

ADDIS ABABA UNIVERSITY

COLLEGE OF BUSINESS AND ECONOMICS

SCHOOL OF COMMERCE

A COMPARATIVE ANALYSIS OF A BUILDING INFORMATION MODELING AND TRADITIONAL COMPUTER -AIDED DESIGN AS PROJECT MANAGEMENT TOOLS: IMPACT ON DESIGN COORDINATION EFFICIENCY AND SCHEDULE PERFORMANCE. A CASE STUDY OF THE REPUBLICAN GUARD HEADQUARTERS PROJECT AT OVID KLING CONSULT

By: Liya Yared

Advisor: Dr. Zegeye M.

A project work submitted to Addis Ababa University, College of Business and Economics, School of Commerce, for the Partial Fulfillment of Master of Arts in Project Management

Addis Ababa, Ethiopia

May, 2026

A COMPARATIVE ANALYSIS OF A BUILDING INFORMATION MODELING AND TRADITIONAL COMPUTER -AIDED DESIGN AS PROJECT MANAGEMENT TOOLS: IMPACT ON DESIGN COORDINATION EFFICIENCY AND SCHEDULE PERFORMANCE. A CASE STUDY OF THE REPUBLICAN GUARD HEADQUARTERS PROJECT AT OVID KLING CONSULT

Liya Yared

A THESIS SUBMITTED TO

ADDIS ABABA UNIVERSITY, SCHOOL OF COMMERCE

PRESENTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF PROJECT MANAGEMENT

Addis Ababa, Ethiopia

May, 2026

Statement of Declaration

I declare that this research paper titled “A comparative analysis of building information modeling and traditional computer- Aided design as project management tools: Impact on Design Coordination Efficiency and Schedule Performance. A Case Study of the Republican Guard Headquarters Project at Ovid Kling Consult” this study is my original work and has not been submitted to any other institution for any academic purpose.

Name: Liya Yared

Signature: _____

Date: _____

ADDIS ABABA UNIVERSITY

SCHOOL OF GRADUATE STUDIES

DEPARTMNET OF PROECT MANAGEMENT

This is to certify that the research titled "A comparative analysis of building information modeling and traditional computer- Aided design as project management tools: Impact on Design Coordination Efficiency and Schedule Performance. A Case Study of the Republican Guard Headquarters Project at Ovid Kling Consult" has been prepared and submitted by Liya Yared in partial fulfillment of the requirement for the master degree of project management at Addis Ababa University.

Examiner: Dr. Hailemichael Signature:  Date: July 8, 2026

Examiner: Wasihun Mohammed (PhD) Signature: _____ Date: _____

Advisor: Dr. Zegeye Muluye Signature: _____ Date: _____

Acknowledgment

First and foremost, I would like to express my deepest gratitude to Almighty God for granting me the strength, patience, and determination to complete this research.

I would like to extend my sincere appreciation to my advisor, Dr. Zegeye M, for his patience, valuable guidance, constructive feedback, and continuous support through the development of this study.

I am also truly grateful to my family for their encouragement and support. In particular, I would like to thank my husband for his constant support, understanding, and for carrying the responsibilities of our home throughout this process. I would also like to express my sincere appreciation to my older brother, Mulugeta Seyoum, for his valuable guidance, encouragement, and continuous support during the course of this study.

Finally, I would like to express my appreciation to the staff of Ovid Kling Consult for their cooperation, for taking the time to respond to the questionnaires, and for allowing me to use data from the Republican Guard Headquarters Project for this study, despite it being a high-security project.

TABLE OF CONTENTS

LIST OF FIGURES ix
LIST OF TABLES ix
ACRONYMS AND ABBREVIATIONS xi
ABSTRACT xii
CHAPTER ONE: INTRODUCTION 1
1.1 Background of the Study 1
1.2 Problem Statement 3
1.3 Research Questions 4
1.4 Objective of the Study 5
1.4.1 General Objective 5
1.4.2 Specific Objectives 5
1.5 Significance of the Study 5
1.6 Scope of the Study 6
1.7 Limitations of the Study 6
1.8 Organization of the Thesis Project 6
1.9 Definition of Key Terms 7
CHAPTER TWO: LITERATURE REVIEW 9
2.1 Introduction 9
2.2 Theoretical Literature Review 9
2.2.1 Building Information Modeling (BIM) 9
2.2.2 Evolution of BIM 13
2.2.3 Traditional CAD-Based Design and Its Effect on Coordination Efficiency 14
2.2.4 Design Coordination and Its Effect on Project Management Performance 14
2.2.5 BIM's Effect on Design Coordination Efficiency and Project Performance 15
2.2.6 Comparative Effect of BIM and CAD on Coordination Efficiency and Project Management Performance 16
2.3 Empirical Literature Review 18
2.3.1 Effect on Design Coordination Efficiency 18
2.3.2 Effect on Schedule Performance 19

2.3.3 Effect on Rework Reduction and Cost Performance 19
2.3.4 Effect on Communication and Stakeholder Collaboration 20
2.3.5 BIM Adoption in Developing Countries and Ethiopia 20
2.4 Conceptual Framework 21
CHAPTER THREE: RESEARCH METHODOLOGY 23
3.1 Description of the Study Area 23
3.2 Research Paradigm, Design and Approach 25
3.2.1 Research Paradigm 25
3.2.2 Research Design 25
3.2.3 Research Approach 26
3.3 Types and Sources of Data 27
3.3.1 Types of Data 27
3.3.2 Sources of Data 27
3.4 Target Population and Sampling Design 28
3.5 Data Collection Methods 29
3.6 Data Validity and Reliability 29
3.6.1 Validity 29
3.6.2 Reliability 30
3.7 Methods of Data Analysis 30
3.7.1 Quantitative Data Analysis 30
3.7.2 Qualitative Data Analysis 30
3.8 Ethical Consideration 31
3.8.1 Informed Consent 31
3.8.2 Confidentiality and Anonymity 31
3.8.3 Compliance with Ethical Guidelines 32
CHAPTER FOUR: RESULT AND INTERPRETATION 32
4.1 INTRODUCTION 32
4.2 Respondents General Information 32
4.3 CAD-Based Design Coordination and Project Management Performance 34
4.3.1 Coordination Method used 34
4.3.2 Frequency of Coordination Meetings 35
4.3.3 Stage at Which Conflicts Were Identified 35

4.3.4 Most Common Types of Coordination Failures 36
4.3.5 Schedule Impact of Late Conflict Detection 36
4.4 BIM-Based Coordination: Comparative Performance Findings 37
4.4.1 Effectiveness of BIM in Clash Detection 37
4.4.2 Stage of Clash Identification 37
4.5 Likert Scale Analysis: Impact of BIM on Project Management Performance 39
4.5.1 Schedule and Time Management 40
4.5.2 Rework Reduction and Cost Performance 40
4.5.3 Coordination Efficiency and Quality 41
4.5.4 Communication: Collaboration and Stakeholder Management 42
4.5.5 Risk Management 43
4.6 Challenges of BIM Implementation 44
4.7 Final Opinions and Professional Recommendations 44
4.8 Qualitative Data Analysis: Thematic Findings from Open-Ended Responses 45
4.9 Qualitative Data Analysis: Case Study of the Republican Guard Headquarters Project 47
4.9.1 CAD-Based Coordination Analysis 47
4.9.2 BIM-Based Coordination Analysis 50
4.9.3 Comparative Analysis: CAD vs BIM Project Management Performance 51
4.10 Discussion of Findings 52
CHAPTER FIVE: SUMMARY, CONCLUSIONS AND RECOMMENDATIONS 55
5.1 Summary of the main findings 55
5.2 Conclusions 57
5.3 Recommendations 57
REFERENCES 59
APPENDIX: 63
Annex A: Questionnaire 63
Annex B: CAD Overlay Drawings 72
Annex C: BIM Models 74
Annex D: Clash Detection Results 76

LIST OF FIGURES

Figure 2.1 BIM maturity level 11
Figure 2.2 BIM dimensions 12
Figure 2.3 Evolution of BIM from the 1970s to the present day 13
Figure 2.4 Conceptual Framework, BIM Implementation and Project Management Performance 23
Figure 3.1 RGHQ Site 24
Figure 4.1: Respondent's positions 33
Figure 4.2: Respondents educational level 34
Table 4.3: BIM Clash Detection Results 50
Figure B.1: Overlay of basement floor architectural and structural drawings used for manual coordination 72
Figure B.2: Overlay of ground floor architectural and structural drawings 72
Figure B.3: Overlay of first floor architectural and structural drawings 73
Figure B.4: Overlay of seventh floor architectural and structural drawings 73
Figure C.1: Integrated BIM model of the Republican Guard Headquarters in Navisworks environment 74
Figure C.2: Architectural BIM model of the multipurpose hall 74
Figure C.3: Structural BIM model of the Republican Guard Headquarters 75
Figure C.4: Structural BIM model showing framing elements 75
Figure D.1: Structural beam intersecting window opening 76
Figure D.2: Door opening intersecting structural column 76
Figure D.3: Curtain wall overlapping with structural column 77
Figure D.4: Door placement conflicting with structural column 77

LIST OF TABLES

Table 2.1: Comparative Characteristics of BIM and CAD as Design Coordination Tools 18
Table 4.1: Questionnaire Response Rate 33
Table 4.2: Coordination Methods Used During CAD-Based Phases (Multiple Responses Permitted, n=53) 35
Table 4.3: Stage of Design Conflict Detection: CAD Phase (Multiple Responses Permitted, n=53) 35
Table 4.4: Types of Coordination Failures in CAD Phase (Multiple Responses Permitted, n=53) 36
Table 4.5: Schedule Impact of Late Conflict Detection — CAD Phase (n=53) 36
Table 4.6: Design Revision Cycles Due to Coordination Errors — CAD Phase (n=53) 37
Table 4.7: Stage of Clash Detection: BIM Phase (n=53) 38
Table 4.8: Summary Comparison: CAD vs BIM Coordination Performance 39
Table 4.9: Likert Scale Mean Score Interpretation Benchmark 40

Table 4.10: Likert Scale Results: Schedule and Time Management(n=53) 40
Table 4.11: Likert Results: Rework Reduction and Cost Performance(n=53) 41
Table 4.12: Likert Results: Coordination Efficiency and Quality(n=53) 41
Table 4.13: Likert Scale Results: Communication, Collaboration and Stakeholder Management (n=53) 42
Table 4.14: Likert Scale Results: Risk Management 43
Table 4.15: Overall Likert Scale Summary by Sub-Theme 43
Table 4.16: BIM Implementation Challenges (Multiple Selections Permitted, n=53) 44
Table 4.17: Overall BIM Recommendation 45
Table 4.18: Project Information 47
Table 4.19: Design Clashes Identified Through CAD-Based Coordination 48
Table 4.20: Planned vs. Actual Schedule: CAD Coordination Phase 49
Table 4.21: Design Revision Cycles: CAD Phase 49
Table 4.23: Revision Cycle Comparison: CAD vs BIM 51
Table 4.24: Comparative Analysis: CAD vs BIM Project Management Performance 52

ACRONYMS AND ABBREVIATIONS

AEC	Architectural Engineering Industry
BIM	Building Information Modeling
RGHQ	Republican Guard Head quarter
OKC	OVID KLING Consult
CAD	Computer-Aided Design
MEP	Mechanical, Electrical and Plumping Design

ABSTRACT

Construction projects in Ethiopia's building industry frequently suffer from schedule delays, cost overruns, and rework resulting from poor interdisciplinary design coordination. This study comparatively analyzes Building Information Modeling (BIM) and traditional Computer-Aided Design (CAD) as project management tools, with particular focus on their effects on design coordination efficiency and schedule performance., using the Republican Guard Headquarters Project at Ovid Kling Consult as a case study. A mixed-methods approach was adopted, combining a semi-structured questionnaire distributed to 58 project professionals, of which 53 valid responses were returned through purposive sampling, with case study analysis of project schedule records and clash detection data. Descriptive statistics and thematic analysis were used to analyze the collected data. The findings reveal that Design coordination using traditional Computer-Aided Design (CAD)-based approach was found to be manual and mostly reactive. Conflicts were detected at late stages of the project and this required multiple design revision cycles with rework and cascading schedule delays across multiple work packages. In contrast, BIM-based design coordination detected and resolved design conflicts at the conceptual design stage with a reduction of 66.7% of design revision cycles. The tool also contributed to improved schedule adherence, reduced rework and enhanced communication between disciplines. Likert scale results confirmed strong professional consensus on Building Information Modeling's superiority across all five project management performance dimensions assessed. The case study further validated that digital modeling improved the accuracy and efficiency of design coordination. In addition, this study identified a number of barriers that exist for the adoption of BIM, including the skills gap, high cost of BIM implementation and resistance to change. Training and investment in BIM software and processes are recommended in order to improve the performance of design coordination in the AEC sector.

Keywords: *Building Information Modeling (BIM), Computer –aided design (CAD), AEC, digital modeling, case study, Ovid kling consult.*

CHAPTER ONE: INTRODUCTION

1.1 Background of the Study

In the past decade, digital transformation has significantly influenced various industrial sectors, leading to improvements in productivity, product quality, and efficiency. Digital technologies have found applications across the Architecture, Engineering, and Construction (AEC) industry, supporting the design, construction, and operation of buildings and infrastructure. Effective design coordination between different disciplines within the broader context of project management has become a critical determinant of project success which in return influence schedule performance, cost efficiency, and overall project quality

The transition from CAD to BIM had one of the most significant effects of all the breakthroughs that have shaped the modern AEC sector. The first automation of the design process using 2D Computer-Aided Design (CAD) drawings improved the accuracy and productivity of individual drafters. However, since CAD files are discrete, independent objects, there are still no automatic links between each file. Therefore, design coordination is done through manual method by overlaying CAD design files which is provided by separate discipline design teams (Eastman et al., 2011).

Building Information Modeling (BIM) is a technology that has been gradually developed on the basis of traditional CAD (Computer Aided Design), and it provides an innovative approach for design integration and collaboration. BIM is an intelligent model-based construction information management method that organizes and manages a wide range of digital building information, from the construction planning and design stage to the construction, operation, and maintenance stage, and finally to the demolition stage. BIM is not simply a three-dimensional digital geometric model containing a large number of data, but it also includes various related non-geometric information of the building. Unlike CAD, BIM allows multiple disciplines to work simultaneously within a shared digital environment, enabling automated clash detection, real-time collaboration, and improved decision-making (Eastman et al., 2011). The clash detection function in the BIM model can pre-identify conflicts during the design before construction stage, which is much easier to resolve than conflicts that occur during actual construction. By reducing rework cycle, improving schedule performance and improving communication among project stakeholders, BIM address project management issues caused by poor design coordination.

Construction industry in developing countries and indeed Ethiopia faces many problems with low productivity, poor handling of information, design errors, design rework and similar other problems (Radosavljevic & Bennett, 2012). Built environment professionals in developing countries like Ethiopia face skill deficiency, poor collaboration, slow technological advancement and other problems. These challenges affect project outcomes across AEC sector, causing schedule overruns, cost escalations, and quality deficiencies that affect project outcomes across the sector

Ovid Kling Consult has started to adopt BIM into design workflow. The Republican Guard Headquarters Project was initially developed in CAD format before moving to BIM format. The models provide a good platform for evaluating design coordination between CAD workflow and BIM workflow.

This study addresses that gap through a comparative analysis of BIM and CAD as project management coordination tools, using the Republican Guard Headquarters Project at Ovid Kling Consult as a case study. A case study method is employed to analyze CAD to BIM modeling processes for Republican Guard Headquarters Project. The results of the study will provide practitioners and industry professional's greater understanding of the potential of BIM to improve design coordination within design practices.

Study Site Overview

This study is conducted at Ovid Kling Consult (OKC), a multidisciplinary architectural and engineering consultancy based in Addis Ababa, Ethiopia. OKC has begun integrating BIM into its design workflow as part of a broader effort to improve project management practices. The case study is based on Republican Guard Headquarters (RGHQ) Project currently under construction at Arat Kilo Area in Addis Ababa. The project is a complex office building (B+G+7 No. floors) with total site area of about 1670 square meters. The Client for this project is Ethiopian Defense Force. In the design of Republican Guard Headquarters Project, the drawings were developed using CAD for coordination that were later transformed into BIM for coordination when it was about the middle of the project. Thus, it is an appropriate case for analyzing BIM induced changes in project management in general and in coordination and schedule management in particular. Furthermore, the CAD developed drawings and the

corresponding BIM models of the same project are available for making a before and after analysis of coordination efficiency and schedule performance.

1.2 Problem Statement

Effective project management is a critical factor in granting the quality, functionality, and constructability of building projects in the Architecture, Engineering, and Construction (AEC) industry. Traditionally, this coordination has been done in a method which relies on separate two-dimensional drawings for each disciplines using Computer-Aided Design (CAD). Although CAD has significantly improved drafting efficiency, it presents limitations in interdisciplinary coordination due to the fragmented nature of design information (Eastman et al., 2011). Ineffective coordination cause schedule delay, excessive costs due to rework & frequent design revisions which are basically project management issues.

In the current CAD-based workflow, design details are initially developed independently by each discipline before being collated and inspected through manual processes in coordination meetings. This manual and time-consuming approach, heavily reliant on individual experience and attention to detail, contains significant room for error and is structurally prone to late detection of conflicts (Eastman et al., 2011). As a result, coordination problems such as misaligned structural elements, spatial conflicts, and discrepancies in levels and dimensions are often identified at later stages of the design process, leading to increased design revisions and inefficiencies resulting costly rework, cascading schedule delays, and significant resource waste (Eastman et al., 2011; Azhar, 2011).

The emergence of Building Information Modeling (BIM) has introduced a more integrated and proactive approach to design coordination. By enabling multiple disciplines are incorporated within a single digital environment within a shared 3D digital environment. BIM environment supports real time collaboration between the various parties and automatically detects errors and manages the information. BIM therefore has a positive effect on the performance of schedule control and the amount of rework resulting in successful projects outcome (Succar, 2009; Eastman et al., 2011).

Although Building Information Modeling (BIM) has been recognized as one of the project management tools used worldwide, its acceptance rate is less than expected. In many countries

and in Ethiopia in particular, numerous studies have identified and laid the causes of inefficiency in the construction industry as well as the management inadequacies. Most notably, Gebrehiwot, (2020) identified the causes of unsuccessful construction project and related them to ineffective coordination and management practices. There are very few empirical studies that describe project management problems that design failures cause and also how BIM can affect the performance of a project.

The Republican Guard Headquarters Project at Ovid Kling Consult presents a uniquely valuable case for investigating this gap. The project was initially designed using CAD-based coordination workflows and significant project management problems were experienced by the design team during the design development and co-ordination phases of the project. The design conflicts that were detected late in the design development process, the need for multiple revision cycles and the subsequent impact on the overall project schedule and the other work packages waiting for completion of the design development work are outlined. Mid-project the design team transitioned to BIM-based co-ordination using Autodesk Revit and Navisworks and the CAD drawings and BIM models from the same project, with the same team working on the same scope are available for this research to conduct a direct comparison.

The shift from traditional CAD-based design to BIM-based design is bringing with it a lot of challenges to project management. However, there is a lack of research to identify and measure the impacts of design changes on coordination efficiency, project schedule, rework and communication between disciplines. This study evaluates the effects of design changes in CAD and BIM-based design coordination before and after design stage in Republican Guard Headquarters Project in Ethiopia. The findings of this study will provide much needed empirical evidence to designers, design managers, construction companies and policy makers in the Ethiopian construction industry whether to adopt BIM or not.

1.3 Research Questions

- What are the design coordination problems encountered in the CAD-based phase of the Republican Guard Headquarters Project compared to the BIM-based phase?
- How did BIM implementation affect design coordination efficiency and schedule performance relative to the CAD-based approach in the same project?

- To what extent did BIM reduce rework frequency and design revision cycles compared to CAD-based coordination?
- How does BIM-based coordination compare to CAD-based coordination in terms of interdisciplinary communication and collaboration among project team members?

1.4 Objective of the Study

1.4.1 General Objective

The general objective of this study is to comparatively analyze the effect of Building Information Modeling (BIM) and traditional Computer-Aided Design (CAD) as project management tools on design coordination efficiency and schedule performance, using the Republican Guard Headquarters Project at Ovid Kling Consult as a case study.

1.4.2 Specific Objectives

- To compare the nature, frequency, and detection stage of design coordination failures between CAD-based and BIM-based coordination phases of the Republican Guard Headquarters Project.
- To evaluate the comparative effect of BIM implementation on design coordination efficiency and schedule performance relative to the CAD-based approach.
- To compare rework frequency and design revision cycles between the CAD and BIM coordination phases.
- To assess the comparative effect of BIM versus CAD on interdisciplinary communication and collaboration among project team members.

1.5 Significance of the Study

This paper aims to provide practice-based evidence for architects, structural engineers and other construction professionals on the BIM implementation's effect on coordination efficiency, project schedule performance and rework reduction. This paper will also contribute to current practice and to academic research in this field by providing empirically derived data.

The study's findings have the potential to benefit the Addis Ababa and the rest of the Ethiopian AEC industry. The research outcome can be utilized for promoting BIM adaptation and advising decision makers and policy makers with evidence-based knowledge that can help the

advancement of BIM execution by demonstrating its measurable project management benefits through a real project case study.

1.6 Scope of the Study

This study examines the design phase of the Republican Guard Headquarters Project at Ovid Kling Consult, focusing specifically on the transition from CAD-based to BIM-based design coordination. As such, the key BIM dimensions analyzed are 3D model integration, and in particular, automated clash detection, whereas 4D BIM, schedule linkage, is analyzed solely in relation to the design submission milestones rather than a full construction simulation. Project management outcomes examined include coordination efficiency, schedule performance, rework frequency, and interdisciplinary collaboration. Other engineering disciplines (MEP services, etc.) and post-design phases including construction and operation, are excluded from the scope of this study.

1.7 Limitations of the Study

The study has some limitations. The study is based on a single project case study at Ovid Kling Consult. Purposive sampling was employed due to the high-security nature of the project and institutional access constraints, meaning findings reflect the perspectives of professionals directly involved in the Republican Guard Headquarters Project rather than a broader population of AEC practitioners. The scope covers the design phase only, excluding construction and post-construction outcomes and MEP disciplines.

1.8 Organization of the Thesis Project

This research work is divided into five chapters. Chapter one of this study introduced the study. In this chapter the background to the study, problems that the study wanted to investigate, research questions, objectives of the study, significance of the study, scope of the study and limitations of the study were discussed. Chapter Two of this research study reviews of literature on BIM, design coordination and performance of projects managed with the aid of design coordination using BIM were discussed. Chapter Three of this study explained how the

researcher carried out the research study. Chapter Four of this research study presented the findings from the analyzed data of the questionnaire and the case study. Chapter Five of this study summarized the findings of the study, drew conclusion from the findings of the study and made recommendations for future research on the topics investigated in the study.

1.9 Definition of Key Terms

1. **Building Information Modeling (BIM):** A digital representation of physical and functional characteristics of a facility, which serves as a shared knowledge resource for information about a facility (Eastman et al., 2011).
2. **Design Coordination:** The process of integrating and harmonizing design information from multiple disciplines to ensure consistency, reduce conflicts, and improve overall project efficiency and constructability (Succar, 2009).
3. **Coordination Efficiency:** The degree to which design conflicts are identified and resolved early in the project lifecycle with minimal resource expenditure, time loss, or rework (Azhar, 2011).
4. **Schedule Performance:** A measure of how well a project adheres to its planned timeline, typically assessed by comparing planned versus actual completion dates of key project activities (PMI, 2017).
5. **Project Performance:** The overall assessment of a project's success in meeting its objectives in terms of time, cost, and quality (PMI, 2017).
6. **Rework:** The repetition or correction of previously completed design work due to errors, conflicts, or changes identified after the initial submission, resulting in additional time and cost expenditure (Eastman et al., 2011).
7. **Project Management:** The process of planning, executing, and overseeing a construction project to meet its objectives in terms of cost, time, and quality (PMI, 2017).
8. **Computer-Aided Design (CAD):** A software-based system used to create two-dimensional design drawings for building construction, widely used in the AEC industry prior to the adoption of BIM (Eastman et al., 2011).

9. **Construction Delays:** The time overrun beyond the completion date agreed upon in a contract due to various factors such as poor planning, resource shortages, and design modifications (Odeh & Battaineh, 2002).
10. **Stakeholders:** Individuals or groups with an interest in a construction project, including contractors, engineers, project managers, and government authorities (Freeman, 1984).
11. **Clash Detection:** A feature in BIM that identifies conflicts between different building elements (e.g., structural, mechanical, and electrical systems) before construction begins (Azhar, 2011).
12. **Mixed-Methods Research:** A research approach that combines qualitative and quantitative methods to provide a comprehensive analysis of a research problem (Creswell, 2014).

CHAPTER TWO: LITERATURE REVIEW

2.1 Introduction

This chapter reviews theoretical and empirical literature relevant to the comparative analysis of Building Information Modeling (BIM) and traditional Computer-Aided Design (CAD) as project management tools, with particular focus on design coordination efficiency and schedule performance in the AEC industry. The chapter initially outlines several key aspects of BIM including its definition, BIM maturity, the dimensions of BIM and a historical overview of BIM's development. The chapter then proceeds to deliver a critical review of the traditional design management using CAD for design coordination between different disciplines and highlights the limitations of such approaches from a project management perspective. The chapter then presents how BIM integrates and coordinates design activities, detects automatically design clashes and enhances collaboration between designers and other project participants. BIM from a project management performance perspective is also reviewed covering its impact on communication, schedule, rework and project outcome. Finally, the chapter outlines a conceptual framework in which to compare BIM with traditional CAD-based design using design coordination efficiency as the mediator and resultant improvements in project management performance as the outcome.

2.2 Theoretical Literature Review

2.2.1 Building Information Modeling (BIM)

The Architecture, Engineering, and construction (AEC) industry is witnessing innovative change and brining about a revolution in BIM. Azhar (2011) defined BIM as a virtual process that involves all aspects, disciplines, and systems of a facility within a single model that is shared with all stakeholders across the project lifecycle. BIM enables various design disciplines to collaborate more effectively during the design process by integrating various types of project information into a single model

Compared to traditional design methods, BIM provides extensive understanding of built environment and components within the project through manipulation of not only geometric but also non-geometric data. According to Succar (2009), BIM is not only a technological tool but also a process that enhances collaboration, communication, and information management among

project participants. Enhanced visualization, better decision-making, and increased design accuracy are some of the unified approaches allowed in BIM system.

One of the key advantages of BIM is the ability to facilitate early detection of design conflicts through automated clash detection. This feature enables designers to identify and resolve issues between different disciplines, such as architectural and structural elements, before construction begins (Azhar, 2011). As a result, BIM advance overall project efficiency since it reduce errors and eliminate rework.

2.2.1.1 BIM Maturity Levels

BIM maturity level used to describe the maturity a BIM project. They are useful in that they identify what the supply chain is expected to deliver, while the client can clearly understand what the supply chain is offering. There is some debate within the industry about the exact meaning of each BIM level (erasmus, 2015). BIM maturity levels provide a framework for organizations to assess their BIM capabilities and identify areas for improvement. By implementing BIM at higher maturity levels, organizations can improve collaboration, reduce errors, and save time and cost. There are some BIM maturity levels listed below: (Butkovic, B 2019).

- Level 0: PRE BIM-This stage is the starting point, the status before the implementation of BIM, and means no collaboration between project team and is defined as unmanaged CAD. 2D documentation is most likely used to share information.
- Level 1: Object based modelling Object-based 3D parametric software tool is used to produce models. Users produce models within all stages of a construction, and the model is the basis for 2D documentation and 3D visualization.
- Level 2: Collaborative BIM: different disciplines are actively cooperating with others through a model-based collaboration process. The collaboration often occurs through a cloud-based application. Contractual amendments become necessary and models can be linked to various analysis tools. Processes are assessed through the models.
- Level 3: Integrated BIM (iBIM): In this level, semantically-rich network based integrated models are created, shared and maintained collaboratively through the project life-cycle phases. Models in this stage become interdisciplinary models, where complex analyses at

early stages of design and construction are allowed. Model deliverables include business intelligence, lean construction principles, green policies and whole life-cycle costing.

.

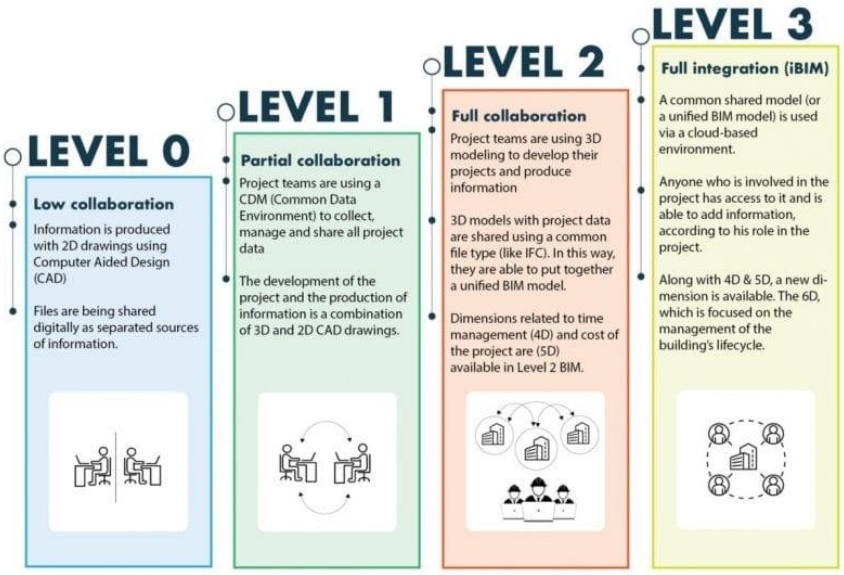


Figure 2.1 BIM maturity level

2.2.1.2 BIM Dimension

It should be noted that BIM Dim-ensions are different from the BIM Level of Development. The level of development standards shows the extent to which a 3D model's geometry, specs, and associated information can be relied on by the team members. On the other hand, BIM Dimensions are details or further information stored within a model, like 3D, 4D, 5D, 6D, 7D, 8D…. (Structures insider, 2015)

- **3 Dimension:** A 3D BIM model contains 3D objects that builds up the information model. These objects represent the building or building spaces, in a virtual reality. These 3D objects contain information, as a minimum, on length, width, and height. Other information can be applied, such as material and finish. Key benefits of a 3D information model are improved coordination, enabled visualization, and general information gathering. 3D modeling requires 3D modeling software and LOD definition.

- **4 Dimension**: time the 4th dimension refers to adding time to the 3D, often called 4D modelling or model-based scheduling. This is done by linking objects from the 3D model, to a task in the construction schedule, using a 4D scheduling tool like Vico Office, Synchro, or Navisworks (archvirtual.com/2013). The 4D simulation consists in linking construction activities in planning to 3D objects in a building model in order to simulate the construction process over time. 4D simulations can be used at different stages of a construction project to analyze the design and its constructability, as well as for construction planning and monitoring using various software authors show that construction projects underwent slippage up to 80 % and cost increased by 40 % from predetermined values.
- **5 Dimension**: Cost 5D modeling or model-based estimating is the 4D model in addition to cost information. A model-based schedule or 4D schedule is associated with information on cost, which allows the owner to know the exact amount the contractor should be billed at a given time.
- **6 Dimension**: Facilities Management The 6th dimension is devoted to Facilities Management and focuses on leveraging the model information to reduce owners' cost over the life cycle of the building or structure.



Figure 2.2 BIM dimensions

2.2.2 Evolution of BIM

The concept of BIM dates back to 1975(Sacks et.al, 2011). The install system that closely resembled modern BIM was the Building Description System (BDS), which was begun by architectural professional Charles Eastman. BDS designed to create a paperless design documentation process that delivered several benefit, including simplified design input for complex building components, reuse of existing elements, and automated generation of building views, renders, schedules, and surveys (Sacks et.al, 2011)

A significant milestone in the examiner of BIM was the identified Building of Virtual by Graphisoft Archicad concept in 1987 (Sacks et.al, 2011). To generate models of 3D building with immediately emanated views and support advanced parametric 3D shapes (Sacks et.al, 2011). The paper emphasized the importance of workflow on a reference model based and the benefit for a well-organized relation between engineering and architectural information systems. (Sacks et.al, 2011)

But it wasn't until 2002—when Autodesk noticed the company behind Revit BIM software and released a white paper on the subject—that the word BIM became well-known (Sacks et al., 2011). The BIM software firms Graphisoft and Bentley Systems, in conjunction with industry experts such as Jerry Laiserin, contributed to the popularization of the word BIM by standardizing its usage for digital representation of the building process. (Sacks and others, 2011)

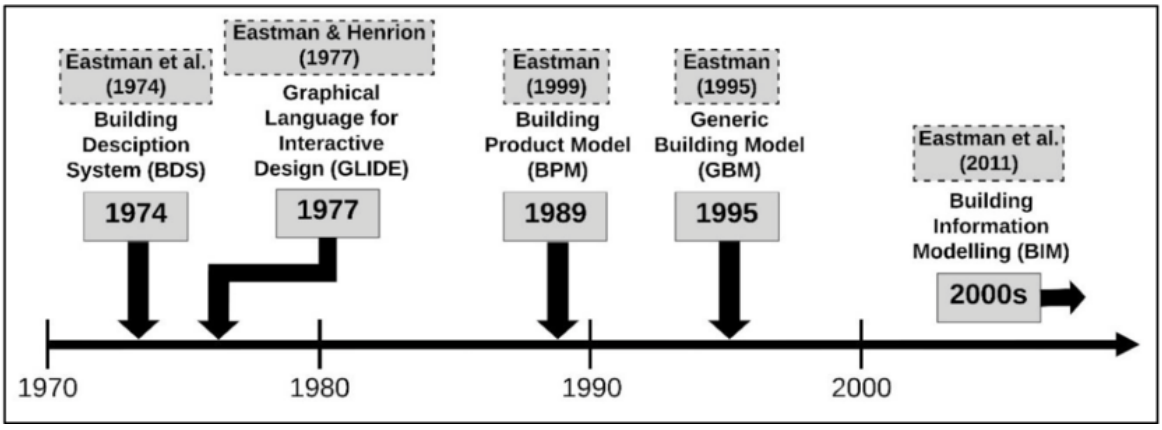


Figure 2.3 Evolution of BIM from the 1970s to the present day

2.2.3 Traditional CAD-Based Design and Its Effect on Coordination Efficiency

In the Architecture, Engineering and Construction (AEC) industry, Computer-Aided Design (CAD) is a commonly accepted practice as a software system which is used as the primary CAD tool to generate two-dimensional (2D) detail design drawings for building construction. This has improved efficiency in drafting workflows, where manual practices were prior methods of production. However, such a CAD-based design approach have some limitations, especially in coordination tasks with other disciplines.

In traditional CAD workflow often result fragmented information since architecture and structural drawings are developed separately. Coordination between disciplines is typically achieved through manual processes, such as overlaying drawings and conducting design reviews. These methods are time-consuming and highly dependent on the experience of designers, increasing the likelihood of errors and inconsistencies (Eastman et al., 2011).

(Almutiri, 2016) claimed that the traditional methods suffer from many issues such as lack of project understanding, poor communication and data loss, problems in sharing information and poor collaboration between team members. (Duell, et al., 2013) illustrated the difference between the BIM and traditional methods in sharing data in which in case of traditional method data is transferred in a fragmented way that the stakeholders in a project obtain data from other stakeholder through different modes of communication and the data is mostly paper based data whereas in BIM concept information is obtained from a central database.

The other comparison is based on clash detection in which in case of traditional method clash is identified at late design and construction stage However, BIM identifies clashes among various designs, early in the conceptual design phase, and before construction gets started that save time and money besides promoting money value and efficiency (Abbasnejad & Moud, 2013).

2.2.4 Design Coordination and Its Effect on Project Management Performance

According to Melhado (2005), design coordination is the activity that integrates designs from all disciplines in order to achieve standards of total quality control of the work. Effective

coordination in Architecture, Engineering and construction (AEC) industry is required for achieving both functional and structural integrity, particularly between designs disciplines (Eastman et al., 2011).

In building projects, continuous information exchange and alignment throughout the design process is critical since all design disciplines work independently on different platform. If this is not achieved early on, unexpected conflicts can occur late in design with adverse effects on the building. For example structural elements may not be aligned with the architecture, structural elements may not be dimensioned to fit between architectural beams, and dimensions may not be consistent throughout the design, and so on. These problems discovered after design can require further design modifications, delays, and costs (Kymmell, 2008).

Traditionally, design coordination is carried out by manually overlaying separated drawing sheets, exchanging hard copy or electronic documents, and conducting coordination meetings and discussions within design teams. Such traditional practices are often time-consuming, error-prone, and open to misinterpretation, mainly because of the disjointed nature of separated data collected from different sources and various disciplines in non-integrated workflow environments (Eastman et al., 2011). Design problems are frequently discovered late in the design process and require considerable time and resources to resolve the resultant design errors.

Design coordination, as a discipline, encounters many problems which have yet to be addressed, especially those that require an integrated and collaborative design approach. The advent of new and advanced digital design tools such as Building Information Modeling (BIM) have allowed for the successful distribution and coordination of design information amongst stakeholders in a variety of formats at multiple levels of complexity (Hardin & McCool, 2015)

2.2.5 BIM's Effect on Design Coordination Efficiency and Project Performance

The use of BIM for design coordination has increased dramatically. Eastman et al. (2011) concluded that in BIM, architectural and structural models are integrated into a coordinated three-dimensional (3D) model for design coordination and, most importantly, all disciplines are able to interact in real time using consistent data.

BIM for coordination provides several features and tools that make design and construction processes easier. One of those tools is called automated clash detection. This feature can detect conflicts between design components created by different discipline such as clash between structural member and architectural feature. Using clash detection allows designers to handle and solve many of the coordination problems early in the design stages of project, thus preventing errors in construction stages. (Eastman et al., 2011; Hardin & McCool, 2015).

In addition to clash detection, BIM provides accurate and visually abundant representations of the design which advance communication among stakeholders. The use of coordinated 3D models improves stakeholders' understanding of spatial relationships and design intent, which facilitates better decision-making and reduces miscommunication of design information (Kymmell, 2008).

Moreover, by enabling multiple disciplines to work simultaneously on a shared model BIM supports a collaborative workflow. Compared to traditional CAD-based system, this integrated approach reduces the need for repetitive revisions and manual coordination processes. Greater efficiency in coordination, better design quality and project outcomes are also achieved (Succar, 2009; Azhar, 2011).

2.2.6 Comparative Effect of BIM and CAD on Coordination Efficiency and Project Management Performance

The industry is going through a significant paradigm shift from being a primarily Computer-Aided Design (CAD) based industry to a Building Information Modeling (BIM) based industry. As the AEC industry transitions from CAD to BIM, the way in which design coordination is managed will also undergo significant changes. While CAD use 2D dimensions representation, whereas BIM models uses 3D virtual a model-based approach that integrates geometric and non-geometric information within a coordinated digital environment (Eastman et al., 2011).

Currently design coordination is performed manually in CAD-based systems by overlaying individual design plans created by different disciplines of expertise such as architectural, structural, mechanical and electrical designers. This process of plan comparison is time-

consuming, and prone to producing inconsistencies and errors, as conflicts between different design disciplines may not be detected until later stages of the design process (Kymmell, 2008). As a result, Traditional CAD system is time consuming and highly dependent on designers' skill and attention to detail.

Unlike CAD, BIM allows for an integrated approach where different design disciplines are developed at the same time within the shared BIM platform. This approach offers the advantage of on-going instant collaboration among architects, engineers, contractors and other project stakeholders. Moreover, as models are developed, conflicts or "clashes" are identified and design problems can be resolved at early design stage before major issues occur on site (Eastman et al., 2011; Hardin & McCool, 2015).

BIM also enhances preconstruction visualization by three-dimensional (3D) model. By doing so, it enables stakeholders to have a better understanding of the design and improve the accuracy of their decisions by reducing errors. Furthermore, BIM improves collaboration by allowing team members to work off the same coordinated digital model at the same time, while increasing productivity of coordination and reducing revisions to incorrect drawings (Succar, 2009).

Even if CAD remains useful for drafting purpose, it is less suitable for handling more complex projects of a multidisciplinary nature due to the lack of tools for integration and cooperation. However, BIM allows early clash detection which improved collaboration and enhanced information management, making it more efficient and reliable approach. It is now therefore the preferred method for design coordination.

Dimension	CAD-Based Coordination	BIM-Based Coordination
Information Model	Fragmented 2D drawing files per discipline	Integrated 3D shared parametric model
Conflict Detection	Manual 2D overlay review, reactive	Automated clash detection, proactive
Detection Stage	Detailed design, documentation, or construction	Concept or schematic design stage
Collaboration Mode	Sequential, discipline-by-discipline	Simultaneous, shared model environment
Version Control	Manual file management, error-prone	Centralized model, consistent

Rework Risk	High, conflicts discovered late	Low, conflicts resolved at design stage
Schedule Impact	Cascading delays from late revisions	Schedule protected by early resolution
Visualization	2D plans and sections only	3D spatial model, stakeholder-accessible

Table 2.1: Comparative Characteristics of BIM and CAD as Design Coordination Tools

2.3 Empirical Literature Review

2.3.1 Effect on Design Coordination Efficiency

BIM increases design coordination efficiency when compared with CAD-based method. The paper by Eastman et al. (2011) provided a comprehensive review of implementation of BIM on various projects. The main findings of the study indicated that by incorporating the models of different disciplines into a shared digital work space as early as possible in the design stage, a large portion of design errors could be solved before they were transferred into the construction phase. BIM-based clash detection tools are able to identify a large number of clashes that would not be detected by a CAD-based clash detection approach. This is especially true for spatial clashes that are caused by the three-dimensional relationships between the various elements of different disciplines, such as structural and architectural. Many of these clashes can be detected by BIM-based approaches that would not be identified by conventional approaches.

Azhar (2011) states that BIM can reduce design errors by 40% by means of enhanced visualization and cross-disciplinary coordination. The biggest potential of BIM for planning coordination, however, is to introduce BIM as early as possible into the planning process. This study's results of detected conflicts in the different CAD phases and the BIM phases are compared with the findings of the above-mentioned study.

Farzaneh et al. (2019) studied BIM adoption in design phase. The study results indicated that model integration enabled by BIM improved accuracy and integrity of cross disciplinary information. The study results also showed positive relationship between BIM coordination

maturity and project management performance. The greatest benefits were achieved in projects when BIM is implemented as a coordination tool from concept design stage onwards.

2.3.2 Effect on Schedule Performance

The relationship between BIM-based construction coordination and schedule performance has substantial empirical support. BIM can cause design conflicts to be resolved earlier in the design process reducing the opportunity for construction related delays resulting from design changes. Hardin and McCool (2015) found in their study that projects using BIM for project development and coordination had lower change orders of a coordination nature and had a lower percentage of schedule delay attributed to design errors than projects using CAD-based methodology.

Succar (2009) described the benefits of BIM for schedule management were not automatic outcome but relied on the depth of integration into coordination workflows based on the positive relation between BIM adoption maturity and schedule performance outcomes. Hence, there is a positive relationship between level of adoption of BIM for design and corresponding schedule performance outcomes. To obtain more advanced schedule performance Bim shall be adopted as mandatory for the coordination from the concept design stage, not only for visualization or documentation with limited added value

2.3.3 Effect on Rework Reduction and Cost Performance

One of the major significant cost drivers in AEC project delivery are rework, repetition or correction of previously completed work due to design errors or conflicts. Research by Azhar (2011) established that improved coordination efficiency derived from BIM resulted in reduction of rework at the construction stage. This reduction in rework was greatest in cases of complex multi-disciplines and was a direct result of identifying conflicts at design stage. At design stage conflicts were solved by revising drawings as opposed to rework on site which results in waste, extended project duration, and on-site modifications and additional costs.

Eastman et al. (2011) noted that the cost-benefit case for BIM adoption is strongest precisely in this domain, the savings in rework and change order management typically exceed the implementation costs of BIM software, training, and process change within a single complex project.

2.3.4 Effect on Communication and Stakeholder Collaboration

One of the most significant identified BIM's benefits over project management is its effect on interdisciplinary communication and stakeholder collaboration. Hardin and McCool (2015) stated that BIM featured a shared 3D virtual environment that reduce errors which could occurred between design disciplines. A great benefit of BIM for non-technical stakeholders was that they could easily understand the design by viewing a 3D model. The use of BIM fostered a collaborative working environment rather than the sequential approach of CAD based methodology of creating and distributing plan documents.

Kymmell (2008) mentioned the 3D visualization capabilities of BIM which enabled the client and other stakeholders including non-design staff participating effectively in the design review processes. Improved stakeholder participation during decision making will result in better decisions at the right time and will prevent changes to design at late stages due to client's misunderstanding by referring to 2D drawings instead of 3D model.

2.3.5 BIM Adoption in Developing Countries and Ethiopia

The majority of empirical studies on BIM's project management benefits have been conducted in technologically advanced construction markets, including the United States, the United Kingdom, Australia, and Singapore. Evidence from Sub-Saharan Africa in general, and Ethiopia in particular, is substantially more limited.

Arayici et al. (2012) examined BIM adoption experiences in developing countries and concluded that fundamental advantages of BIM at project management stage such as coordination, minimizing rework and improved communication can be realized in developing countries even with limited resources and skills by providing adequate training and management commitment. In addition, there are set of barriers affecting BIM adoption in developing countries such as skills, cost of software, national BIM standard, change management and resistance to new technology from designers and draftsmen who work with CAD.

Gebrehiwot (2020) documented that the primary drivers of construction project and cost overrun in Ethiopian AEC sector are coordination failures and information management shortage. This finding establishes the relevance of BIM as a potential remedy for documented project

management failures in the Ethiopian context and creates the empirical foundation for the present study's comparative analysis.

The present study bridges the existing literature gap by providing within project context empirical evidence on BIM-related differences in coordination efficiency and schedule performance. Such evidence is generally lacking in the construction literature to date, particularly in the context of the Ethiopian AEC sector.

2.4 Conceptual Framework

The conceptual framework of this study considers the implementation of Building Information Modeling (BIM) as the independent variable, the project management performance as the dependent variable, and the design coordination efficiency as the mediating variable. The three-variable framework of variables for analysis was derived from the aforementioned empirical studies and was applied to the analysis of CAD and BIM coordination in the Republican Guard Headquarters Project.

The BIM implementation within the framework that is characterized in this framework by three core capabilities model integration, clash detection and collaboration. The paper tries to distinguish between the BIM implementation for project coordination and the conventional CAD implementation for project coordination. Model integration refers to the shared 3D model that is used to manage project information. Automated clash detection between different disciplines allows for the identification of problems at an early stage of the project. Collaboration refers to the implementation of BIM, which allows multiple parties to access and manage project information at the same time.

The degree to which the design conflicts are identified and resolved early in the project lifecycle with minimal resource expenditure, schedule overrun or rework is defined as design coordination efficiency which is also mentioned as mediating variable. While using BIM-based coordination, design errors are identified and resolved automatically at early stage of design before causing major schedule change and rework cost. However, conflicts are identified manually at late design stage which is detailed design stage or construction stage causing extensive rework revision cycle.

Project management performance, the dependent variable, is measured across four dimensions directly relevant to the Republican Guard Headquarters Project case study: schedule performance (adherence to planned design submission milestones), rework reduction (reduction in design revision cycles), cost efficiency (reduction in rework-related expenditure), and communication and collaboration quality (improvement in interdisciplinary information sharing and stakeholder engagement).

The framework of the study assumes that by utilizing BIM as a project management tool, the performance of the project management is improved in all the four performance criteria through the medium of enhanced design coordination efficiency. The relationship is put to test through a comparative analysis of CAD-based and BIM-based coordination data for the Republican Guard Headquarters Project at Ovid Kling Consult, using the same project, team and scope.

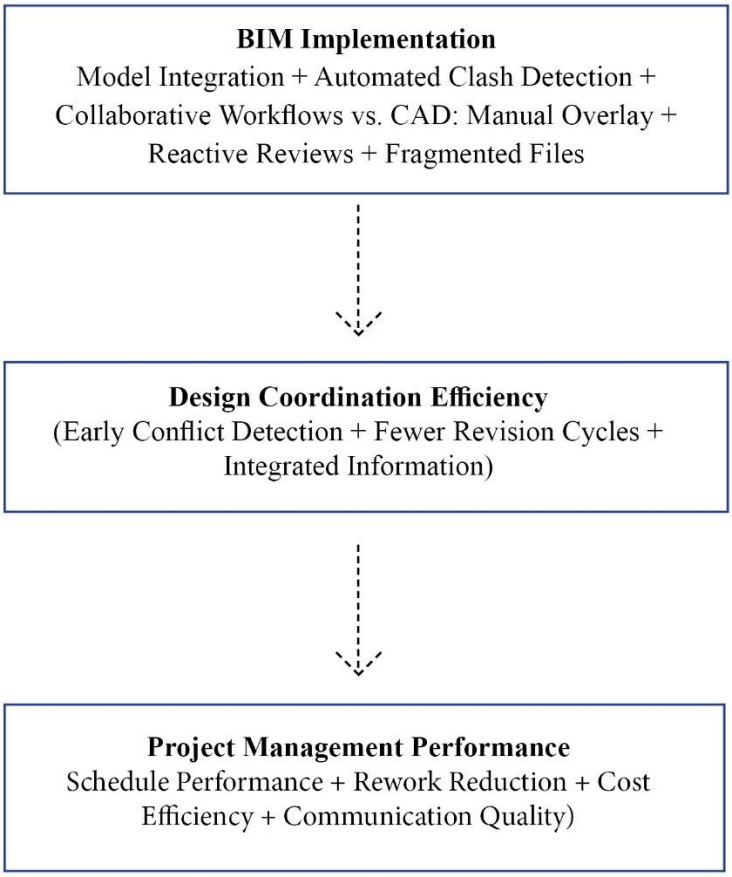


Figure 2.4 Conceptual Framework: Comparative Effect of BIM and CAD on Project Management Performance through Design Coordination Efficiency

CHAPTER THREE: RESEARCH METHODOLOGY

This chapter explains the methodology that has been used to achieve the research objectives of this study to analyze a comparative analysis of building information modeling and traditional computer- Aided design as project management tools: Impact on Design Coordination Efficiency and Schedule Performance. It sets out the study area, research paradigm, research design and approach, the types and sources of data and sampling design. It then describes the data collection methods and instruments, addresses the issue of data validity and reliability, outlines the methods used to analyse the data and finally considers the key ethical issues in the study. The justification for the chosen methodology is set out in the light of the research objectives and explains why the chosen methodology adheres to well established research principles and guidelines and is consistent with relevant research literature.

3.1 Description of the Study Area

The study focuses on the Republican Guard Headquarters Project located in the Arat Kilo area of Addis Ababa, Ethiopia. The site is situated in a strategic urban location surrounded by important landmarks, including the 4 Kilo Police Station and Ambassador Mall to the east, Abrrehot Library to the southeast, and the Basha Wolde Chilot Condominium and Ababa Bikila Youth Center to the north. The project site has approximate dimensions of 25 meters by 65 meters, covering a total area of about 1670 square meters.

The site is characterized by a longitudinal slope difference of approximately four meters, which provides favorable conditions for the integration of a basement level, primarily used for parking. The project itself is a complex development that includes office spaces, a meeting hall, and

supporting facilities such as a café. These diverse functional requirements demand a high level of coordination between architectural and structural design components.

The selection of this study area is justified by the availability of both CAD drawings and BIM models for the same project, which provides a unique opportunity to compare traditional and digital design coordination approaches within a real project context. Furthermore, the complexity of the project and its multidisciplinary nature make it suitable for evaluating coordination challenges and the effectiveness of BIM implementation.



Figure 3.1 RGHQ Site

3.2 Research Paradigm, Design and Approach

3.2.1 Research Paradigm

This study adopts a pragmatic research paradigm, which allows the integration of both qualitative and quantitative research methods. Pragmatism focuses on practical problem solving and enables researchers to select methods that best address the research problem rather than adhering to a single philosophical stance (Creswell & Plano Clark, 2011). In this study, numerical values were used to calculate the coordination efficiency and in-depth illustration of designers' experiences and perceptions related to design coordination process. Thus, pragmatic approach was the most appropriate paradigm to this study to employ mixed methods for an in-depth exploration of the research problem.

3.2.2 Research Design

This study employs an descriptive case study research design. The explanatory design was chosen because the study seeks to establish how and why BIM-based coordination produces different project management outcomes compared to CAD-based coordination, that is, to explain a causal mechanism rather than simply describe a state of affairs (Yin, 2018). The case study methodology is appropriate because the unit of analysis is a real-world project in its natural organizational context, and both CAD and BIM coordination data are available from the same project and team, enabling a rigorous before-and-after comparison (Yin, 2018).

The study is not a cross-sectional study. It is a one point in time data collection and the analysis is of a longitudinal nature. The study compares CAD-coordination projects with BIM-coordination projects within the same project. Hence, it is a before-and-after study of a project, within that specific project, before and after the CAD-coordination and BIM-coordination phase respectively. That is the research design of this study.

This research was carried out using a mixed-methods approach within a case study framework. Quantitative data were collected from project professionals through a questionnaire that comprised of Likert scales as well as a number of closed questions. The open questions from the questionnaire as well as a systematic analysis of the relevant project documents (i.e. CAD

drawings, BIM models, clash detection reports and the project schedule) provided the qualitative data. The use of both quantitative and qualitative data provided methodological triangulation, which enhanced the validity of the research findings (Creswell, 2014).

3.2.3 Research Approach

In order to evaluate BIM and CAD as a project management tools A mixed-methods approach was employed because it requires both measurable numerical evidence and rich contextual understanding of professional experience, neither of which alone would provide a complete comparative picture. Quantitative data has been collected to measure various project management aspects using a structured Likert scale and/or closed-ended questionnaires in order to assess coordination efficiency, the progress of the project on schedule, amount of rework and communication quality. The qualitative part of the study focused on the participants' professional experience and on project specific evidence. The open-ended questions of the questionnaire as well as the systematic analysis of CAD drawings, BIM models, clash detection reports and of the schedules were analyzed. The integration of both components enabled methodological triangulation, enhancing the credibility and completeness of the findings (Creswell, 2014).

The quantitative data collection was intended to measure the coordination efficiency, the schedule performance, the rework and the communication quality by means of a set of closed questions posed to the respondents by using a structured Likert scale. The qualitative data collection aimed at capturing the experience of the users as well as the project-specific data by means of the open questions and the systematic analysis of the project-related documents (e.g. CAD plans and drawings, BIM models and files, clash detection reports, etc. and the schedules). The combination of the quantitative and qualitative data therefore allowed the researcher to apply the methodological triangulation in order to increase the credibility of the research and to achieve a more complete picture (Creswell, 2014).

3.3 Types and Sources of Data

3.3.1 Types of Data

The data from this research study was collected as quantitative and qualitative data. The data was analyzed as per the mixed-methods research design that was chosen for this research study.

The quantitative data was collected through the semi-structured questionnaires containing closed questions. These were mainly presented as closed-ended questions with multiple response options and through the use of a Likert scale measuring the degree of agreement on a five-point scale. In addition to this data, numerical data of the completed projects was collected from a number of sources including the results of clash detection, the number of design revisions and the planned and actual project schedules.

For the qualitative data from two sources have been analyzed. The open-ended questions in Sections F and G of the questionnaire of the experiences of the respondents and their suggestions in words have been analyzed. Qualitative data were also collected through systematic document analysis of CAD drawings, BIM models, clash detection reports, and project schedule records from the Republican Guard Headquarters Project which is conducted as one of the data collection methods within the case study framework.

3.3.2 Sources of Data

This study depends on both primary and secondary sources. Primary sources for this study include semi structured questionnaires conducted with the architects, the structural engineers, and the BIM professionals involved in the Republican Guard Headquarters Project. These questionnaires provide firsthand information on coordination practices and the impact of BIM implementation.

The analysis of the case study is based on secondary data gathered from different sources associated with the Republican Guard Headquarters Project like project documents and CAD drawings, BIM models clash detection reports generated through Autodesk Navisworks, and project schedule records. The use of multiple sources of data within this research has enabled the

use of methodological triangulation. The use of multiple sources of data within this research has increased the credibility of the findings as they have been backed up by evidence from more than one source (Creswell, 2014).

3.4 Target Population and Sampling Design

This study employs purposive sampling as the primary sampling strategy for both the quantitative and qualitative components of the study. Purposive sampling, also known as judgmental or selective sampling, involves intentionally selecting individuals who have relevant knowledge or experience that aligns with the study's objectives (Creswell, J. W., 2014). A Purposive sampling approach is used in this study in order to collect data from the right participants due to four reasons. The first reason is that the research questions asked within this study need project-specific knowledge of the Republican Guard Headquarters Project. Such knowledge can only be gained from professionals who have been part of the project. The second reason is that both the quantitative section of the questionnaire that uses a Likert scale to measure the extent of agreement or disagreement, as well as the qualitative section that includes open-ended questions, require the participants to draw from their very own project experience. As noted by Creswell (2014), selecting participants deliberately is crucial for a quality data collection. The third reason is that a broad or random sampling approach would have been impractical and unethical given the high security of the project under study. The researcher’s access to the participants was granted through the institutional cooperation with Ovid Kling Consult who is specifically involved with the Republican Guard Headquarters Project. The last reason is that Purposive sampling is a method that is used within the chosen pragmatic research paradigm. The pragmatic research paradigm chooses the most suitable methods for achieving the research questions and objectives of a study (Creswell & Plano Clark, 2011). In summary, purposive sampling was chosen as a deliberate methodological decision that aligns with the research questions, case study design, and contextual constraints of the study, ensuring that data collected is both purposeful and relevant.

A total of 58 questionnaires were distributed. Of these, 53 valid and complete responses were returned, representing a response rate of 91.4%, which is considered highly adequate for case study-based research (Creswell, 2014).

3.5 Data Collection Methods

In order to ensure a broad analysis of the research problem, the study applies multiple data collection instruments. CAD drawings and BIM models is reviewed using a document analysis checklist to identify coordination problem and inconsistencies. Document analysis is a research methodology tool that helps to analyze and interpret documents to identify and extract information (Bowen, 2009).

This study also incorporates clash detection analysis using BIM software, such as Revit and Navisworks. The clash detection analysis aims to identify and quantify clash or conflict occurred in the digital BIM model. Beside clash detection, a semi-structured questionnaire is used to collect data from selected professionals. Questionnaires are widely used to gather standardized data efficiently from a defined group of respondents (Creswell, 2014). Observations also are conducted in order to compare workflow in traditional CAD-based design coordination with that of BIM-based design coordination.

3.6 Data Validity and Reliability

3.6.1 Validity

Validity is technical term that refer to the objectivity and credibility of a research project. (Silverman, 2016). Validity is the extent to which the research instruments measure what they are intended to measure. In the paper, the validity of the research data is ensured through data triangulation. In order to achieve a clearer view of the issues under study, different sources of data were involved, namely, CAD files, the BIM models and the results of the questionary. Triangulation enhances the accuracy and credibility of the findings by allowing cross-

verification of data (Creswell, 2014). In addition, real projects data has been used to support this study and strength validity.

3.6.2 Reliability

Saunders et al. (2019) assert reliability in research is critical as it is concerned with whether a study can produce similar results in repeated attempts to collect and analyse data under similar conditions. To address this, reliability in this study is achieved through robust methods of data collection and analysis. A survey questionnaire was distributed to a sample of qualified BIM and design coordination experts. A purposive sampling strategy was used in selecting the sample of experts for this research. This study compares and identifies clashes within CAD and BIM design coordination workflows using similar clash identification criteria, and utilises a number of reliable software packages including Autodesk Revit and Navisworks. Reliability of findings was enhanced by data triangulation through the use of questionnaires, document analysis and a model-based comparison, ensuring that the results can be replicated under similar conditions.

3.7 Methods of Data Analysis

3.7.1 Quantitative Data Analysis

Quantitative data was collected though semi-structure questioner and project document which was analyzed using descriptive statistical methods. By applying frequency distribution and percentage tables, mean scores were calculated using the Likert scale response. Though frequency and comparison tables, direct evidence based comparison of CAD and BIM coordination performance was provided. This was done by analyzing project based data provided such as clash detection results, revisions cycles, and planned versus actual schedule milestones.

3.7.2 Qualitative Data Analysis

The qualitative data from open-ended questionnaire responses and from case study documents were analyzed by using thematic analysis, which involves identifying, analyzing, and reporting patterns within the data. Thematic analysis is used to identify and analyze patterns (themes) within qualitative data obtained from questionnaire, allowing meaningful interpretation of

participants experiences (Braun & Clarke, 2006).Thematic analysis is widely used in qualitative research to interpret textual data and develop meaningful insights (Braun & Clarke, 2006).

The questionnaire responses are organized aligned with the study's research questions, including coordination challenges in CAD-based workflows, BIM's impact on schedule and rework performance, improvements in communication and collaboration, and barriers to BIM adoption in the Ethiopian AEC context. These themes are then used to support and explain the qualitative findings, providing a comprehensive understanding of BIM's impact on project management performance.

3.8 Ethical Consideration

All research is conducted in accordance with the highest standards of ethics as outlined by recognized codes of practice involving human participants.. The following key ethical principles will be observed:

3.8.1 Informed Consent

Participants will be fully informed of the proposed research, provided with all necessary information and asked for their consent, either written or verbal, before data collection commences. They will be informed of the aims and objects of the research and given the option to withdraw from the research and/or to request the destruction of any data held at any point during the research.

3.8.2 Confidentiality and Anonymity

The anonymity of participants will be maintained and their identities will not be disclosed. All the collected data will be anonymized before analysis and used in presentations to ensure that no personal or organizational details are disclosed. The data will be used for academic purposes only and stored securely to prevent unauthorized access.

3.8.3 Compliance with Ethical Guidelines

The research will be carried out in accordance with relevant research ethics guidelines, at both institutional and national level, relevant to Addis Ababa University and Ethiopian research ethics frameworks

CHAPTER FOUR: RESULT AND INTERPRETATION

4.1 INTRODUCTION

This chapter summarizes the findings of this study regarding the comparative analysis of building information modeling and traditional computer- Aided design as project management tools: Impact on Design Coordination Efficiency and Schedule Performance The chapter consists of two sections. The first section summaries the findings obtained from the semi-structured questionnaire survey conducted with 53 project professionals involved in the Republican Guard Headquarters Project. The second section presents a case study of ongoing project, Republican Guard Headquarter, comparing CAD-based and BIM-based coordination performance using project schedule data and clash detection results.

4.2 Respondents General Information

Respondent's Rate

The received response are 53 from a total of 58 questionnaires from which 5 responses are incomplete. This implies the response rate is 91.4%, which is considered adequate for this type of case study-based research (Creswell, 2014).

Item	Number	Percentage
Questionnaires Distributed	58	100%
Valid Responses Returned	53	91.4%
Incomplete / Rejected	5	8.6%

Table 4.1: Questionnaire Response Rate

Professional Roles

The respondents include architects forming of the largest group (16 respondents, 30.2%), followed by structural engineers (9, 17%), BIM coordinators and modelers (7, 13.2%), MEP engineers (7, 13.2%), project managers and coordinators (6, 11.3%), quantity surveyors (5, 9.4%), and other professionals (3, 5.7%). This multidisciplinary composition reflects reliable data across the full project team.

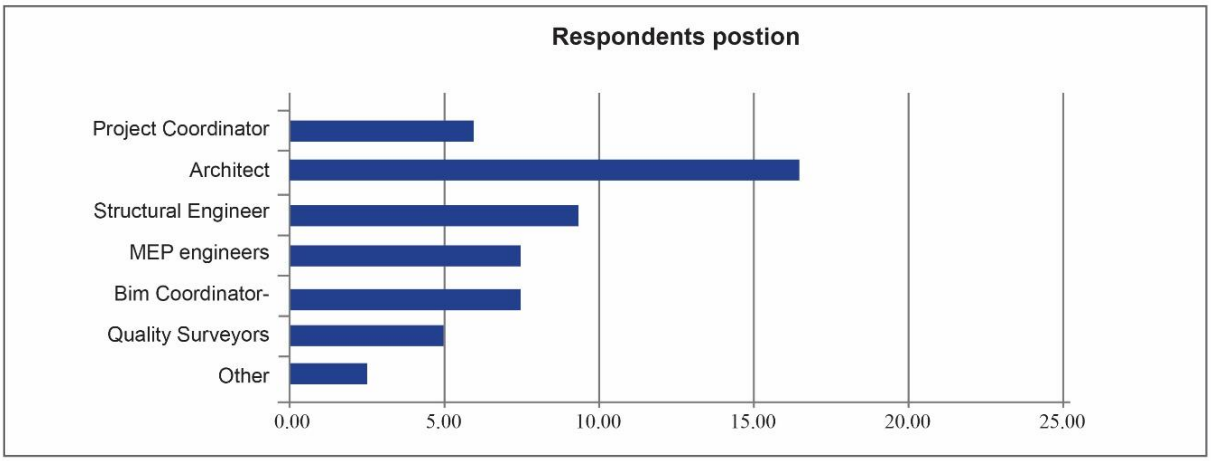


Figure 4.1: Respondent's positions

Respondent’s educational level and years of experience

Most of the respondents' educational level is B.Sc. (69.8 %) and the rest of respondents are MSc holders with 30.1 % share from the total. The majority of respondents had between 5–10 years of experience (22 respondents, 43.1%)), followed by those with 3-5 years (13, 25.5%), more than 10 year (10, 19.6 %), and less than 3 years (8, 15.7%) indicating that the data reflects insights from both experienced and moderately experienced professionals.

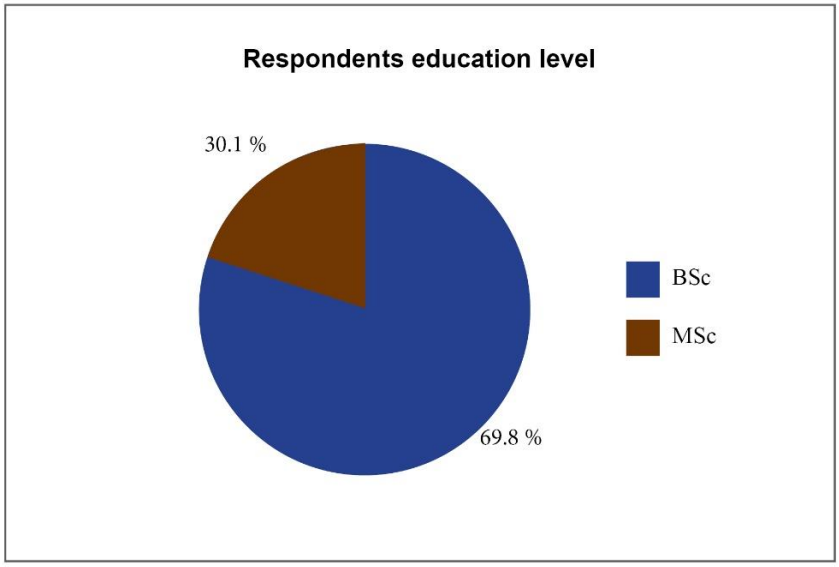


Figure 4.2: Respondents educational level

4.3 CAD-Based Design Coordination and Project Management Performance

This part discusses the findings from Section B of the questionnaire, examining CAD-based design coordination as the comparative baseline against which BIM-based coordination outcomes are assessed in subsequent sections of this chapter.

4.3.1 Coordination Method used

Respondents were asked about how design coordination was typically managed during Cad – based methods. From the multiple answer, many respondents choose "Manual overlay of 2D drawings during coordination meeting (38, 71.7%) and Ad hoc reviews triggered by identified conflicts selected by 48 respondents (90.6%) followed by periodic exchanges via email or shared devices with 25 respondents (47.2%) and regular face to face design reviews sessions by 18

respondents (34.0%). These finding clearly state that CAD-based coordination depended on manual, unstructured and time-consuming methods.

Coordination Method	Frequency	Percentage (%)
Ad hoc reviews triggered by identified conflicts	48	90.6%
Manual overlay of 2D drawings during coordination meetings	38	71.7%
Periodic drawing exchanges via email / shared drive	25	47.2%
Regular face-to-face design review sessions	18	34.0%

Table 4.2: Coordination Methods Used During CAD-Based Phases (Multiple Responses Permitted, n=53)

4.3.2 Frequency of Coordination Meetings

Respondents were asked how design coordination was typically managed during CAD-based phases. Many respondents selected weekly basis (21, 39.6%) or bi weekly (23, 43.4%), while 12 respondents (22,6%) stated that meeting only occurred when conflicts arose. Based on the data, CAD-based coordination causes significant time and resource wastage.

4.3.3 Stage at Which Conflicts Were Identified

Detection Stage	Frequency	Percentage (%)
During construction on site	46	86.8%
Detailed design stage	35	66.0%
Documentation / drawing production stage	21	39.6%
Early design / concept stage	0	0%

Table 4.3: Stage of Design Conflict Detection: CAD Phase (Multiple Responses Permitted, n=53)

Based on the majority respondent answer, the finding reveal a critically late pattern of conflict detection. A higher rate of response (46, 86.8%) reported that conflicts were typically identified during construction phase which is known to be the most costly and troubling stage to identify design errors. moreover 35 respondents (66.0%) choose the option with conflicts being identified during detailed design stage and during documentation stage and drawing production stage (21,

39.6%). These finding clearly states that CAD-based coordinating process cause direct implication on project performance outcomes.

4.3.4 Most Common Types of Coordination Failures

Type of Coordination Failure	Frequency	Percentage (%)
Inadequate circulation space due to structural elements	46	86.8%
Missing information (e.g., slab openings for MEP)	39	73.6%
Structural elements misaligned with architectural elements	37	69.8%
Clashing openings (doors/windows) with structural elements	36	67.9%
Incorrect floor levels or slab extensions	19	35.8%
Inconsistent dimensions between disciplines	16	30.2%

Table 4.4: Types of Coordination Failures in CAD Phase (Multiple Responses Permitted, n=53)

4.3.5 Schedule Impact of Late Conflict Detection

Schedule Impact	Frequency	Percentage (%)
Significant delays (more than 2 weeks)	39	73.6%
Moderate delays (1 – 2 weeks)	14	26.4%
Minor delays (less than 1 week)	0	0%
No schedule impact	0	0%

Table 4.5: Schedule Impact of Late Conflict Detection — CAD Phase (n=53)

The schedule consequences of late conflict detection were significant. A large majority of respondents (39, 73.6%) reported that late detection of design conflicts in the CAD phase caused significant delays of more than two weeks to design submission and moderated delay of one to two weeks was chosen by 14 respondents (26.4 %). Based on the finding, it is confirmed that project schedule was highly negatively affected by CAD-based coordination since no respondents reported minor delay or no schedule impact.

4.3.6 Design Revision Cycles in CAD Phase

Number of Revision Cycles	Frequency	Percentage (%)
1 revision	0	0%
2 – 3 revisions	5	9.4%
4 – 5 revisions	26	49.1%
More than 5 revisions	22	41.5%

Table 4.6: Design Revision Cycles Due to Coordination Errors — CAD Phase (n=53)

The inefficiency of CAD-based coordination was further proved based on the number of design revisions cycles required due to the coordination familiarity. Over half of respondents (26, 49.1%) reported that 4 to 5 revision cycles were required, while 22 respondents (41.5%) reported more than 5 revision cycles. Only 5 respondents (9.4%) reported 2 to 3 revision cycles, and no respondent reported a single revision being sufficient. These finding identified a significant drain on project time and resource on projects managed under CAD-based coordination since the system caused extensive and repeated reword cycles.

4.4 BIM-Based Coordination: Comparative Performance Findings

This section presents findings from Section C, BIM-based coordination versus CAD-based coordination: an impact on project management outcomes.

4.4.1 Effectiveness of BIM in Clash Detection

An overwhelming majority of respondents (43, 81.1%) rated BIM as very effective and 4 respondents (7.5 %) as effective in detecting design clash before construction stage. representing a strong and unified professional approval of BIM's clash detection capability as a project management tool.

4.4.2 Stage of Clash Identification

Detection Stage	Frequency	Percentage (%)
Concept / schematic design stage	42	79.2%
Pre-construction / coordination stage	11	20.8%

Detailed design stage	0	0%
During construction on site	0	0%

Table 4.7: Stage of Clash Detection: BIM Phase (n=53)

Majority of the respondent (42, 79.2%) stated that clashes was identified at the concept and schematic design stage and 11 respondents (20.8) reported clash identified at pre-construction coordination stage. The shift from construction-stage to concept-stage conflict detection represents a fundamental improvement in proactive project risk management.

4.4.3 Effect on Design Revision Cycles

The response stated that BIM in general reduced the rework cycle compared to the CAD-based approach since 42 respondents (79.2 %) reported that BIM substantially reduced the number of design revision by more than 50% compared to CAD based coordination. A further 11 respondents (20.8%) reported moderate reduction of 25 to 50%. No respondent reported no change or increased revisions. This finding approve the theory that BIM function as an effective project management tool for schedule performance improvement.

4.4.4 Effect on Schedule Performance

BIM's impact on overall project schedule performance was highly positive. 45 respondents (84.9%) reported that BIM significantly improved project schedule performance by helping keep the project on schedule.

4.4.5 Effect on Communication and Collaboration

The improvement in team communication and collaboration following BIM adoption was the most unanimously positive finding in this section.48 respondents (90.6%) agreed on that BIM greatly improved communication and collaborations, with all disciplines working from a single coordinated model. This finding supports previous stated evidence that that BIM's effectiveness as a communication management tool.

4.4.6 Effect on Rework Cost Reduction

Majority of the respondents (44, 83.0%) proved that BIM significantly assisted to reduce cost caused by rework, while 3 respondents (5.7%) agreed on moderate cost reduction when using

BIM. This strongly proves BIM's ability to detect clash at early stage translated into measurable cost performance improvements.

Performance Dimension	CAD Phase	BIM Phase
Conflict detection stage	On-site: 86.8%	Concept stage: 79.2%
Schedule delay reported	>2 weeks: 73.6%	Significantly improved: 84.9%
Revision cycles (4+)	90.6% of respondents	>50% reduction: 79.2%
Communication improvement	Ad hoc / fragmented	Greatly improved: 90.6%
Rework cost impact	Significant rework: all respondents	Significantly reduced: 83.0%

Table 4.8: Summary Comparison: CAD vs BIM Coordination Performance

4.5 Likert Scale Analysis: Impact of BIM on Project Management Performance

This section presents and interprets the findings from Section E of the questionnaire, the five-point Likert scale assessment of BIM's impact across five project management performance sub-themes. For each statement, results are presented as frequency distributions with percentages, and a mean score is calculated where 1 = Strongly Disagree and 5 = Strongly Agree. A mean score above 4.0 indicates strong agreement, and above 4.5 indicates very strong agreement across the respondent group.

To facilitate meaningful interpretation of the Likert scale mean scores, the following benchmark scale was established prior to analysis, consistent with standard practice in Likert scale research (Creswell, 2014):

Mean Score Range	Interpretation
1.00 – 1.49	Very Low — Strongly Disagree
1.50 – 2.49	Low — Disagree
2.50 – 3.49	Medium — Neutral
3.50 – 4.49	High — Agree
4.50 – 5.00	Very High — Strongly Agree

Table 4.9: Likert Scale Mean Score Interpretation Benchmark

The results from sections 4.5.1 through 4.5.5 were compared against this benchmark. A mean score falling in the range of 4.50 to 5.00 is classified as Very High, indicating very strong agreement among respondents. A score in the range of 3.50 to 4.49 is classified as High, indicating general agreement.

4.5.1 Schedule and Time Management

Statement	N (3)	A (4)	SA (5)	Mean	Level
BIM reduced schedule delays from coordination failures	0	4 (7.5%)	49 (92.5%)	4.92	Very High
Early clash detection resolved issues before schedule impact	0	2 (3.8%)	51 (96.2%)	4.96	Very High
CAD-to-BIM transition caused initial schedule delays	16 (30.2%)	32 (60.4%)	5 (9.4%)	3.79	High
BIM improved predictability of project timeline	0	3 (5.7%)	50 (94.3%)	4.94	Very High
BIM enabled faster decision-making for schedule adherence	0	8 (15.1%)	45 (84.9%)	4.85	Very High

Table 4.10: Likert Scale Results: Schedule and Time Management(n=53)

Total of four statements fall within the very high range scoring above 4.85, which proves that BIM significantly enhanced schedule management performance. The only exception is the statement related to initial transition delay which have mean value of 3.79 and falls within the high range that reflects temporary setup costs are outweighed by longer-term schedule gains since there is adequate BIM professional in the team which meticulously planned the schedule on head of time.

4.5.2 Rework Reduction and Cost Performance

Statement	N (3)	A (4)	SA (5)	Mean	Level

BIM significantly reduced design revision cycles vs CAD	0	3 (5.7%)	50 (94.3%)	4.94	Very High
Early clash detection prevented costly construction rework	0	5 (9.4%)	48 (90.6%)	4.91	Very High
BIM implementation cost justified by rework savings	0	7 (13.2%)	46 (86.8%)	4.87	Very High
BIM reduced change orders and on-site modifications	0	1 (1.9%)	52 (98.1%)	4.98	Very High
BIM contributed to better cost performance overall	0	2 (3.8%)	51 (96.2%)	4.96	Very High

Table 4.11: Likert Results: Rework Reduction and Cost Performance(n=53)

All the above statements fall within the Very High range (mean 4.87–4.98), resulting the strongest combined sub theme in the Likert scale. Based on project management perspective, BIM eliminating the rework cycles which improve cost performance unlike the traditional CAD-based method which consume substantial project budget and time.

4.5.3 Coordination Efficiency and Quality

Statement	N (3)	A (4)	SA (5)	Mean	Level
BIM enabled real-time coordination across disciplines	0	3 (5.7%)	50 (94.3%)	4.94	Very High
Automated clash detection more reliable than manual CAD	0	0	53 (100%)	5.00	Very High
BIM improved quality and accuracy of documentation	0	8 (15.1%)	45 (84.9%)	4.85	Very High
BIM reduced dependency on manual coordination meetings	0	2 (3.8%)	51 (96.2%)	4.96	Very High
BIM gave all team members consistent project view	0	0	53 (100%)	5.00	Very High
BIM identified issues that would be missed in CAD	0	9 (17.0%)	44 (83.0%)	4.83	Very High
BIM improved completeness of design deliverables	0	7 (13.2%)	46 (86.8%)	4.87	Very High

Table 4.12: Likert Results: Coordination Efficiency and Quality(n=53)

Two statements, automated clash detection more reliable than manual CAD and BIM gave all team members consistent project view scored a perfect mean of 5.00 thus classified as Very High. Thus represents complete professional consensus on BIM's superiority over CAD for coordination reliability and information consistency. Overall the above statements confirms that hat BIM basically improved the efficiency and quality of design coordination on the project.

4.5.4 Communication: Collaboration and Stakeholder Management

Statement	N (3)	A (4)	SA (5)	Mean	Level
BIM improved communication between architectural and structural teams	0	3 (5.7%)	50 (94.3%)	4.94	Very High
BIM improved communication between design team and client	0	6 (11.3%)	47 (88.7%)	4.89	Very High
3D visualization helped stakeholders understand design	0	1 (1.9%)	52 (98.1%)	4.98	Very High
BIM fostered collaborative working environment	0	8 (15.1%)	45 (84.9%)	4.85	Very High
BIM reduced misunderstandings between disciplines	0	3 (5.7%)	50 (94.3%)	4.94	Very High
BIM made reporting coordination issues easier	0	10 (18.9%)	43 (81.1%)	4.81	Very High

Table 4.13: Likert Scale Results: Communication, Collaboration and Stakeholder Management (n=53)

All the above statements in communication sub-themed fall within the Very High range (mean 4.81–4.98) which confirms that BIM communication and collaboration at all level of the project. The highest score was given to the statement 3D visualization helped the stakeholders to understand the design. This supports the point that BIM’s visual communication is far superior to the CAD drawn 2D plans. The findings of the study further support the proposition that BIM is being used as communication and stakeholder management tool as well as technical coordination tool.

4.5.5 Risk Management

Statement	N (3)	A (4)	SA (5)	Mean	Level
BIM identified and mitigated design risks at early stage	0	4 (7.5%)	49 (92.5%)	4.92	Very High
BIM reduced likelihood of unexpected conflicts in construction	0	0	53 (100%)	5.00	Very High
BIM provided better documentation for risk tracking	0	1 (1.9%)	52 (98.1%)	4.98	Very High
Early clash detection reduced overall project risk profile	0	0	53 (100%)	5.00	Very High

Table 4.14: Likert Scale Results: Risk Management

From the four statements, two key statements scored perfect 5.00 point and all classified as Very High which are "BIM reduced likelihood of unexpected conflicts in construction' and 'early detection reduced overall project risk profile'. Overall, those results prove BIM is regarded by all respondents as a highly effective project risk management tool, primarily through its ability to identify and eliminate design-related errors before they cause damage on site.

Sub-Theme	Mean Range	Overall Assessment
Schedule and Time Management	3.79 – 4.96	Very Strong Positive Effect
Rework Reduction and Cost Performance	4.87 – 4.98	Strongest Sub-Theme Overall
Coordination Efficiency and Quality	4.83 – 5.00	Two Perfect Scores Achieved
Communication and Stakeholder Management	4.81 – 4.98	Consistently Very High
Risk Management	4.92 – 5.00	Highest Sub-Theme Overall

Table 4.15: Overall Likert Scale Summary by Sub-Theme

None of the participants answered "Strongly disagree" or "Disagree" to all of the 27 Likert-scale type statements organized under the 5 sub-themes of project management performance. Only one

Neutral answer was obtained for a statement regarding the initial delays in the schedule caused by the BIM transition. This finding, therefore, clearly reveals that BIM is delivering positive impacts for project management and thus strongly supports the study's proposition in an empirical form.

4.6 Challenges of BIM Implementation

Challenge	Frequency	Percentage (%)
Lack of BIM-trained professionals within the team	48	90.6%
Insufficient management support for BIM adoption	48	90.6%
High cost of BIM software and hardware	42	79.2%
Lack of organizational BIM standards and protocols	32	60.4%
Interoperability issues between software platforms	25	47.2%
Resistance to change from team members used to CAD	22	41.5%
Time required to set up and learn BIM tools	19	35.8%

Table 4.16: BIM Implementation Challenges (Multiple Selections Permitted, n=53)

The main BIM barriers for the surveyed parties were found to be organizational and human in nature rather than technical. The two highest rated BIM barriers for the surveyed parties were found to be 'lack of trained professionals' (90.6%) and 'lack of management support' (90.6%). BIM implementation will therefore require more than the implementation of software and related IT infrastructure. It will require institutions to be committed and for capacity to be built.

4.7 Final Opinions and Professional Recommendations

Overall Recommendation

Recommendation Level	Frequency	Percentage (%)
Strongly Recommend	50	94.3%
Recommend	3	5.7%
Neutral / Do Not Recommend	0	0%

Table 4.17: Overall BIM Recommendation

The final section of the Questionnaire established the unified views of professionals and reached a very clear and unified professional position. All comments (n=53) were of the form to confirm BIM as the best tool for design coordination and project management over traditional CAD. Three main advantages of BIM were repeatedly listed by the majority of respondents. These were that BIM provided a shared central digital platform for real-time access to consistent project information; enabled early detection and conflict resolution prior to these affecting the project's time and cost; and that 3D visualization greatly aided stakeholders' understanding and decision making. Most comments stressed the need for BIM to be adopted as a mandatory industry standard in the AEC sector within the Ethiopian context. Comments also stressed that government bodies should develop a policy to allocate funds for BIM training and BIM infrastructure in order to promote its implementation. The comments on the Republican Guard Headquarters project demonstrated how BIM could advance a project's schedule, prevent cost overruns, and improve communication between the disciplines and lead to quality project outcomes. The findings of this section of the Questionnaire confirm the general argument that BIM implementation can lead to measurable and meaningful improvements in project management performance.

4.8 Qualitative Data Analysis: Thematic Findings from Open-Ended Responses

Open-ended responses from Sections F and G of the questionnaire were analyzed using thematic analysis (Braun & Clarke, 2006). Responses were coded inductively and organized into four primary themes corresponding to the study's comparative framework.

Theme 1: Reactive vs. Proactive Coordination Culture

According to the responses CAD-based method is labelled as a reactive and conflict-driven since design revisions are done when challenges become visible due to the reason each discipline working in separate platform. By the time conflicts are identified at late design stage which have already caused negative impact on other cascading design decisions causing costly design revisions. In contrast, BIM have pro reactive method where conflicts are identified automatically

early at concept design stage through a shared model. This caused major shift in project management practice.

Theme 2: Schedule and Cost Consequences of Coordination Approach

Schedule delays that occurred while using CAD – based coordination method are caused by design errors that are identified at late design stages causing downstream delays across MEP Coordination, BOQ and documentation. The cost for such delays is substantial and is mainly caused by rework, extended hours of consultants and site preliminaries. Under BIM, respondents reported markedly improved schedule adherence because conflicts were resolved at the earliest and least costly design stage. In the BIM phase 48 clashes were detected, all of them have the potential of severe cost increases when occurring during the construction phase.

Theme 3: Information Quality and Design Accuracy

Based the data gathered, majority of the respondents mentioned that CAD drawing across disciplines faced many design drafting inconsistencies such as dimension, level specifications which majority of the time discovered by manual design overlay coordination at late design stage. In addition to that, some design errors could not be identified across all disciplines since the CAD method is based on 2D visualizations. BIM used a single shared model platform across all disciplines which advanced information quality shared between disciplines. Automated clash detection identified spatial conflicts, particularly involving circulation space and MEP openings, that were routinely missed under CAD coordination.

Theme 4: Skills Gap and Adoption Barriers

Lack of BIM-competent professionals was identified by the respondents as the dominant implementation challenge. structured training programs at various level was frequently recommended. Also, the lack of management support was seen as a major problem. BIM is usually introduced on team level but on company level it requires investment in software, hardware as well as time to co-ordinate all this. Development of BIM standard and policy was one of the most frequently recommended intervention

4.9 Qualitative Data Analysis: Case Study of the Republican Guard Headquarters Project

A qualitative analysis of the Republican Guard Headquarters case study was conducted by means of thematic analysis (Braun & Clarke, 2006) .The data from various sources have been analyzed, such as the CAD plans, the BIM models, the project schedule and the reports of clashes found during the design process. Four major themes were derived from the systematic coding and review of the data. Those include reactive versus proactive coordination, schedule impact of design coordination failures, design quality and rework, and interdisciplinary communication and collaboration.

Item	Detail
Project Name	Republican Guard Headquarters (RGHQ)
Project Location	Arat Kilo, Addis Ababa, Ethiopia
Project Function	Office Building with Meeting Hall and Support Facilities
Client	Ethiopian Defense Force
Project Area	1,670 SQM
Number of Stories	B + G + 7
Design Firm	Ovid Kling Consult (OKC)

Table 4.18: Project Information

The republican guard headquarter was initially done using traditional cad method before transitioning to BIM-base coordination mid project due to many reasons. Those reasons include coordination failure and schedule delay. Since there is both CAD drawing and BIM models available which provides solid base for a direct before and after comparison of project management performance.

4.9.1 CAD-Based Coordination Analysis

While using traditional cad method, all design disciplines were developed independently and coordinated through manual 2d drawing overlays and regular meeting to review design process(refer to Annex B, Figure B.1 – B.4).This process cause late detection of design clashes which made the whole process reactive.

Design Clashes Identified Through CAD Coordination

Floor Level	Column Misalignment	Extended Slab	Opening Position Error	Inadequate Circulation Space
Basement	✓	✓	✓	✓
Ground	✓	✓	✓	✓
First	✓	✓	✓	✓
Seventh	✓	✓	✓	✓

Table 4.19: Design Clashes Identified Through CAD-Based Coordination

The above listed errors were identified at late stage due to coordination failure caused by the traditional CAD system.

Schedule Impact of CAD Coordination Failures

Date	Planned Activity (Fast-Track Approach)	Actual Progress
Nov 2, 2025	Project Brief	
Nov 10, 2025	Architectural concept design	Architectural concept design done based on schedule
Nov 13, 2025	Project Briefing	Done
Nov 20, 2025	Preliminary architectural and structural design	Completed as scheduled
Nov 27, 2025	Parallel Initiation of MEP Design and BOQ Preparation based on preliminary design	Completed as scheduled
Nov 29, 2025	Submission of preliminary design for site clearing, excavation, and footing works	Delivered as scheduled
Dec 6, 2025	Final architectural and structural design	Postponed due to required revisions to preliminary design
Dec 9, 2025	Coordination Review Meeting	Multiple design errors identified during review
Dec 16, 2025	MEP design development	Delayed due to incomplete final design
Dec 23, 2025	Bill of Quantities (BOQ) preparation	Delayed due to incomplete final design

Dec 30, 2025	Project documentation	Delayed due to incomplete final design

Table 4.20: Planned vs. Actual Schedule: CAD Coordination Phase

The errors were discovered late in the life of the project resulting in delay to numerous activities such as design submission, the commencement of MEP works, the compilation of the final BOQs etc. Many construction activities were put on hold temporarily while design amendments were being carried out.

Initially the project used CAD-based coordination which delivered poor quality workflows, late decision making thus creating a lot of re-work. The 2D coordination process was not capable of identifying complex clashes.

Design Revision Cycles: **CAD Phase**

Discipline	Number of Revision Rounds	Identified errors
Architectural	5	Column misalignment and opening errors
Structural	6	Slab extensions and level inconsistencies
MEP	3	Inadequate area for Mechanical rooms, narrow Duct opening
Combined Coordination	14	Cross-discipline spatial conflicts

Table 4.21: Design Revision Cycles: CAD Phase

Theme 1: Reactive vs. Proactive Coordination

The CAD coordination was on a purely reactive basis. Conflicts were identified only through manual 2D drawing overlays during periodic basis at review meetings resulting design failure as per floor (see Annex B, Figures B.1–B.4). In contrast the BIM enabled CAD coordination to be on a proactive basis to support the planning. Automatic clash detection identified problems as soon as individual models were incorporated into the shared planning model (see Annex C. Figures C.1–C.5).

Theme 2: Schedule Impact of Design Coordination Failures

A single coordination failure at the final design stage cascaded into delay on the MEP, BOQ and project documents work packages. In the BIM environment 48 conflicts have been solved at early design stage without any impact on the rest of the schedule.

4.9.2 BIM-Based Coordination Analysis

The republican guard headquarter model were developed in Autodesk Revit and integrated into centralized coordination environment to enable each discipline to work on central shared system. Real-time detection across disciplines was enabled through Naviswork(refer Annex C, Figures C.1–C.2 for the integrated BIM model of the Republican Guard Headquarters in Navisworks environment, and Figures C.3–C.4 for detailed structural and architectural BIM model views).

Clash Detection Results

ID	Count	File Name
Structural Framing	6	for BIM RGHQ_OKC-M3-ST-S01-P1_detached.rvt
Structural Rebar	2	for BIM RGHQ_OKC-M3-ST-S01-P1_detached.rvt
Ceilings	3	for BIM RGHQ-OKC-M3-AR-S03-P8 (3).rvt
Generic Models	2	for BIM RGHQ-OKC-M3-AR-S03-P8 (3).rvt
Casework	1	for BIM RGHQ-OKC-M3-AR-S03-P8 (3).rvt
Runs	4	for BIM RGHQ-OKC-M3-AR-S03-P8 (3).rvt
Stairs	5	for BIM RGHQ-OKC-M3-AR-S03-P8 (3).rvt
Specialty Equipment	3	for BIM RGHQ-OKC-M3-AR-S03-P8 (3).rvt
Doors	5	for BIM RGHQ-OKC-M3-AR-S03-P8 (3).rvt
Furniture	7	for BIM RGHQ-OKC-M3-AR-S03-P8 (3).rvt
Railings	4	for BIM RGHQ-OKC-M3-AR-S03-P8 (3).rvt
Landings	1	for BIM RGHQ-OKC-M3-AR-S03-P8 (3).rvt
Electrical Fixtures	3	for BIM RGHQ-OKC-M3-AR-S03-P8 (3).rvt
Curtain Panels	2	for BIM RGHQ-OKC-M3-AR-S03-P8 (3).rvt

Table 4.22: BIM Clash Detection Results

While using BIM, all the above listed design clashes were identified at conceptual design stage before construction or any other passes commenced using Naviswork clash detection tool (refer to Annex D, Figures D.1–D.4 for clash detection visualizations). This eliminated the risk of

costly on site modification, prevented cascading schedule delays and reduced the overall project risk profile.

BIM Impact on Design Revision Cycles

Item	Coordination Method	Revision Cycles	Reduction
CAD Phase	Manual 2D overlay	More than 9 cycle	
BIM Phase	Automated clash detection	Less than 4 cycle	66.7%

Table 4.23: Revision Cycle Comparison: CAD vs BIM

Theme 3: Design Quality and Rework

Total of 9 design revision cycles for the CAD process were necessary because of late detection of conflicts. For the design planning using BIM, this number was reduced by 66.7%to only three design revision cycles. The clash detection report for the BIM-based design planning process (Annex D, Figures D.1–D.4) shows that all 48 conflicts were detected earlier and in a more structured manner than for the CAD process. This leads to a significant increase in design quality and to a reduction of most of the subsequent corrections.

Theme 4: Interdisciplinary Communication and Collaboration

CAD coordination for the project was delivered in a fragmented and sequential manner with individual disciplines producing information that was shared at weekly meetings. BIM coordination was delivered utilizing Navisworks as a central hub where all disciplines could access and contribute to information in real-time as opposed to the predominantly reactive process of attending a series of meetings.

4.9.3 Comparative Analysis: CAD vs BIM Project Management Performance

PM Performance	CAD-Based Approach	BIM-Based Approach
Conflict detection stage	Detailed design and construction (reactive)	Concept and design stage (proactive)
Clashes detected early	0	48

Design revision cycles	9 cycle	3 cycle
Schedule impact	Cascading delays to 3+ activities	Schedule adherence maintained
Coordination method	Manual, unstructured, reactive	Automated, integrated, proactive
Communication quality	Fragmented, discipline-specific 2D drawings	Unified , single shared BIM model
Rework cost impact	Significant rework required	Prevented through early detection

Table 4.24: Comparative Analysis: CAD vs BIM Project Management Performance

Based on the comparison, coordination was shifted from reactive to proactive project management process while using BIM methodology. As a result BIM positively influenced the planning of the schedule, it prevented costs for rework and it also positively influenced the design quality.

4.10 Discussion of Findings

This section interprets and triangulates the quantitative findings from the questionnaire survey and the qualitative findings from the case study analysis, and situates these findings within the existing body of literature on BIM and project management performance.

The results of the questionnaire provided strong quantitative evidence to support the benefits that BIM provides to the project management of a project. The results for 26 of the 27 questions received a score of Very High (mean score of 4.50 to 5.00 on the Likert scale). None of the returned questionnaires scored any of the questions as Disagree or Strongly Disagree. The results for the four questions that measured rework and risk management were near perfect with mean scores ranging from 4.87 to 4.98 out of 5 for rework and from 4.92 to 5.00 out of 5 for risk management. The early detection of clashes by BIM was stated to be the greatest benefit to project management by BIM adoption. The only score outside of the Very High score range was the initial schedule delay question with a mean score of 3.79 out of 5. This score highlighted the short term cost of change to using BIM and detailed the range of challenges currently experienced by respondents. 90.6% of respondents stated that lack of skills and lack of management support were barriers to BIM implementation.

Though concrete project evidence organized under four themes, the qualitative case study proves and investigate the quantitative finding. 76.5% of survey respondents who reported major schedule delays associated to CAD coordination failures is confirmed through cascading delay across three downstream work package during CAD phase. Similarly, 79.2% of respondents reported that BIM reduce revision cycle by more than 50% and is also supported by the data documented in case study with 66.7% reduction in revision cycle. The greatest evidence of BIM's ability to transform a reactive traditional method of CAD-based coordination into a proactive project management process, has come from the findings of all 48 design conflicts between teams being identified at early design stage as opposed to none in the CAD phase of project delivery. The findings provide most tangible evidence of the power of BIM to advance the project schedule and deliver which led to eliminate rework costs that occurred through failure to identify errors at the start of the project.

Moreover, the conclusion from professionals lived experience which is analyzed using thematic analysis of open-ended questionaries further reinforce the above-mentioned finding. Based on the response, CAD is described as a reactive, isolation-driven process with cost and schedule implications while BIM was perceived to transform the way of coordination and implied a change in the industry's culture rather than the change of the software used for the coordination of the project. The theme of information quality revealed that BIM eliminates dimensional mistakes and missing spatial details that are typical for manual CAD coordination. The skills gap and management support themes additionally explain why BIM is not being maximally implemented in the Ethiopian AEC sector, even though the benefits of BIM are acknowledged by all.

The findings from the quantitative and qualitative data, collected from the various data sources, converge to form a consistent and coherent conclusion. Thus, all the findings from the questionnaire, the project schedule, the clash detection reports and the observation of the coordination workflow point into the same direction. Design coordination is changed by BIM from a manual, fragmentized and mostly reactive process to an automated, integrated, proactive process with positive outcomes for the core dimensions of project management performance. The survey findings are supported by the project data from the independent data sources. Thus, the findings of this study are in line with the methodological principles of triangulation in mixed-

methods research (Creswell, 2014). The triangulated findings of this study thus answer the four research questions in a positive way: BIM improves the coordination efficiency, it protects the schedule, it reduces rework and it improves the communication between the disciplines.

The findings of this research study are in line with the majority of empirical research that has investigated the performance of the project management and design coordination using BIM against traditional CAD. The early detection of the clashes by BIM enables the design professionals to eliminate design errors and changes and thus saves time and money by preventing delays and cost overruns. The schedule for the Republican Guard Headquarters Project has highlighted the errors that were drawn using CAD and how these errors were detected and enhanced when using BIM. Azhar (2011) stated that design errors could be reduced by up to 40% through the improved coordination using BIM. However, the number of revision cycles were reduced by 66.7% when using BIM as against the traditional CAD-based coordination method. It is also anticipated that the manual process of design coordination while using CAD would prove the benefits of using BIM using automated process. Similar to Arayici et al. (2017) the main perceived barriers while implementing BIM were skills, cost of BIM and management support. Regardless of the challenges of its implementation, BIM was recommended by 53 individuals as a mandatory industry standard and a project management tool for the AEC industry. This level of professional endorsement reflected the particularly stark and directly observable contrast between CAD and BIM performance within the same project context.

CHAPTER FIVE: SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

This chapter as a whole presents the summary of findings, concluding remarks for the main findings in chapter four and important recommendations respectively.

5.1 Summary of the main findings

This study comparatively analyzed Building Information Modeling (BIM) and traditional Computer-Aided Design (CAD) as project management tools in terms of design coordination efficiency and schedule performance, using the Republican Guard Headquarters Project at Ovid Kling Consult as a case study.

A pragmatic research paradigm is adopted using both qualitative and quantitative approach in order to achieve the research objective. Descriptive, explanatory, and explanatory components was used in order to the support the case study research design. Using both primary and secondary sources, data was collected. For primary source of data, semi structured questionnaires was distributed to selected professional such as architects, structural engineers and BIM coordinators using purposive sampling. CAD drawing and BIM model is used as secondary source of information. Using descriptive and thematic analysis, the collected data were analyzed supported by a model based comparison of CAD and BIM workflows.

Current design coordination processes employing CAD-based design models, typically rely on manual interaction amongst design disciplines. This typically involves the creation of drawing

overlays to visually compare models, manual review of interferences and frequent design coordination meetings. Due to the lack of integration between disciplines, this method is found to be ineffective and disrupted. The traditional CAD-methods leads to cascading schedule delays, high revision cycle frequency, and significant rework costs since design conflicts are identified at the later stages of the project, particularly during detailed design, documentation and construction phase.

In contrast, BIM-based design coordination method provides an integrated and collaborative digital environment system which found to significantly improve coordination process. A shared model is provided to all discipline teams simultaneously and allows all parties to work off consistent and up-to-date information. In addition, BIM enables early clash detection and prevention through the use of automated clash detection tools, identifying potential errors and allowing design amendments to be made early enough to prevent propagation to latter stages of the project impacting schedule or budget.

The thematic analysis of open-ended questionnaire responses provided additional qualitative depth to these findings. Professionals described the CAD-to-BIM transition as a fundamental shift in coordination culture rather than a simple software change, confirming that BIM's project management benefits extend beyond technical clash detection to encompass organizational practice, information quality, and interdisciplinary communication. These thematic findings are consistent with and reinforcing of both the quantitative survey results and the case study evidence.

Moreover, the Likert scale mean scores consistency being above 4.8 across PM performance themes and majority of respondent’s agreement on BIM's superiority for clash detection reliability and project information management, Questionnaire findings confirmed these outcomes quantitatively. Despite these benefits, the study identified persistent barriers to BIM adoption, particularly the skills gap and insufficient management support, both cited by 90.6% of respondents as significant constraints on wider BIM implementation in the Ethiopian AEC sector.

5.2 Conclusions

Based on the findings, the following conclusions are drawn in direct response to the study's research questions.

While using traditional CAD-based coordination on republican Guard Headquarter project, the method generated project management cost and schedule delay resulting poor project performance. The manual and reactive approach caused major coordination failure at design level, leading to downstream work package to be delayed due to repeated revision cycle. This critically affected schedule execution, resource efficiency and project quality.

BIM implementation significantly improved project management performance in the reviewed case study by moving conflict detection from the construction phase to the design stage at the concept development stage. Identifying design conflicts at the design stage and solving, safeguarded the schedule, removed all possible rework costs and improved project delivery predictability thereby achieving the objectives of the project management concept.

Moreover, BIM minimized design revision cycles by more than 50%, which reduced the need for on-site modification causing cost overrun. This is one of the key Project Management benefits of BIM investment identified through this research. Furthermore, BIM advanced interdisciplinary communication and stakeholder engagement through a shared digital model.

The findings from the study generally suggest that BIM is better than CAD-based coordinating method for managing construction projects. Thus, the findings from the study are of great significance to the Ethiopian construction industry, where poor project coordination practice has been identified as a major factor contributing to most of the problems encountered in the construction projects. Thus, BIM can be an effective project management tool for delivering AEC complex construction projects on time, within budget and with desired quality.

5.3 Recommendations

Based on the findings and conclusions of this study, several recommendations are proposed to enhance the implementation and application of BIM in design coordination practices within the Ethiopian AEC industry.

It is recommend to adopt BIM at early stage of design hence the greatest benefits of BIM to project management such as schedule protection, rework prevention, and risk reduction can be achieved when design clashes are detected and resolved at early design stage. Based on the skill gap analysis, it is also recommended that AEC organization to invest in BIM training and capacity building and develop BIM standard & coordination policy to achieve effective BIM implementation. Taking those measures will reduce setup time and ensure consistent application across project teams.

At institutional level, it is recommended that senior management and project stakeholder to advocate BIM adaptation by allocating sufficient budget for software, infrastructure and training. Since lack of management support was cited as one of the significant barriers to implementation based on the data collected.

In addition to BIM adoption by AEC industry, government institutions and regulatory bodies should develop policies and guidelines to promote or even mandate BIM adoption for public AEC projects. Support of government and industry stakeholders will highly reduce the high implementation cost and address organizational resistance to change.

REFERENCES

Abbasnejad, B., & Moud, H. I. (2013). BIM and basic challenges associated with its definitions, interpretations and expectations. International Journal of Engineering Research and Applications (IJERA), 3, 287–294.

Almutiri, S. (2016). Benefits of BIM in construction projects.

Arayici, Y., Egbu, C., & Coates, P. (2012). Building information modelling (BIM) implementation and remote construction projects: Issues, challenges, and critiques. Electronic Journal of Information Technology in Construction, 17.

Azhar, S. (2011). Building information modeling (BIM): Trends, benefits, risks, and challenges for the AEC industry. Leadership and Management in Engineering, 11(3), 241–252. https://doi.org/10.1061/(ASCE)LM.1943-5630.0000127

Bowen, G. A. (2009). Document analysis as a qualitative research method. Qualitative Research Journal, 9(2), 27–40.

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. Qualitative Research in Psychology, 3(2), 77–101.

Butkovic, B., & Heesom, D. (2017). Towards a framework for multi-LOD 4D BIM simulations. In International Research Conference 2017 (pp. 578–586). University of Salford.

Creswell, J. W. (2014). Research design: Qualitative, quantitative, and mixed methods approaches (4th ed.). SAGE Publications.

Creswell, J. W., & Plano Clark, V. L. (2011). Designing and conducting mixed methods research (2nd ed.). SAGE Publications.

Duell, O., et al. (2013). Comparison of BIM and traditional workflows.

Eastman, C., Teicholz, P., Sacks, R., & Liston, K. (2011). BIM handbook: A guide to building information modeling for owners, managers, designers, engineers, and contractors (2nd ed.). Wiley.

Farzaneh, A., et al. (2019). BIM adoption and design phase coordination.

Gebrehiwot, M. (2020). The impact of project management deficiencies on Ethiopian construction projects. African Journal of Project Management, 5(2), 112-130.

Hardin, B., & McCool, D. (2015). BIM and construction management: Proven tools, methods, and workflows (2nd ed.). Wiley.

Kothari, C. R. (2004). Research methodology: Methods and techniques (2nd ed.). New Age International.

Kymmell, W. (2008). Building information modeling: Planning and managing construction projects with 4D CAD and simulations. McGraw-Hill.

Melhado, S. (2005). Design coordination in building projects.

Robson, C. (2002). Real World Research: A Resource for Social Scientists and Practitioner-Researchers (2nd ed.). Blackwell Publishing.

Sacks, R., Eastman, C., Lee, G., & Teicholz, P. (2018). BIM handbook: A guide to building information modeling for owners, designers, engineers, contractors, and facility managers. Wiley.

Saunders, M., Lewis, P., & Thornhill, A. (2019). Research methods for business students (8th ed.). Pearson.

Silverman, D. (2016). Qualitative research (4th ed.). SAGE Publications.

Succar, B. (2009). Building information modelling framework: A research and delivery foundation for industry stakeholders. Automation in Construction, 18(3), 357–375. https://doi.org/10.1016/j.autcon.2008.10.003

PMI (2017). A guide to the project management body of knowledge (PMBOK guide). Project Management Institute.

Yin, R. K. (2018). Case study research and applications: Design and methods (6th ed.). SAGE Publications.

APPENDIX:

Annex A: Questionnaire



Addis Ababa University

School Of Graduate Studies

A comparative analysis of building information modeling and traditional computer- Aided design as project management tools: Impact on Design Coordination Efficiency and Schedule Performance. A Case Study of the Republican Guard Headquarters Project at Ovid Kling Consult

By:

Liya Yared Woldegebriel

Advisor:

Dr. Zegeye M.

May, 2026

Purpose: This questionnaire is developed to collect insights from professionals involved in republican guard head quarter project in Addis Ababa. This aims to examine the underlying cause non-effective coordination, evaluate the effective of BIM (building information modeling) in project management, and gather recommendation for improved BIM implementation in such projects.

Confidentiality Statement:

All response will be treated with strict confidentiality and will be used solely for academic research purpose:

SECTION A: RESPONDENT INFORMATION

1. Professional Role (select all that apply)
   - ☐ Architect
   - ☐ Structural Engineer
   - ☐ BIM Coordinator / Modeler
   - ☐ Project Manager / Coordinator
   - ☐ MEP Engineer
   - ☐ Quantity Surveyor
   - ☐ Other (please specify): _____
2. Years of Professional Experience
   - ☐ Less than 3 years
   - ☐ 3 – 5 years
   - ☐ 5 – 10 years
   - ☐ More than 10 years
3. Highest Educational Qualification
   - ☐ Diploma / Certificate
   - ☐ Bachelor's Degree (B.Sc. / B.Arch.)
   - ☐ Master's Degree (M.Sc. / MBA / MPM)
   - ☐ PhD or above
4. Primary Software Experience
   - ☐ AutoCAD only
   - ☐ Revit (BIM)
   - ☐ Navisworks

- ☐ Archicad
- ☐ Both CAD and BIM tools
- ☐ Other:

5. Have you worked on projects where both CAD and BIM were used?
   - ☐ Yes
   - ☐ No

SECTION B: CAD-BASED COORDINATION AND PROJECT MANAGEMENT PERFORMANCE

6. How design coordination was typically managed in CAD-based phases of the project?
   - ☐ Manual overlay of 2D drawings during coordination meetings
   - ☐ Periodic drawing exchanges between disciplines via email / shared drive
   - ☐ Regular face-to-face design review sessions
   - ☐ Ad hoc reviews triggered by identified conflicts
   - ☐ Other: _____
7. How frequently did coordination meetings occur during CAD-based design phases?
   - ☐ Daily
   - ☐ Weekly
   - ☐ Bi-weekly
   - ☐ Monthly
   - ☐ Only when conflicts arose
8. At what stage were most design conflicts identified during CAD-based coordination?
   - ☐ Early design / concept stage
   - ☐ Detailed design stage
   - ☐ Documentation / drawing production stage
   - ☐ During construction on site
9. What were the most common types of coordination failures experienced during CAD-based workflow? (Select all that apply)
   - ☐ Structural elements misaligned with architectural elements

- ☐ Incorrect floor levels or slab extensions
- ☐ Clashing openings (doors/windows) with structural columns or beams
- ☐ Inadequate circulation space due to structural elements
- ☐ Inconsistent dimensions between disciplines
- ☐ Missing information (e.g., slab openings for MEP services)
- ☐ Other: _____

10. How did late detection of design conflicts in the CAD phase impact project schedule?
    - ☐ Caused significant delays (more than 2 weeks) to design submission
    - ☐ Caused moderate delays (1 – 2 weeks)
    - ☐ Caused minor delays (less than 1 week)
    - ☐ No schedule impact
    - ☐ Not sure
11. How many design revision cycles were typically required due to coordination errors in CAD-based workflow?
    - ☐ 1 revision
    - ☐ 2-3 revision
    - ☐ 4-5 revision
    - ☐ More than 5 revisions

SECTION C: BIM-BASED COORDINATION AND PROJECT MANAGEMENT PERFORMANCE

12. Have you used BIM tools for design coordination?
    - ☐ Yes
    - ☐ No

13. Which BIM tools were used for coordination and clash detection on this project? (Select all that apply)
    - ☐ Autodesk Revit
    - ☐ Autodesk Navisworks
    - ☐ BIM 360 / Autodesk Construction Cloud
    - ☐ Inadequate circulation space due to structural elements

- ☐ Archicad
- ☐ Others

14. How effective was BIM in detecting design clashes before construction?
    - ☐ Very effective
    - ☐ Effective
    - ☐ Neutral
    - ☐ Not effective
    - ☐ Not sure
15. At what stage were most clashes identified using BIM?
    - ☐ Concept / schematic design stage
    - ☐ Effective
    - ☐ Documentation stage
    - ☐ Pre-construction / coordination stage
16. Compared to CAD-based coordination, how did BIM affect the number of design revision cycles?
    - ☐ Significantly reduced (more than 50% fewer revisions)
    - ☐ Moderately reduced (25 – 50% fewer revisions)
    - ☐ Slightly reduced (less than 25% fewer revisions)
    - ☐ No change
    - ☐ Increased revisions
17. How did BIM implementation affect the overall project schedule performance?
    - ☐ Significantly improved (helped keep the project on schedule)
    - ☐ Moderately improved
    - ☐ No noticeable impact
    - ☐ Negatively impacted (setup time caused initial delays)
    - ☐ Not sure
18. How did BIM affect communication and collaboration among the project team?
    - ☐ Greatly improved — all disciplines worked from a single coordinated model
    - ☐ Somewhat improved — reduced but did not eliminate coordination meetings
    - ☐ No change compared to CAD
    - ☐ Made collaboration more complex due to software learning curve
    - ☐ Not sure
19. Did BIM implementation help in reducing overall project rework costs?
    - ☐ Yes, significantly
    - ☐ Yes, moderately

☐ Minimal impact

☐ No

☐ Not sure

SECTION E: LIKERT SCALE, IMPACT OF BIM ON PROJECT MANAGEMENT PERFORMANCE

Please rate your level of agreement with each statement below regarding BIM as a project management tool.

Scale: SD = Strongly Disagree (1) D = Disagree (2) N = Neutral (3) A = Agree (4) SA = Strongly Agree (5)

20. Schedule and Time Management

	1	2	3	4	5
1. BIM implementation helped reduce schedule delays caused by design coordination failures					
2. Early clash detection through BIM enabled the project team to resolve issues before they affected the construction schedule					
3. The transition from CAD to BIM caused initial schedule delays due to setup and learning time					
4. BIM improved the predictability of the project timeline by reducing late-stage design changes					
5. BIM enabled faster decision-making that contributed to better schedule adherence					

21. Rework Reduction and Cost Performance

	1	2	3	4	5
1. BIM significantly reduced the number of design revision cycles compared to CAD					
2. Early clash detection through BIM prevented costly rework during the construction phase					
3. The cost of implementing BIM (software, training, setup) was justified by the savings in rework					
4. BIM reduced the number of change orders and on-site modifications caused by design errors					
5. Overall, BIM contributed to better project cost performance compared to CAD-based coordination					

22. Coordination Efficiency and Quality

	1	2	3	4	5
1. BIM enabled real-time coordination between architectural and structural design disciplines					
2. Automated clash detection in BIM was more reliable than manual checking in CAD					
3. BIM improved the overall quality and accuracy of design documentation					
4. BIM reduced dependency on frequent manual coordination meetings					
5. The integrated BIM model gave all team members a consistent and up-to-date view of the project					
6. BIM helped identify coordination issues that would have been missed using CAD					
7. BIM improved the completeness of design deliverables (fewer missing details or omissions)					

23. Communication, Collaboration and Stakeholder Management

	1	2	3	4	5
1. BIM improved communication between architectural and structural design teams					
2. BIM improved communication between the design team and the project client					
3. The 3D visualization provided by BIM helped stakeholders better understand the project design					
4. BIM fostered a more collaborative working environment among multidisciplinary teams					
5. BIM reduced misunderstandings and misinterpretations of design intent between disciplines					
6. BIM made it easier to report and document coordination issues to project management					

24. Risk Management

	1	2	3	4	5
1. BIM helped identify and mitigate design-related project risks at an early stage					
2. The use of BIM reduced the likelihood of unexpected design conflicts arising during construction					
3. BIM provided better documentation that supported project risk tracking and reporting					
4. Early clash detection through BIM reduced the overall risk profile of the project					

SECTION F: CHALLENGES OF BIM IMPLEMENTATION IN PROJECT MANAGEMENT CONTEXT

25. What were the main challenges faced when implementing BIM in this project? (Select all that apply)
    - ☐ Lack of BIM-trained professionals within the team
    - ☐ High cost of BIM software and hardware
    - ☐ Resistance to change from team members accustomed to CAD
    - ☐ Lack of organizational BIM standards and protocols
    - ☐ Interoperability issues between different software platforms
    - ☐ Time required to set up and learn BIM tools
    - ☐ Insufficient management support for BIM adoption
    - ☐ Others
26. How significant was the skills gap as a barrier to BIM implementation in your organization?
    - ☐ Very significant barrier
    - ☐ Significant barrier
    - ☐ Moderate barrier
    - ☐ Minor barrier
    - ☐ Not a barrier
27. In your view, what is the most important step needed to improve BIM adoption in Ethiopia's construction industry?

    _____

    _____

SECTION G: FINAL OPINION AND RECOMMENDATIONS

28. Overall, do you recommend BIM over traditional CAD as a project management tool for design coordination?
    - ☐ Strongly recommend
    - ☐ Recommend
    - ☐ Neutral
    - ☐ Do not recommend
    - ☐ Strongly do not recommend

29. From a project management perspective, what do you consider the single greatest benefit of BIM implementation?

_____

_____

30. What policy or organizational changes would you suggest to support BIM adoption in Ethiopian AEC projects?

_____

_____

31. Any additional comments or observations regarding BIM's impact on project performance at Ovid Kling Consult?

_____

_____

THANK FOR YOUR VALUABLE INPUT

CONTACT US

Liayared700@gmail.com **+251914649737**

Annex B: CAD Overlay Drawings

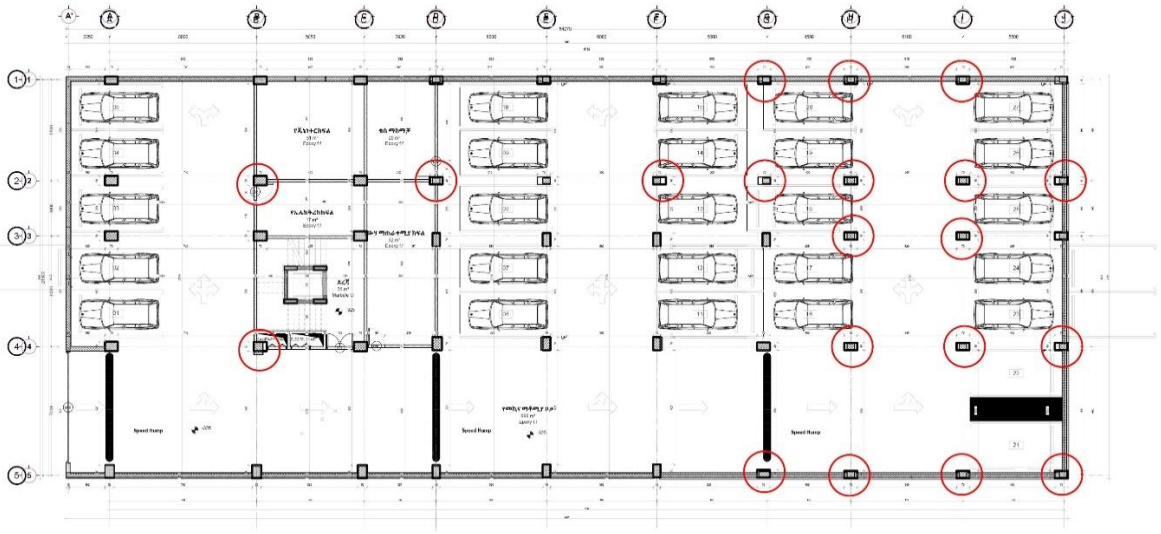


Figure B.1: Overlay of basement floor architectural and structural drawings used for manual coordination

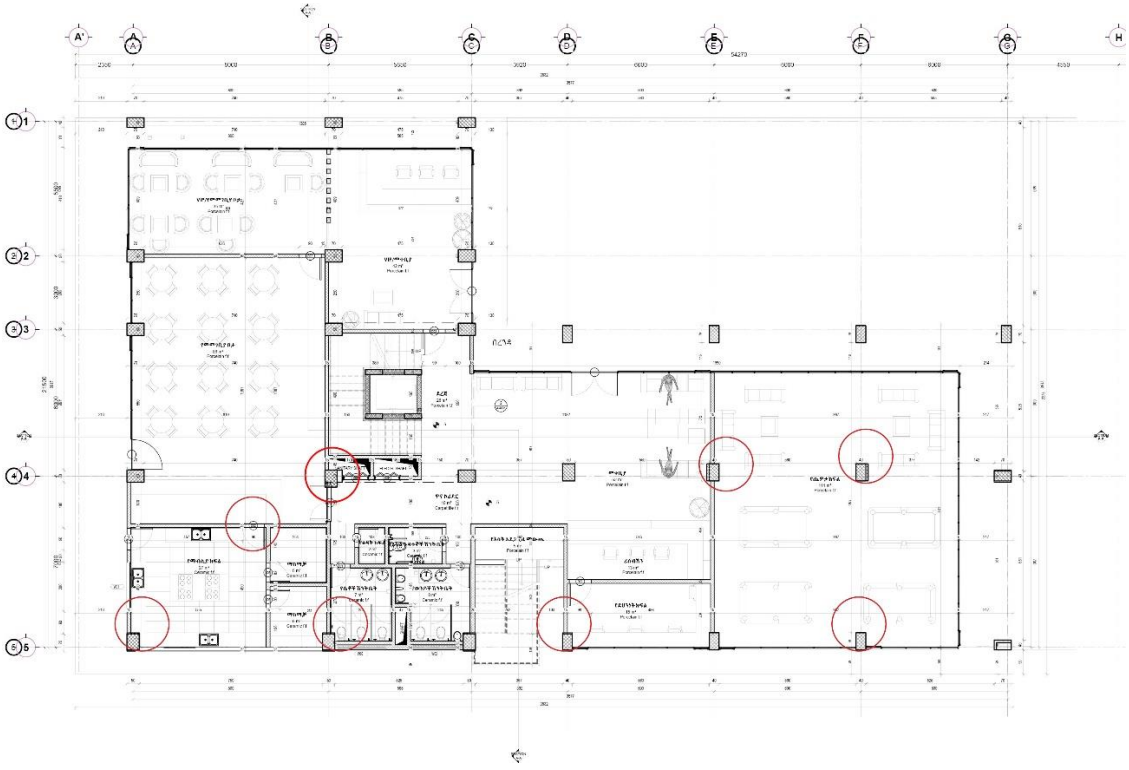


Figure B.2: Overlay of ground floor architectural and structural drawings



Figure B.3: Overlay of first floor architectural and structural drawings

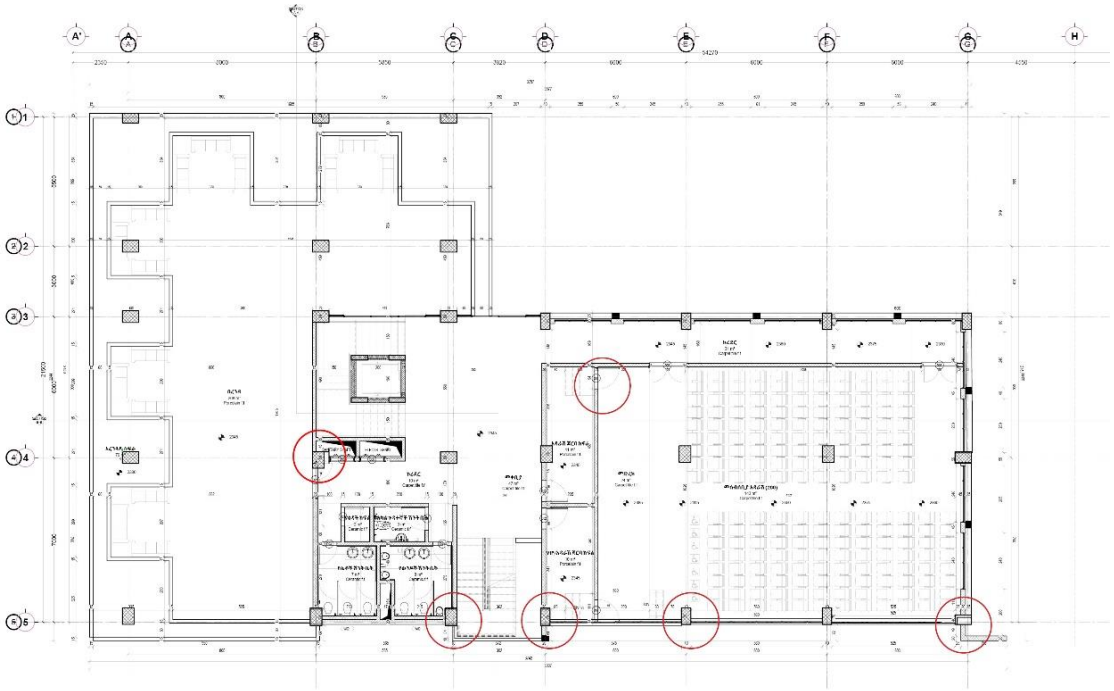


Figure B.4: Overlay of seventh floor architectural and structural drawings

Annex C: BIM Models



Figure C.1: Integrated BIM model of the Republican Guard Headquarters in Navisworks environment



Figure C.2: Architectural BIM model of the multipurpose hall

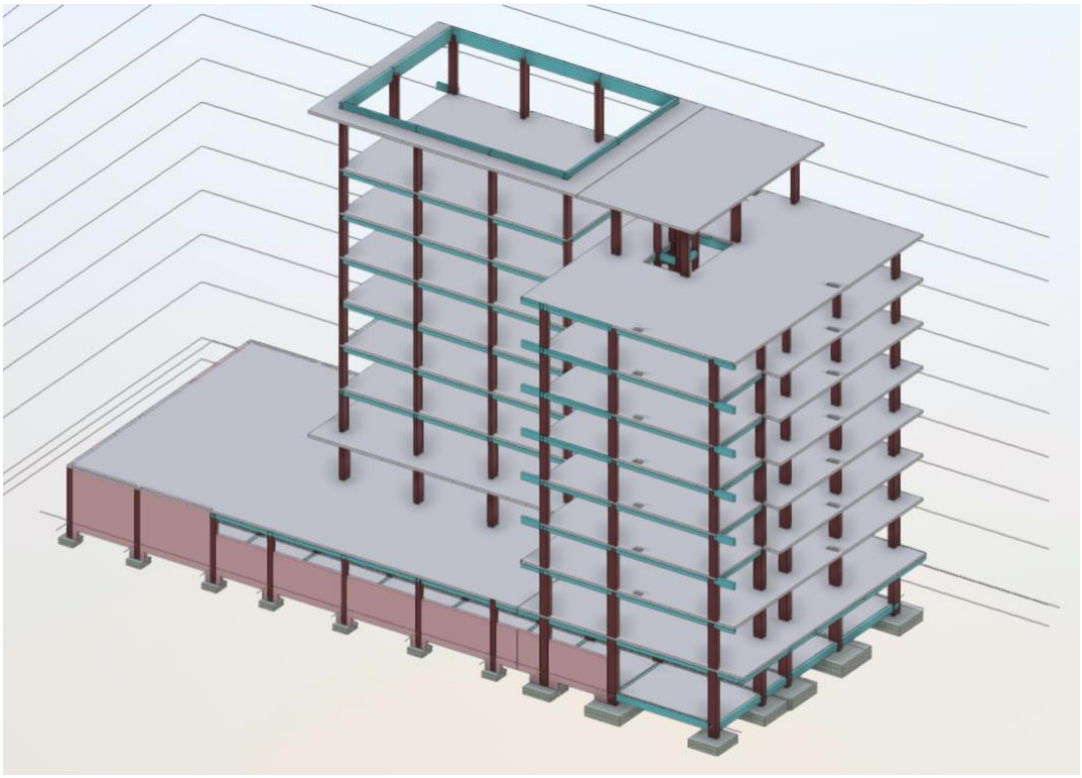


Figure C.3: Structural BIM model of the Republican Guard Headquarters

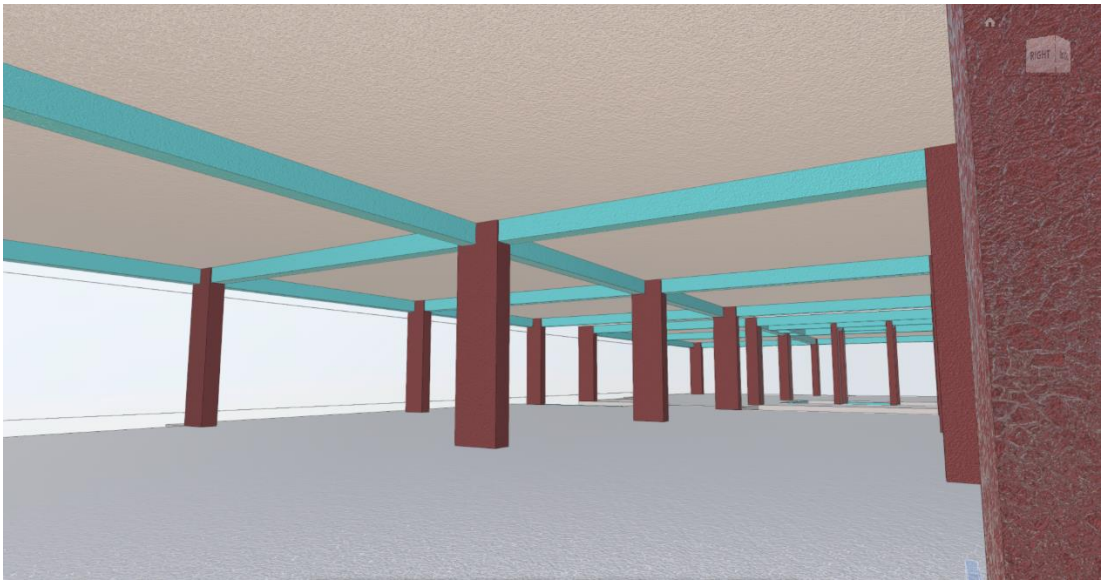


Figure C.4: Structural BIM model showing framing elements

Annex D: Clash Detection Results

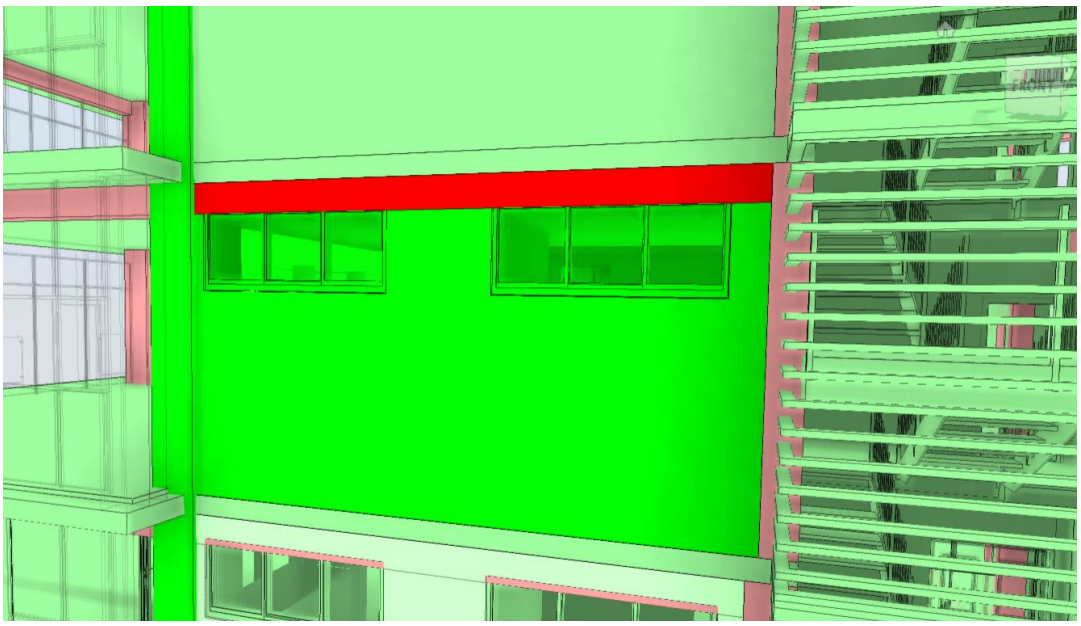


Figure D.1: Structural beam intersecting window opening

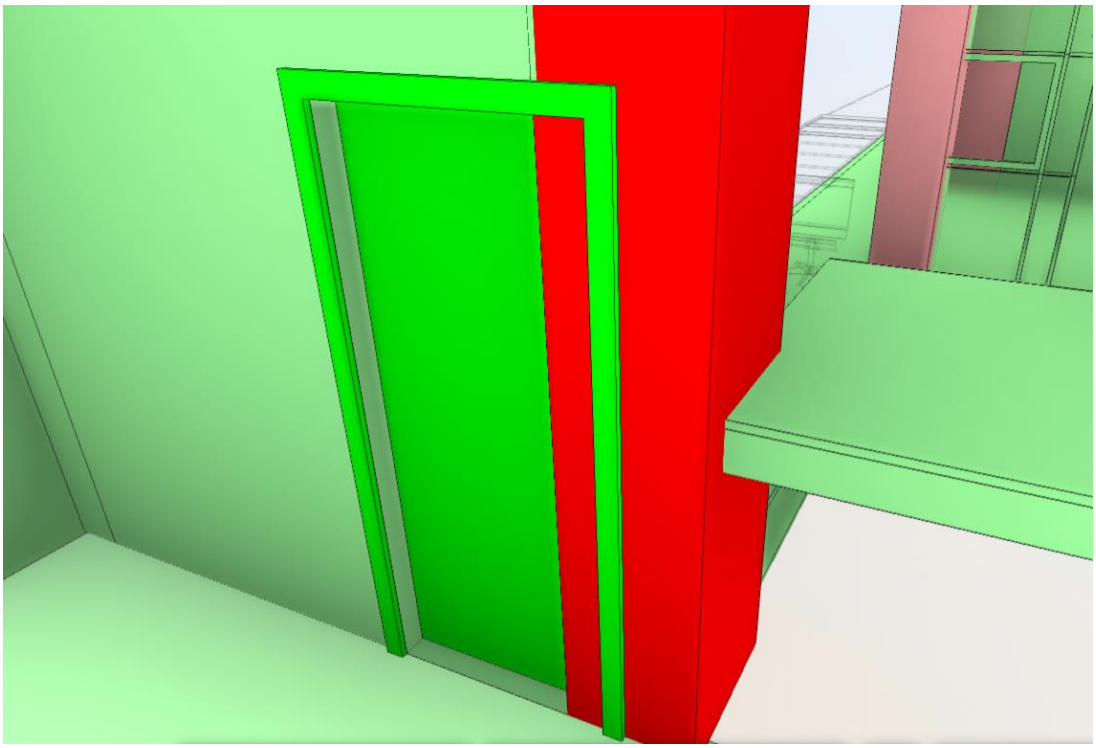


Figure D.2: Door opening intersecting structural column

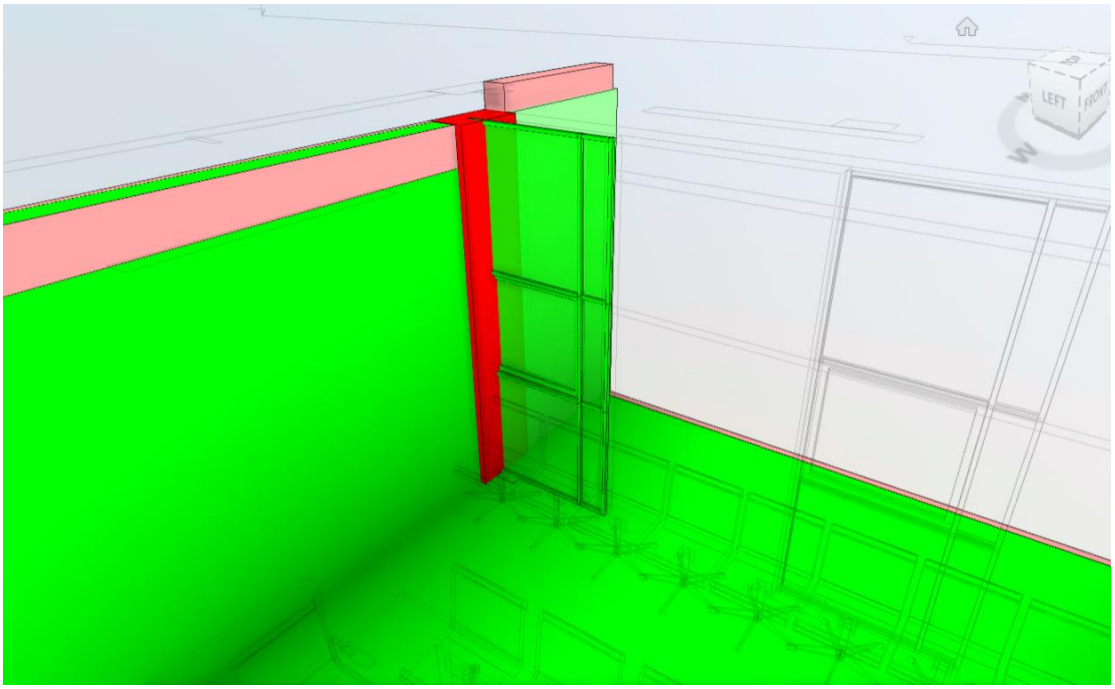


Figure D.3: Curtain wall overlapping with structural column

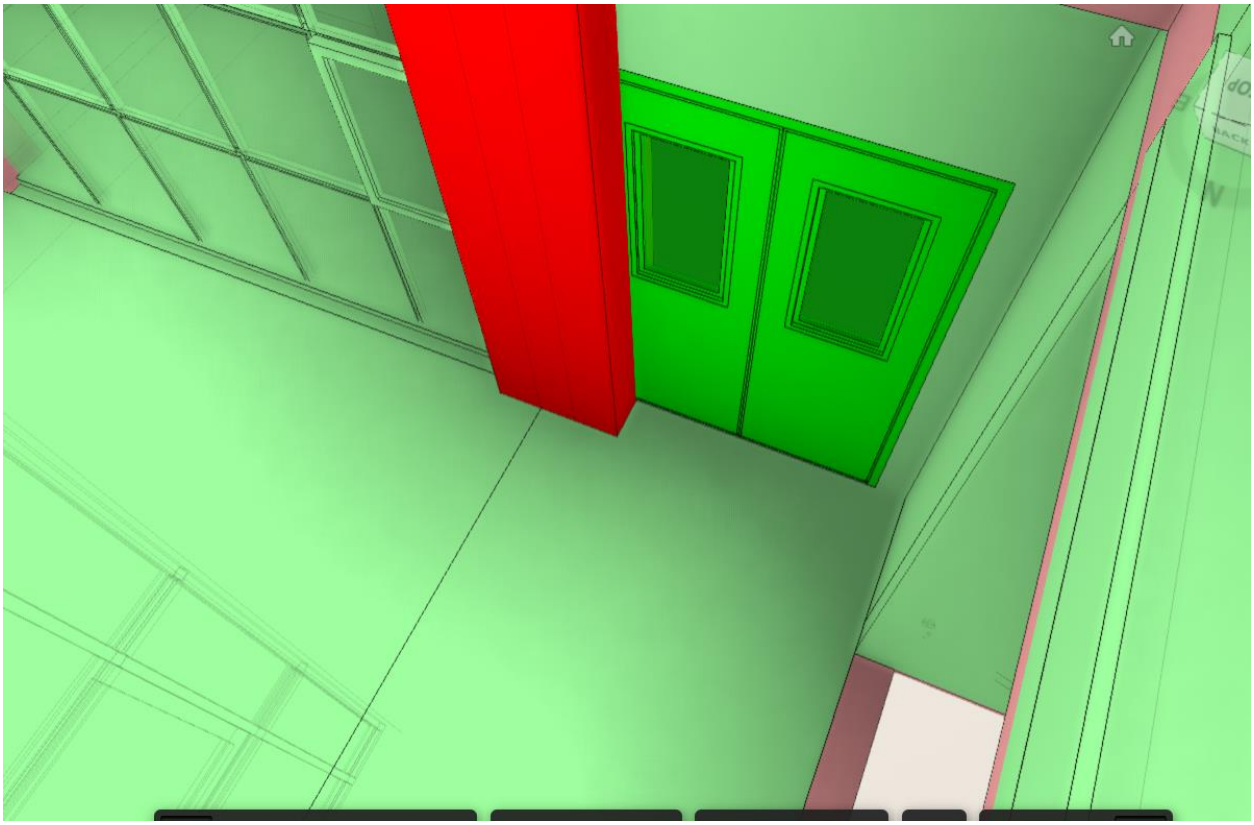


Figure D.4: Door placement conflicting with structural column