear BIM standards remain important barriers. Overall, the results support the importance of BIM implementation in improving engineering project management efficiency, especially when BIM is integrated into scheduling, cost control, quality management, coordination, information exchange, and decision-making. For Saudi construction companies, BIM should therefore be treated as a strategic project management capability and a core element of organizational digital transformation.

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Appendices

Appendix A: Survey Questionnaire

Assessing the Impact of Building Information Modeling (BIM) Implementation on Engineering Project Management Efficiency in Saudi Arabian Construction Companies

Dear Participant,

You are invited to participate in this academic research study, which aims to assess the impact of Building Information Modeling (BIM) implementation on engineering project management efficiency in Saudi Arabian construction companies. The study focuses on project time performance, cost performance, quality performance, and overall project management efficiency.

Your participation is voluntary. The questionnaire is designed for academic purposes only, and all responses will be treated with full confidentiality. No personal names or company-identifying information are required. The results will be analyzed collectively using statistical methods.

Please answer all questions based on your professional experience in construction, engineering, BIM, project management, consultancy, contracting, planning, cost control, or quality management.

Section A: Demographic Information

Please select the answer that best describes you.

No.	Item	Options
1	Gender	☐ Male ☐ Female ☐ Prefer not to say
2	Age	☐ Less than 25 years ☐ 25–34 years ☐ 35–44 years ☐ 45–54 years ☐ 55 years or above
3	Educational Qualification	☐ Diploma ☐ Bachelor's degree ☐ Master's degree ☐ Doctorate degree ☐ Other

4	Current Job Position	☐ Project Manager ☐ BIM Specialist / BIM Coordinator ☐ Civil Engineer ☐ Architectural Engineer ☐ Mechanical / Electrical Engineer ☐ Planning Engineer ☐ Cost Control Engineer / Quantity Surveyor ☐ Quality Engineer / Quality Manager ☐ Consultant ☐ Contractor ☐ Other
5	Type of Organization	☐ Contracting company ☐ Consulting firm ☐ Engineering design office ☐ Project management company ☐ Real estate / development company ☐ Government or semi-government organization ☐ Other
6	Years of Professional Experience	☐ Less than 3 years ☐ 3–5 years ☐ 6–10 years ☐ 11–15 years ☐ More than 15 years
7	Level of Experience with BIM	☐ No experience ☐ Basic awareness only ☐ Beginner user ☐ Intermediate user ☐ Advanced user ☐ Expert / BIM manager level
8	How often is BIM used in your organization or projects?	☐ Never ☐ Rarely ☐ Sometimes ☐ Often ☐ Always

Instructions for Sections B–G

Please indicate your level of agreement with each statement using the following scale:

Scale	Response
1	Strongly Disagree
2	Disagree
3	Neutral
4	Agree
5	Strongly Agree

Section B: BIM Implementation

This section measures the extent to which BIM is implemented and integrated into project practices.

Code	Statement	1	2	3	4	5
BIM1	BIM is used in my organization or projects to support engineering design and coordination.	☐	☐	☐	☐	☐
BIM2	BIM models are used to improve communication among project stakeholders.	☐	☐	☐	☐	☐
BIM3	BIM is integrated into project planning and management activities, not only design visualization.	☐	☐	☐	☐	☐
BIM4	BIM tools are used to detect clashes and conflicts before construction begins.	☐	☐	☐	☐	☐
BIM5	BIM supports better information sharing among engineers, consultants, contractors, and project managers.	☐	☐	☐	☐	☐
BIM6	Management in my organization supports the adoption and use of BIM.	☐	☐	☐	☐	☐
BIM7	Employees receive sufficient training to use BIM tools and processes effectively.	☐	☐	☐	☐	☐
BIM8	BIM is used to support decision-making during different stages of the project.	☐	☐	☐	☐	☐
BIM9	BIM improves coordination between architectural, structural, mechanical, and electrical disciplines.	☐	☐	☐	☐	☐
BIM10	BIM implementation in my organization contributes to better project control and monitoring.	☐	☐	☐	☐	☐

Section C: BIM and Project Time Performance

This section measures the impact of BIM on project scheduling, time control, and delay reduction.

Code	Statement	1	2	3	4	5
TP1	BIM improves the accuracy of project scheduling and time planning.	☐	☐	☐	☐	☐
TP2	BIM helps project teams visualize construction sequences more clearly.	☐	☐	☐	☐	☐
TP3	BIM supports early identification of scheduling conflicts before they affect site work.	☐	☐	☐	☐	☐
TP4	BIM contributes to reducing delays in engineering and construction projects.	☐	☐	☐	☐	☐
TP5	BIM improves progress monitoring during project execution.	☐	☐	☐	☐	☐
TP6	BIM helps project managers compare planned progress with actual progress.	☐	☐	☐	☐	☐
TP7	BIM supports faster decision-making when time-related problems occur.	☐	☐	☐	☐	☐
TP8	BIM improves coordination between project activities and construction phases.	☐	☐	☐	☐	☐
TP9	BIM reduces time wasted due to design conflicts or unclear project information.	☐	☐	☐	☐	☐
TP10	Overall, BIM improves project time performance.	☐	☐	☐	☐	☐

Section D: BIM and Cost Performance

This section measures the impact of BIM on cost estimation, cost control, and budget management.

Code	Statement	1	2	3	4	5
CP1	BIM improves the accuracy of quantity take-off.	☐	☐	☐	☐	☐
CP2	BIM supports more accurate cost estimation during project planning.	☐	☐	☐	☐	☐

CP3	BIM helps project teams understand the cost impact of design changes.	☐	☐	☐	☐	☐
CP4	BIM contributes to better budget control during project execution.	☐	☐	☐	☐	☐
CP5	BIM reduces unexpected project costs caused by errors or rework.	☐	☐	☐	☐	☐
CP6	BIM improves the monitoring of project cost performance.	☐	☐	☐	☐	☐
CP7	BIM supports better resource planning and material estimation.	☐	☐	☐	☐	☐
CP8	BIM helps reduce cost overruns in engineering and construction projects.	☐	☐	☐	☐	☐
CP9	BIM improves coordination between technical design and cost control teams.	☐	☐	☐	☐	☐
CP10	Overall, BIM improves project cost performance.	☐	☐	☐	☐	☐

Section E: BIM and Project Quality Performance

This section measures the impact of BIM on project quality, design accuracy, and error reduction.

Code	Statement	1	2	3	4	5
Code	Statement	1	2	3	4	5
PME1	BIM improves overall coordination among project stakeholders.	☐	☐	☐	☐	☐
PME2	BIM supports more effective project planning and control.	☐	☐	☐	☐	☐
PME3	BIM improves communication between project teams.	☐	☐	☐	☐	☐
PME4	BIM enhances the quality of project management decisions.	☐	☐	☐	☐	☐
PME5	BIM reduces uncertainty during project execution.	☐	☐	☐	☐	☐
PME6	BIM supports better integration between design, planning, cost, and quality management.	☐	☐	☐	☐	☐
PME7	BIM helps project managers monitor project performance more effectively.	☐	☐	☐	☐	☐
PME8	BIM contributes to reducing project risks related to time, cost, and quality.	☐	☐	☐	☐	☐

PME9	BIM improves the overall efficiency of engineering project management.	☐	☐	☐	☐	☐
PME10	BIM should be further integrated into project management practices in Saudi construction companies.	☐	☐	☐	☐	☐
QP1	BIM improves the accuracy of engineering design information.	☐	☐	☐	☐	☐
QP2	BIM helps detect design errors before construction begins.	☐	☐	☐	☐	☐
QP3	BIM reduces clashes between different engineering disciplines.	☐	☐	☐	☐	☐
QP4	BIM contributes to reducing rework during construction.	☐	☐	☐	☐	☐
QP5	BIM improves the consistency and quality of project documentation.	☐	☐	☐	☐	☐
QP6	BIM supports better compliance with project specifications and requirements.	☐	☐	☐	☐	☐
QP7	BIM improves coordination between design teams and construction teams.	☐	☐	☐	☐	☐
QP8	BIM helps project teams identify quality-related risks at an early stage.	☐	☐	☐	☐	☐
QP9	BIM contributes to improving the final quality of construction outputs.	☐	☐	☐	☐	☐
QP10	Overall, BIM improves project quality performance.	☐	☐	☐	☐	☐

Section F: BIM and Overall Engineering Project Management Efficiency

This section measures the broader impact of BIM on project management efficiency.

Code	Statement	1	2	3	4	5
PME1	BIM improves overall coordination among project stakeholders.	☐	☐	☐	☐	☐
PME2	BIM supports more effective project planning and control.	☐	☐	☐	☐	☐
PME3	BIM improves communication between project teams.	☐	☐	☐	☐	☐

PME4	BIM enhances the quality of project management decisions.	☐	☐	☐	☐	☐
PME5	BIM reduces uncertainty during project execution.	☐	☐	☐	☐	☐
PME6	BIM supports better integration between design, planning, cost, and quality management.	☐	☐	☐	☐	☐
PME7	BIM helps project managers monitor project performance more effectively.	☐	☐	☐	☐	☐
PME8	BIM contributes to reducing project risks related to time, cost, and quality.	☐	☐	☐	☐	☐
PME9	BIM improves the overall efficiency of engineering project management.	☐	☐	☐	☐	☐
PME10	BIM should be further integrated into project management practices in Saudi construction companies.	☐	☐	☐	☐	☐

Section G: Challenges of BIM Implementation

This section identifies the main barriers that may limit effective BIM implementation.

Code	Statement	1	2	3	4	5
CH1	The high cost of BIM software and hardware limits BIM implementation.	☐	☐	☐	☐	☐
CH2	Lack of trained professionals is a major barrier to effective BIM implementation.	☐	☐	☐	☐	☐
CH3	Resistance to organizational change limits the adoption of BIM.	☐	☐	☐	☐	☐
CH4	Lack of management support reduces the effectiveness of BIM implementation.	☐	☐	☐	☐	☐
CH5	Lack of clear BIM standards and procedures affects BIM use in projects.	☐	☐	☐	☐	☐
CH6	Interoperability problems between different software platforms limit BIM effectiveness.	☐	☐	☐	☐	☐

CH7	Limited awareness of BIM benefits reduces its adoption in construction companies.	☐	☐	☐	☐	☐
CH8	Weak integration between BIM and project management processes limits BIM benefits.	☐	☐	☐	☐	☐
CH9	Insufficient training programs make BIM implementation more difficult.	☐	☐	☐	☐	☐
CH10	The absence of clear contractual or regulatory requirements limits BIM adoption.	☐	☐	☐	☐	☐

Section H: Optional Open-Ended Questions No

No.	Question	Answer
1	In your opinion, what is the most important benefit of BIM in engineering project management?	
2	What is the main challenge that limits BIM implementation in Saudi construction companies?	
3	What recommendations would you suggest to improve BIM integration into project management practices?	

الملخص

هدفت هذه الدراسة إلى تقييم أثر تطبيق نمذجة معلومات البناء (BIM - Building Information Modeling) على كفاءة إدارة المشاريع الهندسية في شركات المقاولات بالمملكة العربية السعودية، مع التركيز على أداء الوقت، وأداء التكلفة، وأداء الجودة، والكفاءة العامة لإدارة المشاريع الهندسية. واعتمدت الدراسة المنهج الوصفي التحليلي باستخدام المدخل الكمي، حيث جُمعت البيانات من خلال استبانة منظمة استُكملت بواسطة (100) من المهنيين العاملين في قطاع الإنشاءات والهندسة بالمملكة العربية السعودية.

تضمنت الاستبانة قياس مستوى تطبيق نمذجة معلومات البناء (BIM)، وأداء الوقت، وأداء التكلفة، وأداء الجودة، وكفاءة إدارة المشاريع الهندسية، بالإضافة إلى التحديات المرتبطة بتطبيق BIM، وذلك باستخدام مقياس ليكرت الخماسي. وتم تحليل البيانات باستخدام الإحصاءات الوصفية، واختبار الثبات، ومعامل ارتباط بيرسون، وتحليل الانحدار.

أظهرت نتائج الدراسة أن تطبيق نمذجة معلومات البناء (BIM) له أثر إيجابي ودال إحصائياً على أداء الوقت، وأداء التكلفة، وأداء الجودة، والكفاءة العامة لإدارة المشاريع الهندسية. كما سجل بُعد أداء الجودة أعلى متوسط حسابي مقارنةً بأبعاد الأداء الأخرى. وأوضحت النتائج كذلك أن التحديات المرتبطة بتطبيق BIM ما زالت تمثل عاملاً مهماً، ولا سيما التحديات المتعلقة بالتدريب، والجاهزية التنظيمية، والتكلفة، وقابلية التشغيل البيئي، والتكامل مع عمليات إدارة المشاريع.

وتخلص الدراسة إلى أن التطبيق الفعال لنمذجة معلومات البناء (BIM) يسهم بصورة ملحوظة في تحسين كفاءة إدارة المشاريع الهندسية من خلال تعزيز التخطيط، والجدولة الزمنية، وإدارة التكاليف، وإدارة الجودة، والتنسيق بين أصحاب المصلحة، ودعم اتخاذ القرارات. وبناءً على ذلك، توصي الدراسة بتعزيز برامج التدريب على BIM، ورفع مستوى الجاهزية التنظيمية، وتطوير معايير وإجراءات واضحة لتطبيق BIM، وتعزيز تكامله مع نمذجة الجدولة الزمنية رباعية الأبعاد (4D)، وإدارة التكاليف خماسية الأبعاد (5D)، وأنظمة ضمان الجودة، بما يسهم في تحسين أداء المشاريع الهندسية في المملكة العربية السعودية.

الكلمات المفتاحية: نمذجة معلومات البناء (BIM)، تطبيق نمذجة معلومات البناء، كفاءة إدارة المشاريع الهندسية، أداء الوقت، أداء التكلفة، أداء الجودة، قطاع الإنشاءات السعودي.

عنوان البحث

تقييم أثر تطبيق نمذجة معلومات البناء (BIM) على كفاءة إدارة
المشاريع الهندسية في شركات المقاولات بالمملكة العربية السعودية:
(دراسة تحليلية لأداء الوقت والتكلفة والجودة محاسبي)

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