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A Strategic Prioritization Of Critical Success Factors For Bim Implementation In The Public Building Construction Sector In Addis Ababa: A Multi-Method Analysis

A Thesis Paper Submitted To Addis College Of Graduate Studies In Partial Fulfillment Of The Requirements For The Award Of master's degree in construction technology and management

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DECLARATION FORM

I hereby declare that the thesis proposal entitled "A Strategic Prioritization of Critical Success Factors for BIM Implementation in the Public Building Construction Sector in Addis Ababa: A Multi-Method Analysis" is based on my original work and has not been presented for a degree of any other university to the best of my knowledge and all the resources or materials used for the thesis proposal have been duly acknowledged.

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This is to certify that this study, "A Strategic Prioritization of Critical Success Factors for BIM Implementation in the Public Building Construction Sector in Addis Ababa: A Multi-Method Analysis" has been carried out by Shimelis Denberu Aklilu, for the partial fulfillment of the requirement masters of Science in construction technology and management at Addis College, is an original work and not submitted earlier for any degree either at this University or any other University.

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ABSTRACT

The adoption of Building Information Modeling (BIM) in Addis Ababa public construction sector is hindered by multiple barriers and the absence of a clear implementation strategy. This study develops a strategic framework by identifying, prioritizing, and analyzing the structural interrelationships of Critical Success Factors (CSFs) for BIM adoption in Addis Ababa's public building projects. A sequential mixed-method design was employed. Sixteen CSFs were identified from literature and validated through semi-structured interviews with seven purposively selected experts. Quantitative data were then collected from a panel of eleven senior professionals using purposive and expert sampling techniques. The Analytical Hierarchy Process (AHP) was applied to determine the relative importance of the CSFs, while Interpretive Structural Modeling (ISM) was used to map their interdependencies. Analyses were conducted using a combination of software tools, where Microsoft Excel was utilized for initial data organization and management, while all core computations and visualizations for the AHP, ISM, and MICMAC analyses were performed using custom scripts developed in the Python programming language and executed within the Google Colab cloud environment. Findings from the AHP indicate that "Government policy and mandates" (CSF2) is the most critical factor (Global Weight = 0.19), followed by "Top management support" (CSF1) (Global Weight = 0.1538). ISM-MICMAC analysis further confirms CSF2 as the most powerful driver (Driving Power = 10), positioned at the foundation of the hierarchical model. The integrated framework categorizes CSFs into four strategic quadrants: Strategic Drivers (e.g., government policy, skilled workforce), Critical Outcomes (e.g., top management support), Key Enablers (e.g., technological readiness), and Minor Factors. This study offers the first empirically grounded, multi-method strategic framework for BIM implementation in Ethiopia. By moving beyond simple rankings, it provides stakeholders with a nuanced understanding of systemic CSF interrelationships and an actionable roadmap for targeted interventions in the public construction sector.

Keywords: ***Building Information Modeling (BIM), Critical Success Factors (CSFs), Ethiopia, Analytical Hierarchy Process (AHP), Interpretive Structural Modeling (ISM), Public Sector Construction***

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LIST OF ABBREVIATIONS AND OR ACRONYMS

AC…………..........	Addis College
AAU……………......	Addis Ababa University
AHP …...................	Analytic Hierarchy Process
BIM……………........	Building Information Modelling
FDRE…...................	Federal Democratic Republic of Ethiopia
CSF……………......	critical success factors
ISM……………......	Interpretive Structural Modeling
MICMAC…….........	Cross-Impact Matrix Multiplication Applied to Classification
ECMI……….........	Ethiopian Construction Management Institute
ECPMI…….............	Ethiopian Construction Project Management Institute
TOE……………....	Technology-Organization-Environment
DOI……………….	Diffusion of Innovation theory
TAM……………...	Technology Acceptance Model
PU………………...	Perceived Usefulness
PEOU…………….	Perceived Ease of Use
CDBB………………	for Digital Built Britain.
JIT………………….	Just in Time
IFC…………….......	Industry Foundation Classes

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CHAPTER ONE

1 INTRODUCTION

The construction industry is undergoing a rapid transformation driven by digital technologies, with Building Information Modeling (BIM) emerging as one of the most significant innovations in recent decades. Despite its proven benefits, such as improving collaboration, enhancing project visualization, reducing costs, and enabling data-driven decision-making the successful implementation of BIM remains a challenge in many developing contexts. In Ethiopia, particularly in Addis Ababa's public construction sector, BIM adoption is still at a nascent stage. While some initiatives have been introduced through government policies and institutional efforts, numerous barriers such as limited awareness, inadequate technological readiness, lack of skilled professionals, and absence of clear standards continue to hinder widespread implementation. This situation highlights the urgent need to identify and prioritize the Critical Success Factors (CSFs) that can facilitate effective BIM adoption in the Ethiopian context. Accordingly, this chapter introduces the background of the study, outlines the research problem, defines the objectives and research questions, highlights the significance and scope of the research, and presents the organization of the thesis.

1.1 Background of Study

The global construction industry, a significant engine of economic growth and infrastructure development, has long been characterized by persistent inefficiencies. Traditional project delivery methods are frequently plagued by challenges such as cost overruns, schedule delays, and compromised quality, which stem from issues like fragmented communication, poor stakeholder coordination, and a heavy reliance on two-dimensional documentation (Aibinu & Al-lawati, 2010; Ozorhon & Karahan, 2017). In response to these systemic problems, Building Information Modeling (BIM) has emerged globally as a transformative digital technology and process. BIM offers an integrated approach to designing, constructing, and managing buildings and infrastructure, facilitating enhanced collaboration, improved visualization, and data-driven decision-making throughout the project lifecycle (Yusuf et al., 2012).

While developed nations have made significant strides in BIM adoption, often supported by government mandates and established industry standards, the implementation trajectory in developing countries presents a different set of complexities. In these contexts, the potential benefits of BIM are arguably even more critical, yet its adoption is often hindered by more pronounced barriers. These include inadequate technological infrastructure, a shortage of skilled professionals, weak institutional and regulatory frameworks, and significant financial constraints (Antwi-Afaria et al, 2018).

The construction sector in Ethiopia exemplifies this dynamic. It stands as a cornerstone of the national economy, accounting for a substantial portion of the country's Gross Domestic Product (National Bank of Ethiopia, 2020). Despite its vital role, the industry is notoriously beset by the very challenges BIM is designed to mitigate, including project delays, budget overruns, and quality deficiencies that undermine its overall performance (Girma, 2020; Hailu Zewdie, 2016). The conventional, fragmented nature of project delivery, particularly within the public building sector in Addis Ababa, is a primary contributor to these issues, marked by poor communication and coordination among stakeholders (Yimam, 2011).

Recognizing this potential, the Ethiopian government, through bodies such as the Ethiopian Construction Project Management Institute (ECPMI), has acknowledged the importance of BIM and initiated preliminary steps towards its adoption, including the development of a strategic roadmap (Tessema, 2021). However, implementation remains in its nascent stages, impeded by a multitude of localized barriers. Recent studies have consistently identified a lack of skilled professionals, inadequate training opportunities, the absence of clear guidelines and standards, and insufficient government support as critical obstacles in the Ethiopian context (Alemayehu et al., 2022; Belay et al., 2021; Kebede, 2021).

Although these barriers are known, there remains a critical gap in the existing research: a lack of strategic prioritization and structural analysis of the Critical Success Factors (CSFs) required to overcome them. While studies may list various factors, they often treat them as isolated elements without determining their relative importance or understanding their complex interrelationships within the specific context of Addis Ababa's public construction sector. Without a clear hierarchy and an understanding of the cause-and-effect dynamics between these factors, stakeholders' efforts to promote BIM adoption risk being scattered, inefficient, and ultimately ineffective.

Therefore, this research aims to address this gap by moving beyond simple identification. It seeks to systematically identify, prioritize, and analyze the hierarchical structure and interdependencies of CSFs for BIM implementation. By employing a multi-method approach that combines the Analytical Hierarchy Process (AHP), Interpretive Structural Modeling (ISM), and MICMAC analysis, this study intends to develop a robust, evidence-based strategic framework. This framework will provide actionable insights for policymakers, public sector clients, and construction firms, guiding targeted interventions to enhance BIM adoption and effectiveness in Addis Ababa.

1.2 Statement of the Problem

BIM (Building Information Modeling) is widely recognized globally for improving efficiency, collaboration, cost savings, and sustainability in construction projects. In many developed countries (e.g., UK, USA, Singapore), BIM has become mandatory in public projects, leading to measurable improvements in project delivery. However, in developing countries like Ethiopia specifically in Addis Ababa, BIM adoption is still at an early and fragmented stage.

The construction sector in Ethiopia contributes significantly to the economy Accounts for 29.2% of GDP (National Bank of Ethiopia, 2020). Within the industry sector, construction contributes 68.5% (National Bank of Ethiopia, 2020). Despite this economic significance, the sector faces low productivity, high project delays, and cost overruns (World Bank, 2019; UN-Habitat, 2021).Studies (Belay et al., 2021; Waheed et al., 2024) highlight limited BIM awareness, lack of standards, weak policy enforcement, insufficient training, and resistance to change as key barriers. Government initiatives through ECPMI (Ethiopian Construction Project Management Institute) have started roadmaps and training programs, but these remain at pilot levels with no large-scale, sustainable implementation.

While the Ethiopian government, through institutions like the Ethiopian Construction Project Management Institute (ECPMI), has acknowledged the importance of BIM and initiated its adoption, the implementation remains in its nascent stages. The ECPMI has been involved in creating a BIM roadmap and providing training to professionals in the sector (Tessema, 2021). However, the widespread and effective implementation of BIM in Addis Ababa's public building construction sector is impeded by a multitude of barriers. Studies have consistently identified a lack of BIM standards, insufficient awareness and knowledge, a shortage of trained professionals, and limited government support as critical obstacles (Kebede, 2021). (Alemayehu et al.,2022) specifically highlighted the absence of BIM professionals, inadequate training opportunities, a lack of BIM-ready stakeholders, and the absence of clear guidelines and supportive delivery methods as top barriers in the Ethiopian context. Furthermore, (belay et al.,2021) pointed to inadequate IT infrastructure and the need for more BIM-related research and university courses as significant hindrances.

Although the benefits of BIM, such as improved communication, early multidisciplinary coordination, and enhanced visualization, are acknowledged by professionals in Ethiopia, a comprehensive understanding of the critical success factors (CSFs) essential for overcoming the aforementioned barriers is lacking (Waheed et al., 2024). Previous research has identified various CSFs for BIM implementation in developing countries, including government support, adequate training, and process re-engineering (Aibinu & Al-lawati, 2010; Ozorhon & Karahan, 2017). However, the unique socio-technical and economic context of Addis Ababa's public construction sector necessitates a localized and strategic approach to prioritizing these factors. Without a clear understanding of which CSFs are most critical and how they interrelate, efforts to promote BIM are likely to be inefficient and ineffective. This research, therefore, seeks to address this gap by systematically identifying, prioritizing, and analyzing the interdependencies of CSFs for BIM implementation in public building construction projects in Addis Ababa. The aim is to develop a strategic framework that can guide policymakers, public clients, and construction firms in their efforts to leverage BIM for improved project delivery and enhanced sector performance.

1.3 Objectives of the Study

1.3.1 General Objective

The general objective of this research is to systematically identify and strategically prioritize the critical success factors influencing the effective implementation of Building Information Modeling (BIM) within the public building construction sector in Addis Ababa, using a comprehensive multi-method analytical approach.

1.3.2 Specific Objectives

To systematically address the research problem and achieve the general objective, this study is guided by the following specific objectives:

1. To identify a validated list of Critical Success Factors (CSFs) relevant to BIM implementation within the specific context of the public building construction sector in Addis Ababa.
2. To determine the relative importance of the identified CSFs for BIM implementation in Addis Ababa using the Analytical Hierarchy Process (AHP).
3. To model the hierarchical structure among the identified CSFs using Interpretive Structural Modeling (ISM).
4. To classify the CSFs into distinct categories based on their driving power and dependence using Cross-Impact Matrix Multiplication Applied to Classification (MICMAC) analysis.
5. To develop an integrated strategic framework by categorizing the CSFs into distinct quadrants based on their AHP-derived importance (priority) and ISM/MICMAC-derived influence, facilitating targeted intervention strategies.

1.4 Research Questions

This study is structured around carefully formulated questions that directly correspond to its specific objectives. These questions serve as the foundation for investigating the factors influencing BIM implementation in Ethiopia's public construction industry, and they are designed to provide both theoretical insights and practical solutions. By systematically addressing these questions, the research ensures clarity of focus, methodological consistency, and alignment between objectives, data collection, and analysis. The key research questions are therefore articulated as follows.

1. What are the relevant Critical Success Factors (CSFs) for BIM implementation in the public building construction sector of Addis Ababa?
2. What is the relative importance of these CSFs according to industry experts in Addis Ababa?
3. How are the identified CSFs hierarchically structured?
4. Based on their interrelationships, how can the CSFs be classified in terms of their driving power and dependence?
5. What strategic framework can be developed by integrating priority, hierarchy, and driver-dependence analysis to guide effective BIM implementation in the target sector?

1.5 Significance of Study

The significance of this research lies in its pivotal contribution to both practice and theory regarding technology adoption within the construction industry of a developing nation. Practically, this study provides an urgently needed, evidence-based strategic framework for stakeholders in Ethiopia's public construction sector. By moving beyond a mere enumeration of potential success factors, the research offers a prioritized and structurally analyzed roadmap that provides actionable guidance for policymakers in developing targeted mandates, for construction firms in allocating resources for training and technology, and for academic institutions in reforming their curricula to meet industry demands.

The findings are intended to help accelerate BIM adoption, thereby addressing long-standing industry challenges of project delays, cost overruns, and poor quality, ultimately enhancing the efficiency and value delivery of public infrastructure projects in Addis Ababa. Theoretically, the study enriches the existing body of knowledge by applying an integrated multi-method approach (AHP, ISM, MICMAC) to analyze BIM implementation in a public sector context within a developing country, a domain that remains underexplored. This provides a nuanced model that highlights the supreme importance of governmental drivers in such environments, offering a valuable comparative perspective to studies conducted in more mature markets.

1.6 Scope of the Study

This study is encircled thematically, spatially, and temporally to maintain clarity, precision, and focus in addressing the stated research objectives. The thematic delimitation defines the specific concepts, variables, and issues under investigation, ensuring that the research remains aligned with its core purpose and avoids unnecessary deviations. The spatial delimitation establishes the geographical boundaries within which the study is conducted, thereby situating the findings within a defined context. The temporal delimitation specifies the time frame covered by the study, providing a clear boundary for data collection, analysis, and interpretation. Together, these delimitations enhance the study's coherence and enable a more systematic and manageable exploration of the research problem.

a. Thematic Scope

The research thematically concentrates on the Critical Success Factors (CSFs) for the implementation of Building Information Modeling (BIM) in the public building construction sector. It emphasizes the identification, prioritization, and structuring of factors that influence BIM adoption, such as organizational culture, technological readiness, top management support, skilled workforce, financial capacity, regulatory frameworks, and stakeholder collaboration. The study employs multi-method analysis using the Analytic Hierarchy Process (AHP) and MICMAC analysis, to analyze the hierarchical relationships and interdependencies among these factors. The focus is strictly on public building projects, while other sectors such as purely private housing, transportation infrastructure (roads, bridges), or unrelated industries are not included.

b. Spatial Scope

Geographically, the study is confined to Addis Ababa, Ethiopia, the capital city and administrative center of the country. Addis Ababa was selected due to its concentration of large-scale public building projects and the presence of key stakeholders such as the Ethiopian Construction Works

Corporation (ECWC), Oromia Construction Corporation (OCC), Federal Housing Corporation (FHC), Engineering Corporation of Oromia (ECO), and Addis Ababa Design and Construction Works Bureau, along with major private contractors and consultants. The findings are therefore context-specific to Addis Ababa but may also provide insights applicable to other Ethiopian regions with similar construction dynamics.

c. Temporal Scope

The temporal boundary of this study is dual. First, it considers the last decade (2015–2025) as the historical reference period during which Ethiopia's construction industry has undergone significant urban growth and an increasing push for digital adoption. This provides context for understanding the progression of BIM awareness and its current challenges. Second, the research implementation period (2024–2025) marks the specific timeframe for data collection, expert interviews, and analysis, ensuring that the findings reflect up-to-date realities in the industry. While future implications of BIM adoption may be discussed in the recommendations, the empirical scope remains limited to factors relevant up to 2025.

1.7 Limitations of the Study

While this study makes significant contributions to understanding the critical success factors (CSFs) for BIM implementation in public building projects in Addis Ababa, it is not without limitations. From those limitations the majors as discussed below.

a. Geographical Limitation: The research is spatially confined to Addis Ababa, which is the hub of most public building projects in Ethiopia. Although the findings provide valuable insights, they may not fully represent the conditions of other Ethiopian regions, especially rural or less urbanized areas where construction practices and resources differ.
b. Sectoral Limitation: The study specifically targets the public building construction sector. Other construction sectors such as transport infrastructure (roads, bridges, and railways), industrial facilities, and residential housing projects are excluded. Therefore, the conclusions may not be generalizable to these sectors without further validation.

c. Data Source Limitation: The research relies heavily on expert opinions, survey responses, and secondary literature. Since expert judgment is subjective, there is a possibility of bias in pairwise comparisons and prioritizations, particularly in methods such as AHP and MICMAC analysis. Although consistency checks were applied, complete objectivity cannot be guaranteed.
d. Temporal Limitation: The study focuses on the period between 2015 and 2025, with data collection conducted mainly in 2024–2025. Considering the rapid pace of technological development, the findings may evolve as new BIM technologies, policies, and international standards (such as ISO 19650) continue to emerge.
e. Resource and Accessibility: Limitation Due to constraints of time, finance, and accessibility, the research does not cover a wider pool of stakeholders (e.g., all contractors, clients, and government offices). The study primarily included participants who were available and willing to provide responses, which may affect the completeness of the dataset.

1.8 Thesis Structure

This thesis is organized into five distinct chapters to present the research in a logical and coherent manner. Chapter One introduces the research, establishing the context by outlining the background of the study, defining the statement of the problem, and articulating the research questions and objectives. It also details the significance, scope, and limitations of the investigation, providing a comprehensive overview of the research undertaking.

Chapter Two presents a comprehensive literature review. This chapter explores the theoretical foundations of Building Information Modeling, its global implementation trends, and its specific context within Ethiopia. It delves into the concept of Critical Success Factors (CSFs) and reviews the methodological approaches namely AHP, ISM, and MICMAC that form the analytical basis for this study, culminating in the identification of a critical research gap. Chapter Three details the research methodology. It explains the sequential mixed-methods design, describes the population and the purposive sampling techniques used, and outlines the phased data collection procedures and instruments. This chapter provides a step-by-step account of the analytical methods applied to the qualitative and quantitative data.

Chapter Four presents the results and discussion of empirical findings. This core chapter details the validated list of CSFs, presents the prioritization results from the AHP analysis, illustrates the hierarchical model derived from the ISM analysis, and discusses the influence dynamics revealed by the MICMAC analysis. It culminates in the presentation and interpretation of the integrated strategic framework. Chapter Five concludes the thesis. It summarizes the key findings of the research, draws overarching conclusions, and proposes a set of actionable recommendations for key industry stakeholders. The chapter concludes by suggesting potential directions for future research to build upon the work presented herein.

CHAPTER TWO

LITERATURE REVIEW

2. Introduction

Building Information Modeling (BIM) has emerged as one of the most transformative innovations in the global construction industry, revolutionizing how projects are conceived, designed, executed, and managed throughout their lifecycle. It facilitates digital representation, coordination, and integration among multidisciplinary teams, enabling enhanced collaboration, cost efficiency, and project quality. By creating a shared information environment, BIM bridges the traditional fragmentation of the construction process and promotes a data driven approach to decision-making across all project stages.

Despite its proven potential, BIM implementation in developing countries, including Ethiopia, remains at an early and often fragmented stage. In contexts such as Addis Ababa's public building construction sector, several systemic barriers, such as limited technical capacity, lack of standardized policies, insufficient stakeholder awareness, and resource constraints continue to hinder full-scale adoption. These challenges not only delay digital transformation but also impede productivity and efficiency gains that are vital for the sustainable development of the national construction industry.

Recognizing these constraints, the identification and prioritization of Critical Success Factors (CSFs) become essential. CSFs refer to the key conditions, enablers, or drivers that must be effectively managed to ensure successful BIM adoption. This study adopts a multi-method approach combining qualitative exploration with quantitative prioritization to identify, analyze, and structure the CSFs relevant to Addis Ababa's public construction sector. The literature review therefore plays a foundational role in this research. It provides a conceptual, theoretical and empirical basis for defining the research problem, framing the analytical model, and identifying methodological gaps that justify the present study. Accordingly, this chapter systematically reviews existing literature under three main dimensions.

2.1 Theoretical Review

Theoretical literature provides conceptual frameworks and models that explain why and how BIM is adopted and the role of Critical Success Factors (CSFs) in achieving successful implementation. The theories offer insights into technology adoption, organizational dynamics, interrelationships among factors, and prioritization strategies. A strong theoretical foundation is essential to guide research design, methodology, and analysis

The Critical Success Factor (CSF) Theory introduced by (Rockart,1979, emphasizes that certain key areas must be prioritized and managed effectively to ensure organizational success. In the context of Building Information Modeling (BIM), this theory provides a strategic lens for identifying foundational elements that drive successful implementation. These include strong leadership to champion change, comprehensive training programs to build technical capacity, and robust infrastructure to support digital workflows. Without attention to these CSFs, BIM initiatives risk stagnation or failure, especially in complex public sector environments like Addis Ababa, where institutional inertia and resource constraints can pose significant challenges.

The Diffusion of Innovation Theory by (Rogers,2003) offers a behavioral and sociological perspective on how new technologies like BIM spread within organizations and across sectors. It highlights five key attributes relative advantages, compatibility, complexity, trialability, and observability that influence the rate and success of adoption. For Addis Ababa's public institutions, understanding how BIM aligns with existing practices (compatibility) and the perceived benefits it offers (relative advantage) is essential for crafting effective change management strategies. Moreover, the theory underscores the importance of early adopters and opinion leaders in accelerating diffusion, suggesting that targeted engagement with influential stakeholders could catalyze broader acceptance.

The Technology Acceptance Model (TAM) further deepens this understanding by focusing on individual attitudes toward technology. Developed to explain user acceptance of information systems, TAM identifies perceived usefulness and perceived ease of use as the primary drivers of adoption. In the BIM context, stakeholders ranging from engineers and architects to policymakers must believe that BIM will enhance their productivity and decision-making capabilities. Simultaneously, the system must be intuitive and accessible enough to minimize resistance. In Addis Ababa's public sector, where digital literacy levels and exposure to advanced technologies may vary widely, TAM provides a valuable framework for assessing readiness and tailoring interventions that address psychological and practical barriers to adoption.

Together, these three theories form a comprehensive foundation for analyzing and guiding BIM implementation. CSF Theory pinpoints what must be done, Diffusion of Innovation explains how change spreads, and TAM reveals why individuals choose to embrace or reject new technologies. Applying this integrated theoretical approach can help policymakers, project managers, and institutional leaders in Addis Ababa design more effective strategies for embedding BIM into public infrastructure development, ultimately driving efficiency, transparency, and innovation across the sector.

To effectively analyze and prioritize Critical Success Factors (CSFs) for Building Information Modeling (BIM) implementation in Addis Ababa's public sector, this study integrates multiple decision-making and modeling approaches rooted in established theoretical foundations. Multi-Criteria Decision-Making (MCDM) techniques offer a systematic way to evaluate complex decisions involving multiple factors. Among these, the Analytic Hierarchy Process (AHP), developed by Saaty (1980), provides a structured methodology for ranking alternatives based on expert judgment. AHP facilitates the quantification of the relative importance of CSFs by enabling pairwise comparisons and generating weighted scores. This ensures that decision-makers can prioritize BIM-related factors such as leadership, training, and infrastructure based on their strategic significance.

Systems Theory views BIM implementation not as an isolated initiative, but as a dynamic system composed of interdependent components. This perspective justifies the use of Interpretive Structural Modeling (ISM) and MICMAC analysis to explore the relationships and dependencies among CSFs. ISM helps construct a hierarchical model that reveals how certain factors influence others, uncovering hidden structural patterns that may not be immediately apparent. Structural

Modeling Theory underpins ISM’s capability to map these interconnections, offering a deeper understanding of the systemic nature of BIM adoption.

Building on ISM, MICMAC (Cross-Impact Matrix Multiplication Applied to Classification) analysis categorizes CSFs based on their driving power and dependence, allowing for the identification of autonomous, dependent, linkage, and driving factors. This classification is crucial for strategic planning, as it highlights which factors should be addressed first to trigger broader systemic change.

By combining AHP, ISM, and MICMAC, the study develops a quadrant-based framework that supports targeted interventions. This integrated approach enables policymakers and practitioners to not only prioritize CSFs but also understand their structural roles within the BIM ecosystem. Such a framework is instrumental in designing phased implementation strategies, allocating resources efficiently, and ensuring sustainable adoption across Addis Ababa’s public sector

2.2 Conceptual Literature

Conceptual literature forms the foundation for understanding the key constructs, frameworks, and interrelationships that explain how Building Information Modeling (BIM) can be effectively implemented within the construction industry. It links theoretical assumptions with empirical evidence by integrating insights from previous studies that have examined the factors influencing BIM adoption, their causal linkages, and the mechanisms through which they contribute to project performance and digital transformation.

BIM implementation is conceptualized as a multi-dimensional and systemic process that requires alignment among organizational capacity, technological readiness, human competence, and supportive government policies. Drawing from established theoretical models such as the Technology–Organization–Environment (TOE) Framework, Diffusion of Innovation (DOI) Theory, and Unified Theory of Acceptance and Use of Technology (UTAUT), this study conceptualizes BIM implementation as an outcome of interdependent factors working in synergy.

The proposed conceptual framework therefore positions BIM implementation as the dependent variable, while the Critical Success Factors (CSFs) are categorized as independent variables under five major dimensions:

Management and Organizational Factors: including top management support, financial readiness, and change management.

Policy and Standards Factors: covering government mandates, standardization, and client requirements.

Training and Resource Factors: encompassing workforce competence, education integration, and availability of BIM consultants.

Technology and Process Factors: addressing technological readiness, interoperability, and pilot project implementation.

Environmental and Institutional Factors: focusing on awareness campaigns, professional collaboration, and industry-wide support mechanisms.

The conceptual framework emphasizes that these factors interact dynamically rather than functioning in isolation.

2.2.1 Definition of Key Terms

This section defines the key terms, concepts, and technical language used throughout the study. While some of these words may carry different meanings in everyday usage, they are assigned specific and precise definitions within the context of this research. This ensures that readers and fellow researchers interpret them accurately and consistently in relation to the study's framework.

Table 2.1 Definition of Key Terms

Term	Definition
Building Information Modeling (BIM)	A digital process that integrates multi-dimensional data (3D, 4D, 5D, and beyond) support planning, design, construction, and operation of buildings, enabling collaboration among stakeholders.
Critical Success Factors (CSFs)	The essential organizational, technical, human, and policy-related conditions that must be achieved for the successful adoption and implementation of BIM.
Public Building Construction Sector (Ethiopia)	Government-owned or funded building projects in Ethiopia, including offices, schools, hospitals, and infrastructure facilities, managed under public procurement and regulatory frameworks.
Sequential Mixed-Method Research	A research design combining qualitative and quantitative approaches in a stepwise manner, first identifying factors through expert interviews, then prioritizing and structuring them through surveys and modeling techniques.
Analytical Hierarchy Process (AHP)	A structured decision-making method used to prioritize CSFs by assigning relative weights through pairwise comparison of factors.
Interpretive Structural Modeling (ISM)	A methodology for analyzing and structuring the interrelationships among CSFs, producing a hierarchical model of influence.
MICMAC Analysis	A classification tool that categorizes CSFs based on their driving power and dependence power into four groups: autonomous, dependent, linkage, and independent drivers.

Driving Power	The extent to which a factor influences other CSFs in BIM implementation.
Dependence Power	The extent to which a factor is influenced or controlled by other CSFs.
Strategic Drivers	High-influence CSFs (e.g., government policy, training, skilled workforce) that form the foundation of BIM adoption strategies.
Key Enablers	Supporting CSFs (e.g., ICT infrastructure, technical readiness) that facilitate implementation but depend on strategic drivers.
Critical Outcomes	Results of successful BIM implementation, such as improved project performance, stakeholder collaboration, and management efficiency.
Linkage Factors	CSFs that both influence and are influenced by other factors, creating feedback loops in the BIM adoption process.
Autonomous Factors	CSFs with weak driving and dependence power play a limited role in BIM adoption.
Expert Sampling (Purposive Sampling)	A non-probability sampling technique where participants are selected based on their expertise in BIM, construction management, or policy to provide informed judgments.
Super Decisions Software	A decision-support tool used to calculate weights in AHP and analyze priorities among CSFs.
ISM-MICMAC Framework	An integrated modeling approach combining ISM and MICMAC analysis to map both the hierarchical structure and classification of CSFs for BIM adoption.

Construction Industry (Ethiopia)	The sector comprising public and private organizations engaged in design, supervision, and execution of building and infrastructure projects in Ethiopia.
Adoption Barriers	Challenges hindering BIM implementation, such as lack of policy, limited technical skills, financial constraints, and resistance to change.
Implementation Framework	A structured guideline or roadmap that outlines how BIM can be systematically introduced and managed in Ethiopia's public construction projects.
Custom Scripts	User-defined programming codes or routines (often developed in software such as Dynamo for Revit, Python, or C# APIs) designed to automate repetitive tasks, enhance model functionality, and customize BIM tools to meet project-specific requirements.

2.2.2 Identification of Critical Success Factors (CSFs) for BIM

The term Critical Success Factors (CSFs) was originally introduced by (Rockart,1979) who defined them as "the limited number of areas in which satisfactory results will ensure successful performance for the individual, department, or organization." In both project management and technology adoption, CSFs represent the small set of conditions or actions that, if properly addressed, will make the greatest difference between success and failure. According to (M.F. Antwi et al, 2018) in Project Management CSFs are often linked to achieving project success in terms of scope, time, cost, and quality. For example, clearly defined objectives, competent leadership, and effective communication are frequently cited CSFs in project delivery. But In Technology Adoption CSFs focus on readiness, acceptance, and integration of new systems. This may include user buy-in, compatibility with existing systems, adequate training, leadership commitment, and supportive policies.

In Ethiopia’s construction industry where digital adoption is still at an embryonic stage understanding and prioritizing these CSFs becomes even more vital. Without deliberate focus on these critical elements, BIM adoption efforts may become fragmented, underutilized, or fail altogether. Below shown on table 2.2 examples highlight the practical value of CSFs in shaping national-level strategies and company-level outcomes over the world (Ganiyu,2018).

Conceptual studies in BIM adoption identify key factors influencing successful implementation. Common CSFs in construction include Top Management Support, Skilled Workforce, Government Policies and Mandates, Technological Infrastructure, Integration into Education and Training, Stakeholder Collaboration and Communication.

According to (Muluken,2020) Several interrelated barriers slow BIM uptake in Ethiopia . for example Limited Awareness (Many construction professionals have minimal understanding of BIM benefits or processes,(Skill Shortages: Lack of qualified BIM practitioners and trainers),Technological Infrastructure Gaps(Inadequate access to modern computing hardware, software licenses, and reliable internet),Regulatory Vacuum(No formal BIM mandates, standards, or policies exist at the national or municipal level),Financial Constraints (High costs of software and training are prohibitive for many firms),Resistance to Change (Preference for traditional, paper-based methods and skepticism toward new technologies) and Industry Fragmentation(Poor coordination among contractors, consultants, and clients limits collaborative BIM workflows).These barriers reflect the broader challenges faced by developing countries but are compounded by Ethiopia’s specific socio-economic and institutional conditions (Haleluya, 2019).

Table 2.2 Conceptual CSFs for BIM Implementation

CSF	**Conceptual Description**	**Reference**
Top Management Support	Commitment and leadership in promoting BIM adoption	Smith et al., 2019
Skilled Workforce	Availability of trained professionals	Zhao & Lucas, 2020

Government Policies	Regulatory frameworks, mandates, and incentives	Ahmed et al., 2021
Technological Infrastructure	IT systems, BIM software, and hardware	Wang et al., 2020
Integration into Education	BIM training in universities and professional programs	Khosrowshahi & Arayici, 2012
Collaboration and Communication	Effective exchange of information among stakeholders	Eastman et al., 2018

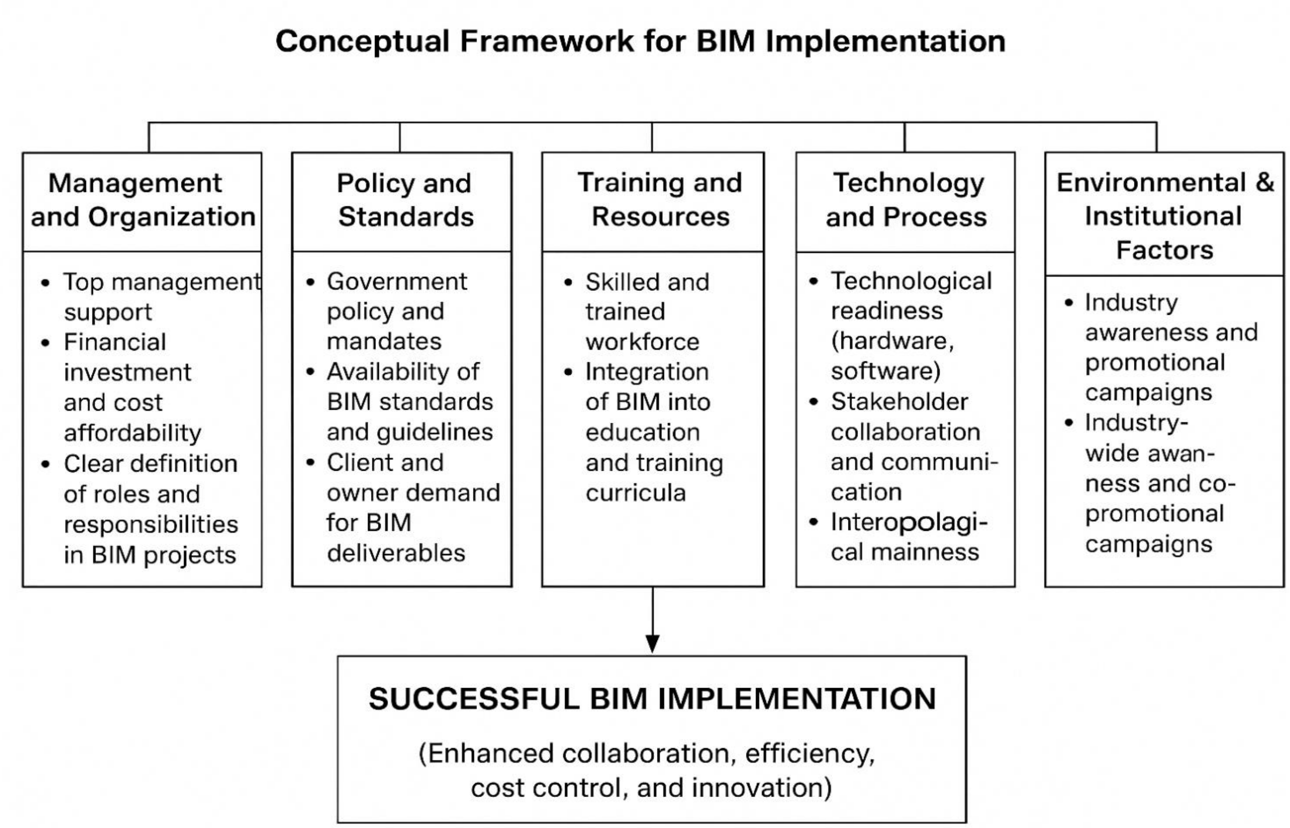

Figure 2.1 Conceptual Framework for BIM Implementation

2.2.3 Interrelationships Among CSFs

Conceptual literature proposes that CSFs are interconnected, and one factor may influence others. Examples: Top Management Support affects Training and Workforce Development, Government Policies affects Technological Adoption, Collaboration affects Technology Utilization.

The interrelationships among Critical Success Factors (CSFs) typically fall into two categories: causal models and structural models. Causal models aim to distinguish between driver CSFs those that exert influence and dependent CSFs those that are shaped by other factors. Structural models, on the other hand, map the hierarchical influence among CSFs, serving as a foundational step toward Interpretive Structural Modeling (ISM).

To assess the relative importance, influence, or impact of CSFs on BIM implementation, many studies employ Multi-Criteria Decision-Making (MCDM) frameworks. Among the most widely used are the Analytical Hierarchy Process (AHP) for prioritization, and the combined ISM–MICMAC approach for structural and dependency analysis. Within these frameworks, driver-dependent analysis plays a critical role in identifying leverage points for strategic intervention. For example, top management support and government policy are frequently classified as driver CSFs due to their high influence and low dependence. In contrast, factors such as skilled workforce, collaborative practices, and technology utilization are often categorized as dependent CSFs, as they tend to be outcomes shaped by broader organizational and policy-level drivers.

2.2.4 Integrated Multi-Method Approaches for Strategic Analysis

Each method, AHP, ISM, and MICMAC provides valuable but distinct insights. By integrating these methods, the study gains a more comprehensive understanding of the CSFs.

AHP quantifies importance, while ISM and MICMAC reveal structural interdependencies. Combining quantitative prioritization with qualitative structural insights mitigates the limitations inherent in any single method. This integration supports creating actionable, strategically informed recommendations by connecting factor priority with influence pathways. Here, Stakeholders can identify not just the most important factors but also understand how improvements in certain drivers cascade through the system (Filippo et al.,2025).

As per (Filippo et al.,2025) steps to this multi method analysis is first Use AHP to derive a ranked list of BIMs CSFs based on expert pairwise comparisons, next apply ISM to model how these CSFs interact and influence each other hierarchically, then using MICMAC to classify CSFs into driver-dependence categories to identify leverage points, finally Combine findings to develop a strategic roadmap highlighting priority areas with the greatest system impact. This integrated approach aligns directly with the study's objectives, particularly the need to prioritize and analyze CSFs through a multi-method framework, and to develop strategic insights that enhance BIM adoption effectiveness in Ethiopia.

Strengths of multi method analysis AHP offers clarity and quantitative rigor in ranking factories and MICMAC reveal complex causal relationships, enabling systems thinking, Integration facilitates a nuanced understanding of both factor importance and system dynamics, Methods are widely validated in construction management and technology adoption literature (Solomon et al. (2022).

Limitations of multi method analyses is Reliance on expert judgments introduces potential biases, hence, careful expert selection and consistency checks are essential, ISM and MICMAC are primarily qualitative and may be subjective without rigorous consensus-building, The complexity of multi-method analysis requires careful coordination and interpretation, Data collection and analysis can be time-consuming, especially when dealing with large numbers of factors and experts (Nega et al, 2024).

Despite these challenges, the integrated methodology provides a balanced and thorough approach suited for the complex domain of BIM implementation in developing contexts such as Ethiopia.

This study's methodological framework capitalizes on the complementary strengths of AHP for prioritization and ISM-MICMAC for structural analysis. This multi-method approach ensures a comprehensive, reliable, and strategically valuable analysis of BIM Critical Success Factors, ultimately contributing to more effective planning, policymaking, and practice in the Ethiopian construction industry.

2.3 Empirical Literature

2.3.1 Empirical Studies on BIM CSFs

Ethiopia is currently in the early stages of BIM adoption. Though still limited in practice, there is growing interest from government agencies, construction firms, and academic institutions. Key initiatives include (Solomon et al,2021)The Ethiopian Construction Project Management Institute (ECPMI) leading efforts to develop a national BIM roadmap focusing on awareness creation and capacity building. Universities and technical colleges incorporating BIM concepts into civil engineering and construction management programs.

Recent empirical studies have provided robust insights into the Critical Success Factors (CSFs)**,** implementation barriers, and prioritization frameworks within Ethiopia's construction sector. For instance, (Solomon et al,2021) employed a mini-Delphi methodology to analyze CSFs across public and private projects, revealing sector-specific priorities such as adequacy of funds*,* political environment, and clear project goals in public works. Another study by (Belay et al,2022) used Kendall's coefficient to compare stakeholder perceptions, identifying consultant competency*,* clear goals, and track record as top-ranked CSFs, while also highlighting divergence in priorities among owners, contractors, and consultants.

In parallel, Gutema (2021) explored barriers to BIM adoption in Ethiopia through qualitative methods, identifying challenges such as limited awareness*,* lack of skilled personnel*,* and institutional inertia*,* The study emphasized the need for targeted training and policy alignment to overcome these barriers and foster a culture of BIM integration.

According to (Feven,2024) Organization barriers have the strongest correlation; Technology barriers have the lowest correlation with BIM adoption in the OVID Company. Strong and statically significant relationship between the chosen obstacle of BIM adoption regions were shown by the correlation study: "Operation barriers, Technology barriers, Organization barriers, Human/stakeholder barriers and Standard, policies and guideline-related barriers" in the case of OVID group with Pearson Correlation Coefficient value of 0.085**, 0.078**, 0.074**, 0.063** and 0.003** respectively.

According to (Munir,2020) From findings identified the key drivers of BIM are government pressure (RII of 0.94), accurate construction sequencing (RII of 0.93) and clash detection and automation of schedule/register generation (RII of 0.93). Making project communication easier (RII of 0.96) and shortening project duration (RII of 0.9) are the main benefits of BIM .The last finding that the researcher identified was related to barriers to adopting BIM, lack of expertise (RII of 0.88) and lack of training (RII of 0.87) are the main barriers to adopting BIM.

According to (CHAN KOK YENG,2024) The findings revealed that Environment Readiness is the main CFS to developer in deciding the adoption of BIM. The sub-criteria of Ownership & Copyright, Coordination & Cooperation, and Competitor Pressure was the CSF for the respective categories. The highest weightage was calculated in Competitor Pressure factor, which indicated the developer needs to remain on par with the industry benchmark and stay competitive in ensuring the profitability of the organization. It also revealed varying priorities among different stakeholders. This pioneering research has provided valuable insights into the CSFs influencing the implementation of BIM in the industry, specifically from the developers' perspective.

2.4 Research Gap

A review of the existing literature reveals methodological limitations in previous studies. For instance, Solomon et al. (2021) employed only the mini-Delphi method with a small sample of three participants in their study titled "Enhancing BIM Implementation in the Ethiopian Public Construction Sector: An Empirical Study." Similarly, Gutema (2021) investigated barriers to BIM adoption in Ethiopia using qualitative methods exclusively. Furthermore, Feven (2024) examined the challenges of technological adoption in the context of BIM implementation within the OVID Group in Addis Ababa, relying solely on correlation analysis.

Overall, these studies did not incorporate Analytic Hierarchy Process (AHP) or Interpretive Structural Modeling (ISM) with MICMAC analysis, which are essential for prioritizing and analyzing the interdependencies among Critical Success Factors (CSFs) in BIM implementation within Addis Ababa's public building construction sector. Here several critical gaps remain that this research seeks to address are Lack of Prioritization of CSFs (While multiple studies have enumerated various CSFs, there is a notable deficiency in prioritizing these factors according to their relative significance within Ethiopia's unique socio-economic and institutional environment. Prioritization is vital to guide stakeholders in allocating limited resources effectively)Absence of Structural Analysis of CSFs (Existing research often treats CSFs as isolated factors without sufficiently exploring their interrelationships, dependencies, and influence pathways. Understanding how CSFs interact is crucial for designing integrated strategies that leverage synergies and mitigate cascading risks),Limited Focus on Addis Ababa's Public Construction Sector. By addressing these gaps, this research aims to provide a comprehensive, contextualized, and actionable understanding of BIM CSFs that reflects Ethiopia's realities and public construction sector needs.

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 Chapter Overview

This chapter delineates the systematic and rigorous multi-method approach employed to achieve the research objectives: to identify, validate, prioritize, and analyze the interrelationships of Critical Success Factors (CSFs) for Building Information Modeling (BIM) implementation within the public building construction sector in Addis Ababa. The chapter is structured to provide a comprehensive understanding of the research design, the phased data collection procedures, and the analytical techniques utilized. This methodical exposition ensures transparency and replicability of the study's findings.

3.2 Research Design and Approach

Based on its overarching goal, this study falls under applied research, aiming to develop a practical framework that aids policymakers and industry practitioners in accelerating the adoption of Building Information Modeling (BIM). In terms of its objectives, the research is both descriptive and exploratory: it seeks to describe the barriers, drivers, and critical success factors (CSFs) influencing BIM adoption, while also exploring the interrelationships among these CSFs within the Ethiopian context, where BIM implementation remains in its early stages.

Regarding the research approach, the study employs a mixed-methods design, integrating both qualitative and quantitative techniques. Qualitative methods are used to identify CSFs through an extensive literature review and expert consultations, while quantitative methods—specifically the Analytic Hierarchy Process (AHP) and Interpretive Structural Modeling with MICMAC analysis (ISM-MICMAC) are applied to prioritize and structurally analyze the interdependencies among the identified CSFs.

Based on research design, this study adopts a non-experimental type, as it does not involve any experimental procedures in data collection or analysis. With respect to data type, the study employs both primary (field research) and secondary (desk study) sources. Primary data are collected through structured questionnaires, pairwise comparison matrices (for AHP), and contextual relationship matrices (for ISM). Secondary data are obtained from scholarly journals, conference proceedings, government policy documents, BIM guidelines, and previous studies on BIM adoption and implementation.

The sampling technique used is purposive sampling, aimed at selecting experts with significant experience and knowledge of BIM and the construction sector. The sample size varies depending on the analysis method: for AHP, a panel of 5–15 experts is considered sufficient to ensure reliable judgments, while for ISM-MICMAC, a group of 8–20 experts is recommended to ensure robust modeling of interrelationships among CSFs.

For data analysis, multiple techniques are applied. The Analytic Hierarchy Process (AHP) is used to derive relative weights and priorities of the identified CSFs based on expert pairwise comparisons. Interpretive Structural Modeling (ISM) is employed to develop a hierarchical structure of the CSFs, highlighting their interdependence. MICMAC analysis is then conducted to classify the CSFs into four categories—autonomous, dependent, linkage, and driver factors—based on their driving and dependence power. To support and validate the analysis, software tools such as MS Excel and Python scripts are employed.

This study adopted a sequential mixed-methods design, integrating both qualitative and quantitative research paradigms. This approach was chosen to leverage the complementary strengths of each method, providing a holistic and robust understanding of the complex phenomenon of BIM implementation CSFs.

The initial phase involved qualitative inquiry through semi-structured interviews with industry experts. This phase was crucial for validating and contextualizing an initial list of CSFs derived from a comprehensive literature review. The interviews ensured that the identified factors were relevant and applicable to the specific socio-economic and institutional realities of the public construction sector in Addis Ababa, thereby enhancing the ecological validity of the study. This approach allowed for the capture of nuanced perspectives and expert insights that might not be discernible through purely quantitative means.

Following qualitative validation, the study transitioned to a quantitative phase, employing structured surveys based on the Analytic Hierarchy Process (AHP) and Interpretive Structural

Modeling (ISM). The AHP survey was utilized to quantify the relative importance and prioritize the validated CSFs, reflecting the collective judgment of the expert panel. Subsequently, the ISM survey was deployed to map the complex interdependencies and hierarchical relationships among these CSFs.

The sequential mixed-methods design offers a robust framework by combining the rich, contextual depth of qualitative inquiry with the structured, analytical rigor of quantitative methods (AHP and ISM-MICMAC). This synergistic combination allowed for the identification of contextually relevant factors, their prioritization based on expert consensus, and a detailed understanding of their interrelationships, ultimately leading to the development of a more robust and actionable strategic framework for BIM implementation.

3.3 Research Area

The research was conducted in Addis Ababa, the capital city of Ethiopia, chosen due to its relevance to the study and proximity to the research subjects. Addis Ababa also serves as the headquarters of major continental institutions, including the African Union (AU) and the United Nations Economic Commission for Africa (ECA), reinforcing its strategic importance. Geographically, the city is centrally located within Ethiopia and lies at an elevation ranging from 2,200 to 3,000 meters above sea level. Its terrain varies from gently rolling landscapes to steep, hilly gradients.

The municipality covers approximately 527 square kilometers, comprising 11 sub-cities and 116 Woredas. Of this area, 220 square kilometers are designated as green space, with 80 square kilometers covered by vegetation predominantly Eucalyptus trees, though the city also hosts a diverse array of rare flora and fauna.

Addis Ababa is rapidly emerging as a major construction center in Eastern Africa, with widespread development of buildings, roads, and infrastructure projects visible throughout the city. This dynamic urban expansion underscores the relevance of the study, particularly in the context of Building Information Modeling (BIM) implementation within the public construction sector.

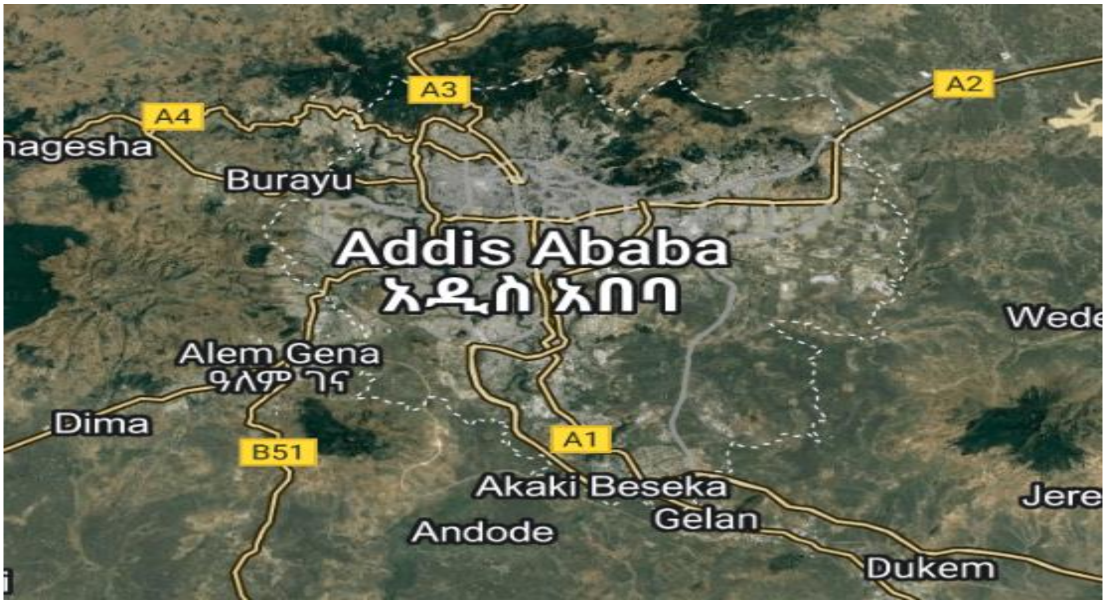

Figure 3.1 Satellite map of Research Location

3.4 Population and Sampling

The population for this study comprises professionals and experts engaged in Ethiopia's specifically Addis Ababa public building construction sector, including project managers, engineers, consultants, policymakers, and BIM specialists. These participants were purposively selected because of their substantial knowledge, experience, and direct involvement in BIM-related practices, challenges, and decision-making processes. To ensure both contextual relevance and analytical rigor, a purposive sampling technique was adopted, which is widely recommended in expert-based studies where specialized knowledge is required (Etikan et al, 2016). A two-stage expert sampling process was employed to align with the sequential phases of the methodology, in the first stage, experts were consulted to validate and refine the critical success factors (CSFs) identified from the literature and in the second stage, expert panels participated in pairwise comparisons for AHP and contextual relationship assessments for ISM-MICMAC. Consistent with prior methodological guidance, 5–15 experts were considered adequate for AHP to ensure reliable prioritization (Saaty, 1980; Goepel, 2013), while 8–20 experts were involved in ISM-MICMAC to ensure strength in the structural modeling of interrelationships (Warfield, 1974; Janes, 1988). This deliberate sampling approach enhanced the validity and reliability of the findings by ensuring that the data collected were grounded in expert judgment and reflective of the contextual realities of BIM implementation in the Ethiopian construction sector.

3.5 Target Population

The target population for this research comprised seasoned professionals and key stakeholders with deep-seated knowledge and direct experience in Ethiopia's construction industry, specifically within the public building sector of Addis Ababa. The selection criteria mandated that participants possess a demonstrable understanding of Building Information Modeling (BIM) whether through practical application, policy development, or academic research and a nuanced perspective on the sector's operational, institutional, and economic realities.

The study population consisted of a diverse group of stakeholders selected to provide a comprehensive understanding of the critical success factors (CSFs) for BIM implementation. It included six policymakers and government officials from institutions overseeing construction regulation and project management, nine senior practitioners from the private sector such as architects, engineers, project managers, and contractors with extensive experience in both public and private projects and three academics and researchers from universities specializing in construction management and technology. This multidisciplinary mix was intentionally chosen to ensure a holistic and well-rounded perspective, capturing insights from regulatory, practical, and academic viewpoints relevant to BIM adoption in Ethiopia Addis Ababa.

3.5.1 Sampling Technique and Sample Composition

Given the specialized nature of the research objectives and the reliance on informed, expert judgments, a purposive sampling technique was employed. This non-probability method is particularly well-suited for AHP and ISM studies, which prioritize the quality and richness of data from a select group of knowledgeable individuals over the statistical generalizability of a random sample. The core rationale was to select participants who could provide credible, in-depth, and reliable data for both validating the CSFs and analyzing their complex interrelationships.

The study utilized two distinct expert panels for its sequential research phases:

a) Panel for Qualitative Validation (Expert Interviews)

For the initial qualitative phase, which focused on validating and contextualizing the list of CSFs derived from the literature, a focused panel of seven (7) experts was convened. This smaller group was intentionally selected for their deep, hands-on experience and ability to provide rich, nuanced insights during semi-structured interviews. The primary objective for this panel was to ensure the ecological validity of the CSFs confirming their relevance, refining their definitions, and uncovering any context-specific factors pertinent to Addis Ababa's public sector. The composition of this panel included representatives from key vantage points, such as the Ethiopian Construction Project Management Institute (ECPMI), senior architectural design, international BIM management, and public sector client representation, to ground the study in practical reality.

b) Panel for Quantitative Analysis (AHP and ISM-MICMAC Surveys)

For the subsequent quantitative phase, a second, larger panel of eleven (11) experts was engaged to complete the AHP and ISM-MICMAC surveys. The rationale for expanding the panel was to broaden the base of judgment, thereby increasing the reliability and stability of the aggregated quantitative results. A larger and more diverse group helps mitigate individual biases and ensures that the final prioritization and structural model reflect a more comprehensive consensus among key industry stakeholders.

This panel was carefully composed to represent a cross-section of the target population, including policy advisors, lead architects, academic researchers, senior project managers from both contracting and consulting firms, and BIM specialists. This diversity was crucial for capturing varied perspectives on the relative importance and influence of each CSF, leading to a more robust and defensible strategic framework. All eleven participants met the stringent selection criteria of having significant industry experience (average of over 15 years) and direct involvement with BIM and public sector projects.

3.6 Data Collection Instruments and Procedure

The data collection process employed in this study integrated both primary and secondary data sources, applied in a sequential, multi-phased manner to ensure consistency and contextual relevance. This approach enabled the study to progress logically from identifying potential Critical

Success Factors (CSFs) through literature to empirically validating, prioritizing, and structurally analyzing them.

a. Secondary Data Sources

Secondly, data collection constituted the foundational stage of the research. A comprehensive literature review was conducted to identify an initial set of potential CSFs for BIM implementation. This review encompassed global, regional, and national studies, including peer-reviewed journal articles, conference proceedings, BIM guidelines, government reports, and previous empirical studies. Such secondary sources provided a robust theoretical basis and ensured that the initial CSF inventory was aligned with international best practices while remaining sensitive to the Ethiopian construction context (Creswell, 2014).

b. Primary Data Sources

Primary data were collected directly from professionals and experts in Ethiopia's public construction sector through structured instruments, applied across three sequential phases:

Phase 1: CSF Identification and Validation**:** Semi-structured interviews were conducted with a panel of seven industry experts to validate and contextualize the CSFs derived from the literature. The primary instrument for this phase was an interview guide, which elicited expert perspectives on the clarity, applicability, and relevance of the proposed CSFs. This qualitative step refined and confirmed a final set of 16 CSFs, serving as the foundation for subsequent quantitative analyses.

Phase 2: AHP Survey for Prioritization**:** A structured AHP questionnaire was designed to prioritize the validated CSFs. Experts were required to make pairwise comparisons within and across four categories Management & Organization, Policy & Standards, Training & Resources, and Technology & Process. Judgments were recorded using Saaty's (1980) 9-point fundamental scale**,** which enabled the conversion of subjective expert judgments into quantitative priority weights. This procedure yielded a definitive ranking of CSFs, providing insight into their relative importance.

Phase 3: ISM-MICMAC Survey for Interrelationship Analysis: To investigate interrelationships among the CSFs, the same panel of experts participated in completing an ISM questionnaire**,** presented in the form of a Structural Self-Interaction Matrix (SSIM). Using Warfield's (1974) ISM methodology**,** experts defined the directional influence between CSFs through VAXO symbols (*V, A, X, O*). The resulting SSIMs were transformed into a reachability matrix and hierarchical structure. This was followed by MICMAC analysis, which classified the CSFs into autonomous, dependent, linkage, and driver factors (Duperrin & Godet, 1973). This phase provided a systemic understanding of the causal structure underlying BIM implementation success factors.

In summary**,** the study utilized secondary data (literature, reports, policy documents) to establish a theoretical foundation, and primary data (expert interviews, AHP surveys, and ISM-MICMAC matrices) to validate, prioritize, and structurally analyze CSFs within Ethiopia's public construction sector. This multi-source and multi-method data collection ensured both contextual validity and analytical robustness

3.7 Data Analysis Methods

The analysis of the collected data was conducted in a systematic, multi-stage process that mirrored the sequential mixed-methods research design. This section provides a detailed, step-by-step explanation of the analytical techniques applied, moving from the initial qualitative refinement of the Critical Success Factors (CSFs) to the final integrated strategic framework. The analytical workflow was facilitated by a combination of software tools, where Microsoft Excel was utilized for initial data organization and management, while all core computations and visualizations for the AHP, ISM, and MICMAC analyses were performed using custom scripts developed in the Python programming language and executed within the Google Colab cloud environment.

3.7.1 Qualitative Analysis

The qualitative analysis in this study employed thematic analysis, a method recognized for its flexibility and rigor in identifying, analyzing, and reporting patterns within qualitative data (Braun & Clarke, 2006). This approach was selected due to its suitability for validating and contextualizing concepts such as critical success factors (CSFs) in underexplored settings. Thematic analysis allows for the integration of both established theoretical frameworks and emerging insights, making it particularly effective in environments where empirical grounding is still developing. Moreover, it supports ecological validity, which was essential given that BIM implementation in Ethiopia remains in its early stages and demands careful contextual adaptation.

The analysis process commenced with transcribing data collected from semi-structured expert interviews. These transcripts were then systematically organized and managed using Microsoft Excel to support the open coding phase, during which key statements, concepts, and expressions linked to each critical success factor (CSF) were identified and tagged. Following this, the initial codes were carefully reviewed, refined, and grouped into broader conceptual categories to form the foundation for thematic interpretation.

The primary purpose of employing thematic analysis was to ensure that the final list of 16 validated CSFs was not simply extracted from literature but was also definitely attached to the lived experiences and professional judgments of practitioners. This step enhanced the ecological validity of the study by ensuring that the CSFs reflected the socio-economic and institutional realities of the Ethiopian context.

3.7.2 Quantitative Analysis

The quantitative analysis in this study was designed to systematically evaluate and prioritize the Critical Success Factors (CSFs) influencing Building Information Modeling (BIM) implementation in Addis Ababa's public construction sector. This phase followed the initial qualitative exploration and aimed to provide objective, measurable insights into the relative importance and interrelationships among the identified CSFs.

The quantitative component employed multi-criteria decision-making (MCDM) and structural modeling techniques, specifically the Analytical Hierarchy Process (AHP), Interpretive Structural Modeling (ISM), and MICMAC analysis. These tools collectively allowed for both ranking and structural interpretation of the CSFs in a manner suitable for strategic framework development.

a. Analytical Hierarchy Process (AHP)

Following the qualitative phase, the quantitative data collected from the AHP surveys were analyzed to determine the relative priority of the CSFs. The analysis was executed through a sequence of computational steps within a custom-developed Python script. First, the pairwise comparison judgments from the eleven experts were aggregated using the geometric mean method to form a single, composite judgment matrix for each of the four CSF categories and another for the main categories themselves. These matrices were initially compiled and checked for completeness in MS Excel before being imported into the Google Colab environment for processing.

The core of the AHP analysis involved calculating the local priority weights from these composite matrices. This was achieved by computing the principal eigenvector of each matrix, a task for which Python's NumPy library is exceptionally well-suited. A crucial subsequent step was to assess the reliability of the expert judgments through a consistency check. The Consistency Ratio (CR) was calculated for each matrix to measure the degree of transitivity in the experts' responses. All matrices were confirmed to have a CR of less than the acceptable threshold of 0.1, thereby validating the judgments as sufficiently consistent and reliable for further analysis. Finally, the local weights of each CSF were synthesized with the weights of their respective categories to compute a global weight for all 16 CSFs. This final step, also performed within the Python script, produced an overall priority ranking, which holistically represents the collective judgment of the expert panel on the relative importance of each factor.

b. Interpretive Structural Modeling (ISM) and MICMAC Analysis

The data from the ISM survey were processed to map the structural interrelationships and influence dynamics among the CSFs. This analytical phase was also conducted primarily using Python scripts in Google Colab. The first step involved developing the aggregated Structural Self-Interaction Matrix (SSIM) by consolidating the VAXO-based judgments from the eleven experts based on a majority consensus rule. This aggregated SSIM, initially tabulated in MS Excel, was then converted into a binary initial reachability matrix, where an entry of '1' denoted a relationship and '0' denoted its absence.

To account for transitivity and reveal indirect relationships, this initial matrix was transformed into a final reachability matrix through a process of matrix multiplication, iterated until the matrix stabilized (i.e., $Rs = Rs \cap As$). This computationally intensive task was efficiently handled by Python. Based on the final reachability matrix, a level partitioning process was executed. For each

CSF, the reachability set (factors it influences) and the antecedent set (factors that influence it) were identified. CSFs for which these two sets had an identical intersection were grouped into hierarchical levels, beginning from the top of the hierarchy. This partitioning formed the structural basis for the final ISM hierarchical model.

Subsequently, a MICMAC (Cross-Impact Matrix Multiplication Applied to Classification) analysis was performed using the final reachability matrix. The Driving Power for each CSF was calculated by summing the entries in its corresponding row, while the Dependence Power was calculated by summing the entries in its column. These two values, representing the extent to which a factor influences and is influenced by the system, respectively, were used to classify each CSF into one of four distinct quadrants: Independent (Driver), Linkage, Autonomous, or Dependent.

c. Integrated AHP-MICMAC Quadrant Analysis

The final and most synthesized analytical step involved integrating the quantitative outputs from the AHP (importance) and the MICMAC (influence) analyses. This integration was designed to produce a comprehensive strategic framework for prioritizing interventions. A Python script was used to plot each of the 16 CSFs onto a two-dimensional matrix. The horizontal axis (X-axis) represented the 'Importance' of each CSF, as determined by its AHP-derived global weight. The vertical axis (Y-axis) represented the 'Influence,' as determined by its MICMAC-derived driving power. The resulting scatter plot, generated using Python’s Matplotlib and Seaborn libraries, visually categorized the CSFs into four strategic quadrants: Strategic Drivers, Critical Outcomes, Key Enablers, and Minor Factors. This integrated framework provides a nuanced and actionable guide for decision-makers, highlighting not only which factors are most important but also which ones offer the greatest leverage for systemic change.

3.8 Reliability and Validity

A systematic and multi-faceted approach was implemented throughout the research process to ensure credibility, trustworthiness, and scholarly rigor of the findings. The study's design incorporated specific measures to address both the validity and reliability of the data and the resulting analyses, thereby strengthening confidence in the final conclusions and the proposed strategic framework.

The primary strategy for enhancing the robustness of the study was the use of methodological triangulation. By employing a sequential mixed-methods design, the research did not rely on a single source of data or a solitary analytical technique. Instead, it integrated qualitative expert interviews with two distinct quantitative methods: the Analytic Hierarchy Process (AHP) for prioritization and Interpretive Structural Modeling (ISM) with MICMAC for structural analysis. This approach allowed for the cross-validation of findings across different methodological paradigms. For instance, themes that emerged as critical during qualitative interviews could be compared against the factors that received high priority weights in the AHP analysis and those identified as key drivers in the ISM-MICMAC model. This convergence of evidence from multiple methods significantly mitigates the potential for biases inherent in any single approach and provides a more comprehensive and well-substantiated understanding of the phenomenon.

To ensure validity the extent to which the study accurately measures what it intends to do several deliberate steps were taken. Content validity was rigorously established during the initial phase of the research. The process began with a comprehensive literature review to identify an exhaustive list of potential CSFs, which was then subjected to scrutiny by a panel of seven domain experts. Through semi-structured interviews, these experts validated, refined, and contextualized the factors, ensuring the final list of 16 CSFs was not only theoretically sound but also possessed high ecological validity, accurately reflecting the operational realities of the public construction sector in Addis Ababa. Furthermore, the internal logic and causal pathways of the system were addressed through the ISM methodology, which provides a structurally valid model of the interrelationships as perceived by the expert panel.

Measures to ensure reliability, the consistency and stability of the results, were embedded within each analytical phase. For the AHP analysis, the reliability of the expert judgments was quantitatively verified using the Consistency Ratio (CR) check. A strict threshold of $CR < 0.1$ was applied to the aggregated judgment matrix for each set of comparisons. The successful adherence to this threshold confirmed that the experts' pairwise judgments were internally consistent and not random, lending high reliability to the derived priority weights. For the ISM and MICMAC analyses, reliability was enhanced by aggregating the judgments from the eleven-member expert panel. This process of establishing a consensus-based Structural Self-Interaction Matrix (SSIM) helped to smooth out individual idiosyncrasies and produced a more stable and representative model of the system's structure. Procedural reliability was further guaranteed by conducting all core computations for the AHP, ISM, and MICMAC analyses using custom scripts in the Python programming language within a Google Colab environment. This programmatic approach eliminated the potential for manual calculation errors and ensured that the analytical process was repeatable and transparent.

3.9 Ethical Considerations

This research adhered to established ethical standards to ensure the integrity, credibility, and fairness of the study. Since the study relied heavily on expert opinions obtained through interviews and questionnaires, careful attention was paid to protecting the rights, privacy, and confidentiality of all participants.

First, informed consent was obtained from all experts prior to their participation. Each participant was provided with a clear explanation of the study's purpose, procedures, potential benefits, and their right to withdraw at any time without penalty (Creswell, 2014). Consent was recorded verbally or in writing, depending on participant preference.

Second, confidentiality and anonymity were strictly maintained. No identifying information about individual experts was disclosed in the thesis or any related publications. Responses were coded and aggregated to ensure that data could not be traced back to individual participants (Saunders, Lewis & Thornhill, 2019).

Third, the research complied with principles of voluntary participation**,** ensuring that no respondent was pressured or coerced into taking part. Participation was entirely based on professional willingness and availability and Fourthly, data security was prioritized. Raw data from interviews, questionnaires, and matrices were stored in password-protected files accessible only to the researcher. Printed materials, if any, were securely stored.

Finally, to uphold academic integrity**,** all secondary sources used in this research were appropriately cited and referenced to avoid plagiarism. The study also ensured transparency in reporting findings by presenting results objectively without manipulation or bias. These practices are consistent with international ethical standards such as the Belmont Report (1979) and widely accepted research ethics frameworks (Flick, 2018).By following these ethical considerations, the study sought to ensure respect for participants, uphold professional research standards, and produce valid and trustworthy results.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Chapter Overview

This chapter presents and interprets the empirical findings derived from the multi-method analysis conducted to identify, prioritize, and analyze the interrelationships of Critical Success Factors (CSFs) for Building Information Modeling (BIM) implementation in the public building construction sector in Addis Ababa. The exposition follows logical progression, commencing with the validated list of CSFs, proceeding through the Analytic Hierarchy Process (AHP) results concerning factor importance, followed by the Interpretive Structural Modeling (ISM) and Cross-Impact Matrix Multiplication Applied to Classification (MICMAC) analyses revealing structural and influence dynamics, and culminating in an integrated strategic framework. Each section systematically presents the findings and discusses their implications within the specific context of the study.

4.2 Profile of Survey Respondents

The credibility and robustness of the empirical findings in this study are fundamentally anchored in the expertise and composition of the professional panels consulted. A two-stage sampling process was employed, utilizing two distinct expert panels to align with the sequential mixed-methods design: a focused group for the initial qualitative validation of Critical Success Factors (CSFs), and a broader group for the quantitative AHP and ISM-MICMAC analyses. This section details the demographic and professional profiles of both panels to provide a transparent foundation for the results that follow.

4.2.1 Profile of the Expert Panel for CSF Validation

The initial phase of this research, aimed at validating and contextualizing the CSFs, involved in-depth, semi-structured interviews with a panel of seven leading experts. The profiles of these individuals are summarized in Figure 4.1. This panel was intentionally selected to provide deep, contextual insights, ensuring the CSFs were relevant to the local realities of Addis Ababa's public construction sector.

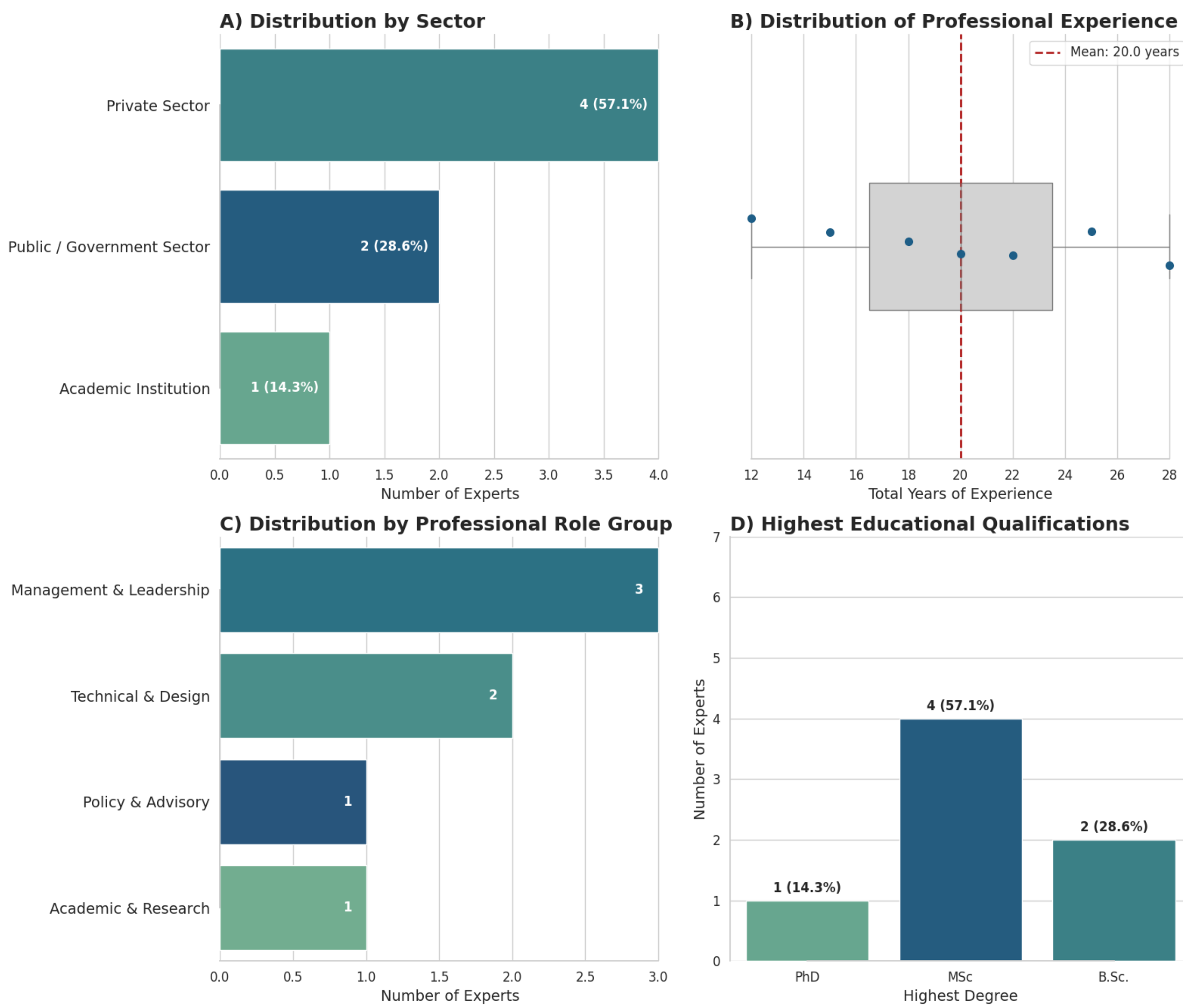

Figure 4.1: Validation Panel Profile (7 Experts)

As shown in Figure 4.1(A), the validation panel was composed of experts primarily from the Public/Government Sector (42.9%) and the Private Sector (42.9%), ensuring a balanced view between regulatory bodies and implementing firms. The panel's profound experience is highlighted in Figure 4.1(B), with an average of 20.0 years in the industry, underscoring their senior standing. The diversity of their professional roles (Figure 4.1(C)) and high educational attainment (Figure

4.1(D)), with 71.4% holding an MSc or PhD, further confirms their suitability for grounding this research in authentic, practical knowledge.

4.2.2 Profile of the Expert Panel for AHP and ISM-MICMAC Analysis

For the quantitative phase of the study, a larger panel of eleven experts was engaged to provide judgments for the AHP and ISM-MICMAC surveys. This expanded panel was designed to ensure a broad consensus and enhance the statistical stability of the aggregated data. The comprehensive profile of this panel is presented in Figure 4.2.

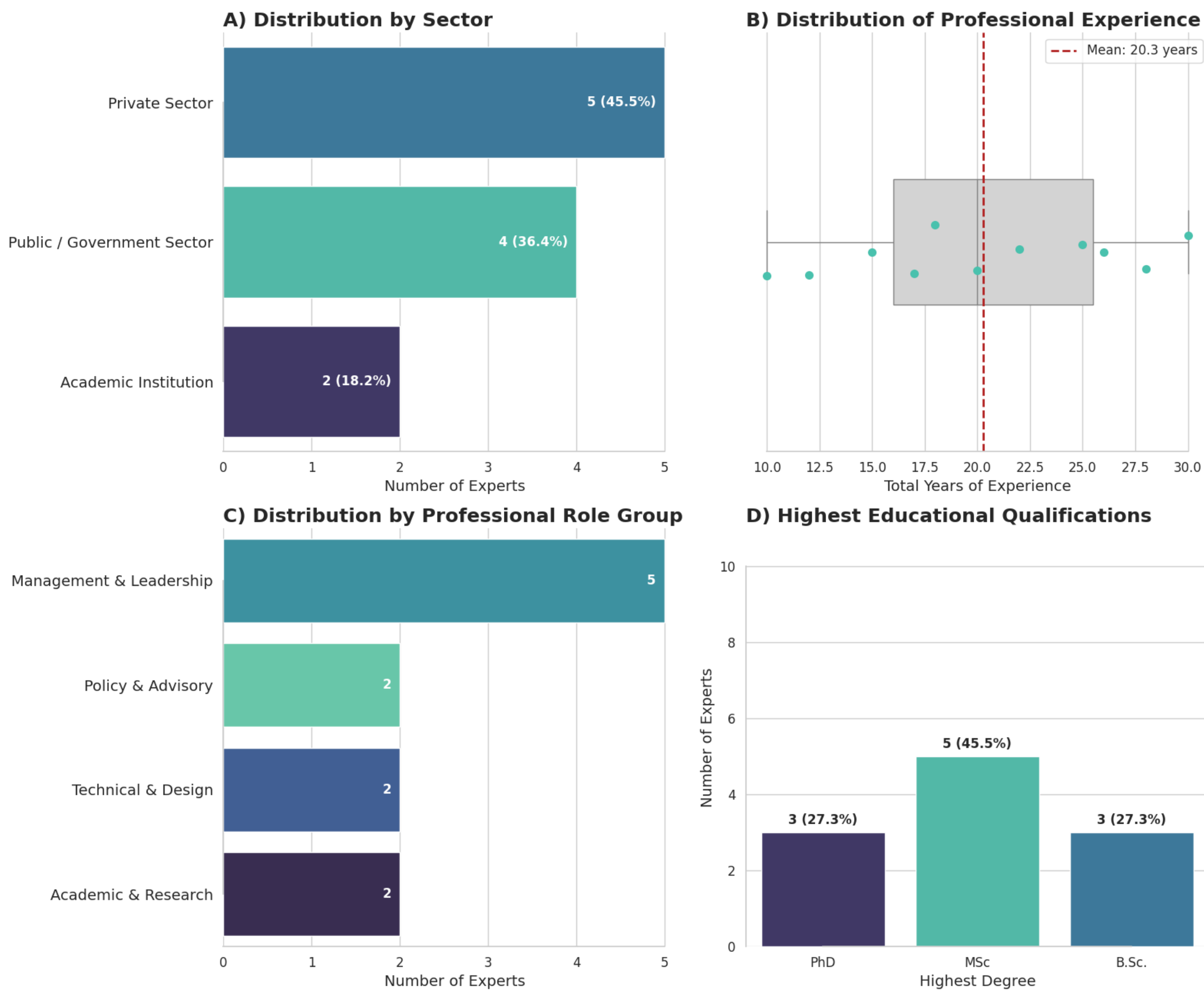

Figure 4.2: Quantitative Panel Profile (11 Experts)

The sectoral distribution of the quantitative panel, shown in Figure 4.2(A), maintained a strong representation from the Private Sector (45.5%) and the Public/Government Sector (36.4%), supplemented by a valuable academic perspective (18.2%). The remarkable depth of experience within this group is detailed in Figure 4.2(B); the panel boasts an average of 20.3 years of professional experience, with a cumulative experience base spanning from 10 to 30 years. This high level of seniority ensures the analytical inputs are based on decades of practical observation. As seen in Figure 4.2(D), the panel's academic qualifications are exceptional, with 81.8% possessing an MSc or PhD. In summary, the collective profiles of both expert panels provide a robust foundation of authority and credibility for the research findings presented in the subsequent sections of this chapter.

4.3 Validated Critical Success Factors and Their Categories

The foundational step of this investigation involved the systematic identification and validation of Critical Success Factors (CSFs) pertinent to BIM implementation in the public building construction sector of Addis Ababa. This process commenced with a comprehensive literature review, which generated an initial pool of potential CSFs. To ensure the contextual relevance and applicability of these factors, a series of semi-structured interviews were conducted with seven experts from diverse backgrounds within the Ethiopian construction industry. These experts, selected for their direct experience with public sector projects and profound knowledge of BIM, provided invaluable perspectives that validated, refined, and contextualized the initial list. This qualitative validation step was crucial for grounding the subsequent quantitative analyses in the unique socio-economic and institutional realities of Addis Ababa, thereby enhancing the external validity and practical applicability of the research outcomes.

The expert consensus confirmed 16 distinct CSFs, which were subsequently categorized into four overarching themes: Policy and Standards (PS), Management and Organization (MO), Training and Resources (TR), and Technology and Process (TP). This categorization aligns with established theoretical frameworks, particularly the Technology-Organization-Environment (TOE) framework, which provides a structured lens for understanding the multifaceted influences on technology adoption. The meticulous validation process, incorporating expert perspectives, ensures that the identified CSFs are not merely generic but are specifically pertinent to the challenges and opportunities within the target sector.

The final list of validated CSFs, along with their assigned categories, is presented in Table 4.1. This table serves as the definitive reference point for all factors analyzed throughout this chapter, providing clarity and transparency regarding the specific elements under investigation.

Table 4.1: Final List of Validated CSFs for BIM Implementation in Addis Ababa and Their Categories

CSF ID	Critical Success Factor	Category
CSF1	Top management support	Management and Organization
CSF2	Government policy and mandates	Policy and Standards
CSF3	Skilled and trained workforce	Training and Resources
CSF4	Integration of BIM into education and training curricula	Training and Resources
CSF5	Technological readiness (hardware, software)	Technology and Process
CSF6	Financial investment and cost affordability	Management and Organization
CSF7	Availability of BIM standards and guidelines	Policy and Standards
CSF8	Client and owner demand for BIM deliverables	Policy and Standards
CSF9	Stakeholder collaboration and communication	Technology and Process
CSF10	Clear definition of roles and responsibilities in BIM projects	Management and Organization
CSF11	Change management and internal communication strategies	Management and Organization
CSF12	Availability of pilot or demonstration BIM projects	Technology and Process

CSF13	Interoperability of BIM tools and software compatibility	Technology and Process
CSF14	Availability of local BIM consultants or service providers	Training and Resources
CSF15	Industry-wide awareness and promotional campaigns	Training and Resources
CSF16	Integration of BIM into national construction codes	Policy and Standards

4.4 AHP Results: The Relative Importance of CSFs

This section details the findings from the Analytic Hierarchy Process (AHP) analysis, which quantitatively assessed the relative importance and priority ranking of the identified CSFs and their overarching categories, reflecting the collective judgment of the expert panel.

4.4.1 Importance of CSF Categories

The AHP analysis first determined the aggregated weights and final ranking of the four main CSF categories: Policy and Standards (PS), Management and Organization (MO), Training and Resources (TR), and Technology and Process (TP). These results provide a high-level understanding of where strategic focus should be directed, as perceived by the experts.

Table 4.2: Ranking and Weights of CSF Categories

Category	Weight	Rank
Policy and Standards (PS)	0.376	1
Management and Organization (MO)	0.314	2
Training and Resources (TR)	0.210	3
Technology and Process (TP)	0.100	4

As presented in Table 4.2, 'Policy and Standards' emerged as the most important category, with a weight of 0.376, followed closely by 'Management and Organization' (0.314). This prioritization indicates a strong consensus among experts that non-technical, governance-related factors are paramount for successful BIM implementation in the Addis Ababa public construction sector. This finding is consistent with the inherent nature of public sectors, which are often driven by top-down mandates, clear regulatory frameworks, and robust organizational commitment. For instance, Expert 1, a Government Official from ECPMI, explicitly stated that "Government policy and mandates is non-negotiable" and emphasized the necessity of "clear procurement policies" to drive industry adaptation. Similarly, Expert 6, a Local BIM Consultant, highlighted "Top management support" as the most critical factor for any company's success, underscoring the importance of strong leadership.

The lower ranking of 'Technology and Process' as a category, despite BIM being a technological innovation, suggests that the foundational, non-technical enablers (policy, management) are perceived as more critical for initiating and sustaining BIM adoption in this specific context. This perspective is particularly relevant for developing economies where institutional and regulatory frameworks often lag behind technological advancements, making a structured, top-down approach more effective than relying solely on technological readiness or individual firm initiatives. The emphasis on governance and leadership suggests that without a clear policy directive and strong organizational backing, efforts in other areas might be fragmented or unsustainable.

4.4.2 Global Ranking and Priority of Individual CSFs

Moving from categories to individual factors, the AHP analysis provided a granular understanding of the relative importance of all 16 CSFs, as perceived by the expert panel. This comprehensive ranking is presented in Table 4.3.

Table 4.3: Global Weights and Final Ranking of All CSFs

Global Rank	CSF	Global Weight	Category
1	CSF2: Government policy and mandates	0.1987	Policy and Standards (PS)
2	CSF1: Top management support	0.1538	Management and Organization (MO)

3	CSF7: Availability of BIM standards and guidelines	0.1026	Policy and Standards (PS)
4	CSF3: Skilled and trained workforce	0.0955	Training and Resources (TR)
5	CSF4: Integration of BIM into education and training curricula	0.0821	Training and Resources (TR)
6	CSF11: Change management and internal communication strategies	0.0806	Management and Organization (MO)
7	CSF8: Client and owner demand for BIM deliverables	0.0542	Policy and Standards (PS)
8	CSF6: Financial investment and cost affordability	0.0463	Management and Organization (MO)
9	CSF9: Stakeholder collaboration and communication	0.0442	Technology and Process (TP)
10	CSF10: Clear definition of roles and responsibilities in BIM projects	0.0327	Management and Organization (MO)
11	CSF5: Technological readiness (hardware, software)	0.0311	Technology and Process (TP)
12	CSF15: Industry-wide awareness and promotional campaigns	0.0215	Training and Resources (TR)
13	CSF16: Integration of BIM into national construction codes	0.0202	Policy and Standards (PS)
14	CSF13: Interoperability of BIM tools and software compatibility	0.0147	Technology and Process (TP)
15	CSF14: Availability of local BIM consultants or service providers	0.011	Training and Resources (TR)
16	CSF12: Availability of pilot or demonstration BIM projects	0.0106	Technology and Process (TP)

The top-ranked CSFs provide specific areas for strategic focus. CSF2, "Government policy and mandates," holds the highest global rank (1st) with a weight of 0.1987. This reinforces the qualitative statements from Expert 1, the Government Official, who deemed it "non-negotiable" for nationwide adoption. Following closely is CSF1, "Top management support," ranked 2nd

(0.1538), a factor consistently emphasized by Expert 3 (BIM Manager) and Expert 6 (Local BIM Consultant) as fundamental for any BIM initiative. CSF7, "Availability of BIM standards and guidelines," ranked 3rd (0.1026), was also highlighted by Expert 1 and Expert 6 as crucial for avoiding chaos and improving efficiency.

Human capital development factors, CSF3 ("Skilled and trained workforce," 4th rank, 0.0955) and CSF4 ("Integration of BIM into education and training curricula," 5th rank, 0.0821), also feature prominently among the top priorities. Expert 4, a University Professor, specifically identified CSF4 as the "number one CSF for sustainable, long-term adoption," noting the significant gap between academic curricula and industry needs. Experts from various roles, including a Senior Architect, Project Manager, and Client Representative, concurrently stressed the importance of a skilled workforce (CSF3). These top-ranked factors collectively underscore a strategic imperative for institutional and human capital development as primary drivers for BIM adoption in Addis Ababa.

A notable observation from the AHP global ranking is the relatively lower position of CSF5, "Technological readiness (hardware, software)," which ranks 11th with a global weight of 0.0311. This might initially appear counterintuitive, given that BIM is a technology-driven process. However, when juxtaposed with its placement in the ISM hierarchical model (Image 1) and MICMAC analysis (Image 2), a more nuanced understanding emerges. In the ISM model, CSF5 is positioned at Level 1, indicating its foundational role as a driver that influences many other factors. Furthermore, MICMAC analysis classifies CSF5 as an "Independent (Driver)" with a driving power of 5, one of the highest among all CSFs. Expert 3, a BIM Manager from an international firm, explicitly identified technological readiness as the "most critical technical barrier". This divergence suggests that while technological readiness is a necessary enabler, its importance might be overshadowed by the more immediate perceived need for policy and management interventions in the public sector context. It implies that while technology must be in place, experts may not view it as the primary strategic lever for initiating widespread BIM adoption in the same way they view policy. Policymakers should therefore ensure that technological infrastructure is developed concurrently with policy mandates, even if experts do not rank it as the most important factor for overall success. This highlights a nuanced distinction between a factor's perceived "importance" and its "foundational necessity" within the system.

Furthermore, the classification of CSF3 ("Skilled and trained workforce") and CSF4 ("Integration of BIM into education and training curricula") as "Linkage" factors in the MICMAC analysis (Image 2) is significant. While these factors are highly important (ranked 4th and 5th respectively in AHP) and possess substantial driving power, their "linkage" nature implies that their success is also heavily dependent on other elements, particularly foundational drivers like government policy (CSF2) and the availability of standards (CSF7). For example, without clear policy mandating BIM, the demand for a skilled workforce might not materialize sufficiently, and educational institutions might lack the incentive or funding to update curricula to meet industry needs. This indicates a reciprocal relationship where policy creates the demand for skills, and skilled professionals, in turn, enable the effective implementation of policy. This dynamic suggests that interventions aimed at human capital development must be integrated with broader policy and regulatory efforts to achieve maximum impact.

4.5 ISM-MICMAC Results: Structural and Influence Analysis

This section moves beyond the prioritization of CSFs to explore their underlying structural relationships and influence dynamics, providing a deeper understanding of how these factors interrelate within the complex system of BIM implementation.

4.5.1 ISM Hierarchical Model

The Interpretive Structural Modeling (ISM) analysis revealed a multi-level hierarchical structure of the CSFs, visually represented in Figure 4.3. This model illustrates the contextual relationships between factors, with those at lower levels acting as foundational drivers and those at higher levels being more dependent outcomes.

The ISM hierarchical model (Figure 4.3) provides a visual representation of the driving and dependence relationships among the 16 CSFs. The model is structured into three distinct levels, with factors at lower levels acting as foundational drivers that influence those at higher levels. Level 1, positioned at the base of the hierarchy, comprises CSF2 ("Government policy and mandates") and CSF5 ("Technological readiness (hardware, software)"). These factors are identified as the fundamental drivers that must be addressed first, as they possess the highest driving power and are least dependent on other factors within the system. For instance, the presence of clear government policies and the availability of necessary technology are prerequisites for the effective implementation of other CSFs. Without these foundational elements, efforts to address factors at higher levels are likely to be constrained or ineffective

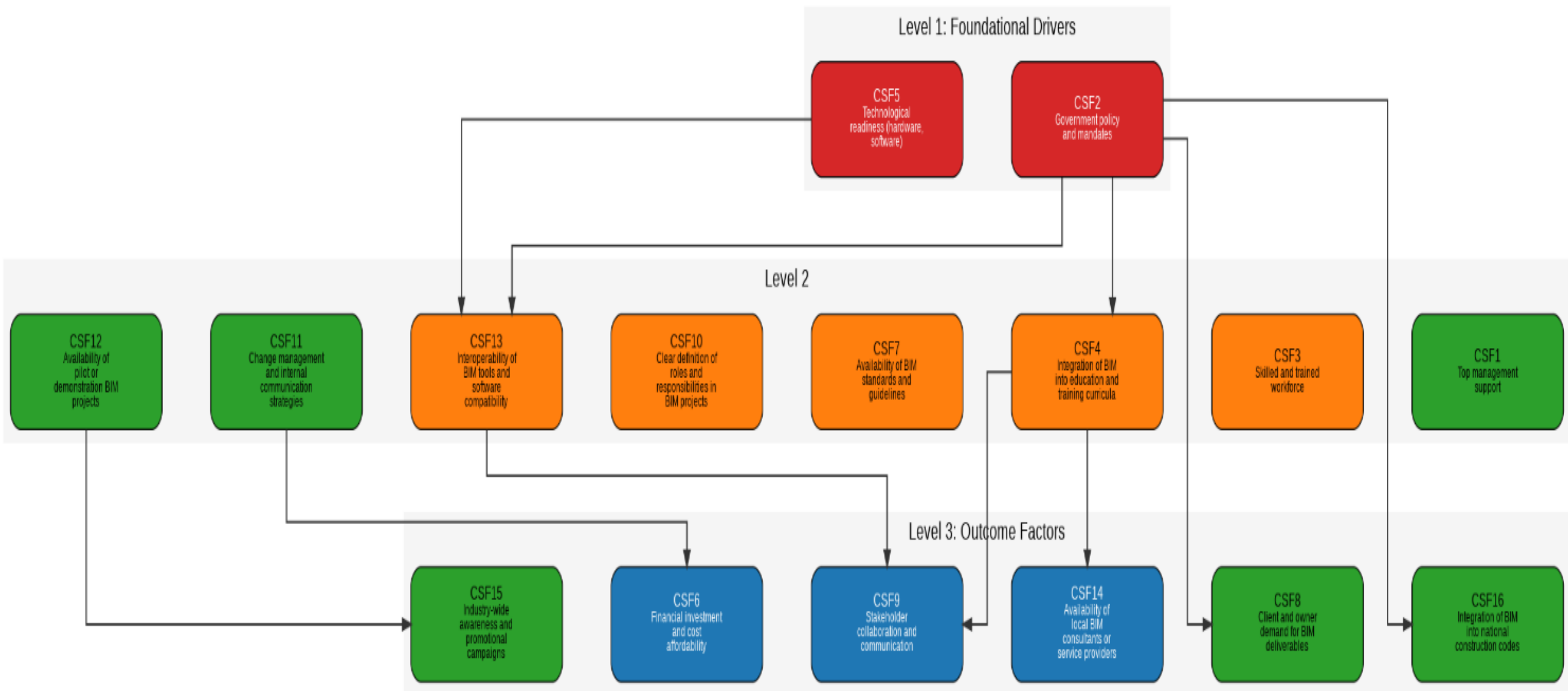

Figure 4.3: ISM-based Hierarchical Model of CSFs for BIM Implementation

Level 2 includes CSFs such as CSF1 ("Top management support"), CSF3 ("Skilled and trained workforce"), CSF4 ("Integration of BIM into education and training curricula"), CSF7 ("Availability of BIM standards and guidelines"), CSF10 ("Clear definition of roles and responsibilities in BIM projects"), CSF11 ("Change management and internal communication strategies"), CSF12 ("Availability of pilot or demonstration BIM projects"), and CSF13 ("Interoperability of BIM tools and software compatibility"). These factors are influenced by Level 1 drivers and, in turn, influence factors at Level 3. Their position indicates that while they are crucial for BIM implementation, their success is contingent upon the establishment of robust policies and technological infrastructure.

Finally, Level 3, at the top of the hierarchy, consists of CSF6 ("Financial investment and cost affordability"), CSF8 ("Client and owner demand for BIM deliverables"), CSF9 ("Stakeholder collaboration and communication"), CSF14 ("Availability of local BIM consultants or service providers"), CSF15 ("Industry-wide awareness and promotional campaigns"), and CSF16 ("Integration of BIM into national construction codes"). These are largely outcome factors, highly dependent on the successful implementation of factors at lower levels. For example, increased client demand for BIM deliverables (CSF8) is likely to emerge once government policies (CSF2) and a skilled workforce (CSF3) are in place. The hierarchical structure thus provides a clear roadmap for intervention, emphasizing that strategic efforts should begin with the foundational drivers to create a cascading positive effect throughout the system.

4.5.2 MICMAC Analysis: Driving and Dependence Power

The MICMAC (Cross-Impact Matrix Multiplication Applied to Classification) analysis further elucidates the influence dynamics among the CSFs by classifying them into four quadrants based on their driving power and dependence power. This analysis is crucial for identifying the most influential factors that can serve as levers for change.

Figure 4.4: MICMAC Driver-Dependence Diagram for CSFs

The MICMAC driver-dependence diagram (Figure 4.4) visually categorizes the CSFs, while Table 4.4 provides the quantitative basis for this classification.

Table 4.4: Driving Power, Dependence Power, and Quadrant for Each CSF

CSF Code	Description	Driving Power	Dependence Power	Quadrant
CSF1	Top management support	3	2	Autonomous
CSF2	Government policy and mandates	10	1	Independent (Driver)
CSF3	Skilled and trained workforce	4	3	Linkage
CSF4	Integration of BIM into education and training curricula	4	3	Linkage
CSF5	Technological readiness (hardware, software)	5	1	Independent (Driver)
CSF6	Financial investment and cost affordability	1	3	Dependent
CSF7	Availability of BIM standards and guidelines	4	5	Linkage
CSF8	Client and owner demand for BIM deliverables	1	2	Autonomous
CSF9	Stakeholder collaboration and communication	1	8	Dependent
CSF10	Clear definition of roles and responsibilities in BIM projects	4	5	Linkage
CSF11	Change management and internal communication strategies	3	2	Autonomous
CSF12	Availability of pilot or demonstration BIM projects	2	1	Autonomous

CSF13	Interoperability of BIM tools and software compatibility	4	5	Linkage
CSF14	Availability of local BIM consultants or service providers	1	4	Dependent
CSF15	Industry-wide awareness and promotional campaigns	1	2	Autonomous
CSF16	Integration of BIM into national construction codes	1	2	Autonomous

The MICMAC analysis classifies the 16 CSFs into four distinct quadrants:

Independent (Driver) Factors: These factors possess high driving power and low dependence power, making them the key levers for change within the system. CSF2 ("Government policy and mandates") with a driving power of 10 and dependence power of 1, and CSF5 ("Technological readiness (hardware, software)") with a driving power of 5 and dependence power of 1, fall into this quadrant. This confirms their foundational role, as also observed in the ISM model. Interventions targeting these factors are expected to have a significant ripple effect across the entire BIM implementation ecosystem. Expert 1, a Government Official, emphasized CSF2 as "non-negotiable" for nationwide adoption, while Expert 3, a BIM Manager, identified CSF5 as the "most critical technical barrier," reinforcing their driver status.

Linkage Factors: These factors exhibit both high driving power and high dependence power, indicating their unstable nature. They are crucial for the system but are also highly influenced by other factors. CSFs in this quadrant include CSF3 ("Skilled and trained workforce"), CSF4 ("Integration of BIM into education and training curricula"), CSF7 ("Availability of BIM standards and guidelines"), CSF10 ("Clear definition of roles and responsibilities in BIM projects"), and CSF13 ("Interoperability of BIM tools and software compatibility"). Managing these factors requires careful attention, as changes in other parts of the system can significantly impact them, and in turn, they can influence many other factors. For instance, while a skilled workforce (CSF3) is a strong driver, its development is dependent on educational integration (CSF4) and policy support (CSF2).

Autonomous Factors: These factors have low driving power and low dependence power, suggesting they are relatively disconnected from the system. CSF1 ("Top management support"), CSF8 ("Client and owner demand for BIM deliverables"), CSF11 ("Change management and internal communication strategies"), CSF12 ("Availability of pilot or demonstration BIM projects"), and CSF15 ("Industry-wide awareness and promotional campaigns"), and CSF16 ("Integration of BIM into national construction codes") are classified as autonomous. While important in their own right, they are less critical for initiating widespread systemic change compared to driver or linkage factors. For example, while top management support (CSF1) is vital for individual firm success, it does not drive as many other factors across the broader industry as government policy does.

Dependent Factors: These factors have low driving power but high dependence power, meaning they are primarily outcomes influenced by other factors. CSF6 ("Financial investment and cost affordability"), CSF9 ("Stakeholder collaboration and communication"), and CSF14 ("Availability of local BIM consultants or service providers") fall into this category. These factors are largely results of the successful implementation of driver and linkage factors. For example, financial investment (CSF6) becomes more affordable when the overall ecosystem supports BIM, and stakeholder collaboration (CSF9) improves when clear roles (CSF10) and standards (CSF7) are in place.

4.6 Integrated Strategic Framework: Combining Importance and Influence

This section represents the culmination of the AHP and MICMAC analyses, synthesizing their findings to develop a comprehensive strategic framework. This framework categorizes CSFs based on both their perceived importance (from AHP) and their influence dynamics (from MICMAC), providing a nuanced guide for targeted interventions.

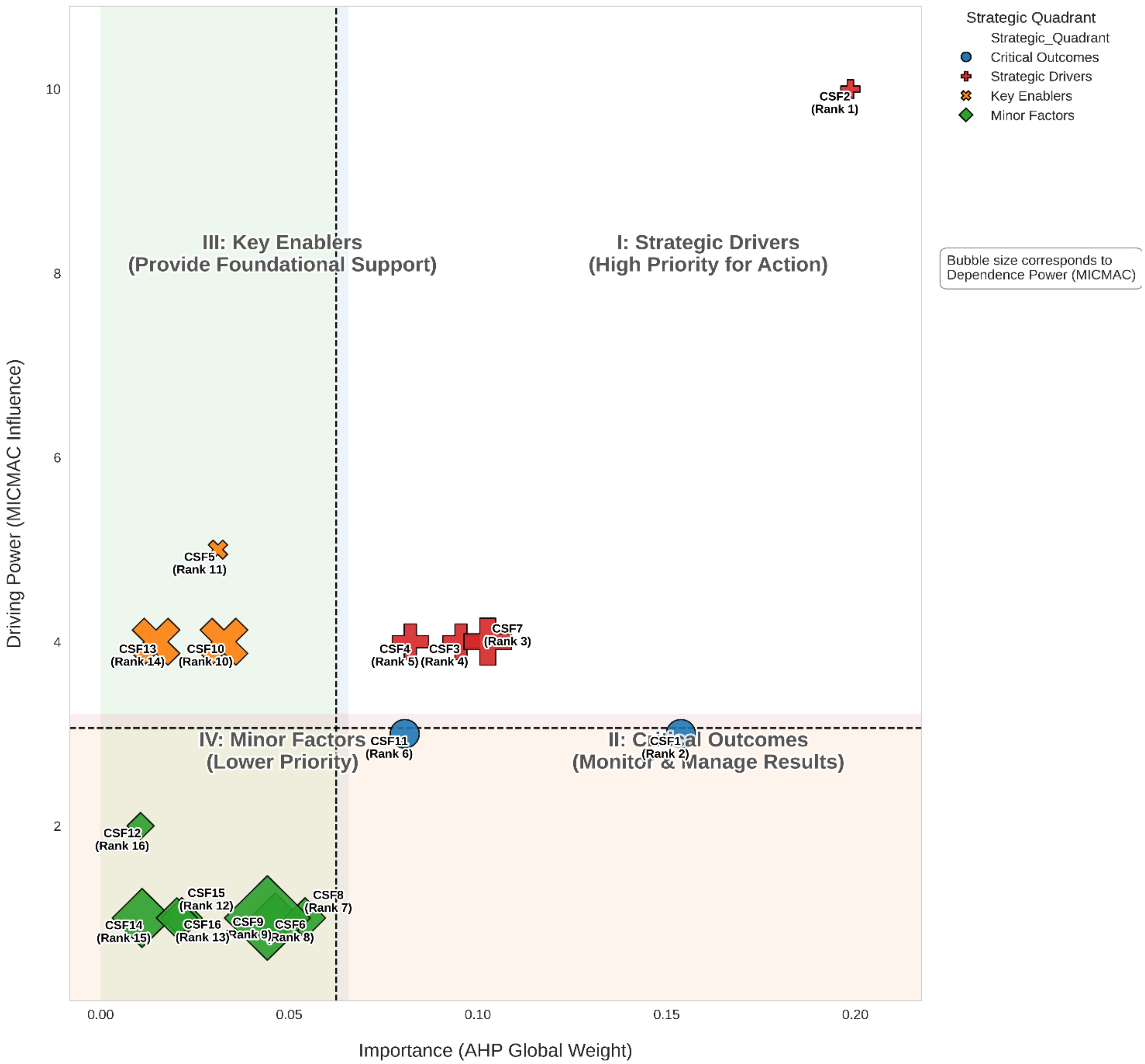

Figure 4.5: Strategic Framework for BIM Implementation CSFs

The integrated strategic framework (Figure 4.5) visually plots each CSF, while Table 4.5 provides the underlying data for this classification.

Table 4.5: AHP-MICMAC Integrated Quadrant Analysis of CSFs

CSF Code	Description	Driving Power	Dependence Power	Global Weight	Global Rank	Strategic Quadrant
CSF1	Top management support	3	2	0.1538	2	Critical Outcomes
CSF2	Government policy and mandates	10	1	0.1987	1	Strategic Drivers
CSF3	Skilled and trained workforce	4	3	0.0955	4	Strategic Drivers
CSF4	Integration of BIM into education and training curricula	4	3	0.0821	5	Strategic Drivers
CSF5	Technological readiness (hardware, software)	5	1	0.0311	11	Key Enablers
CSF6	Financial investment and cost affordability	1	3	0.0463	8	Minor Factors
CSF7	Availability of BIM standards and guidelines	4	5	0.1026	3	Strategic Drivers
CSF8	Client and owner demand for BIM deliverables	1	2	0.0542	7	Minor Factors
CSF9	Stakeholder collaboration and communication	1	8	0.0442	9	Minor Factors
CSF10	Clear definition of roles and responsibilities in BIM projects	4	5	0.0327	10	Key Enablers

CSF11	Change management and internal communication strategies	3	2	0.0806	6	Critical Outcomes
CSF12	Availability of pilot or demonstration BIM projects	2	1	0.0106	16	Minor Factors
CSF13	Interoperability of BIM tools and software compatibility	4	5	0.0147	14	Key Enablers
CSF14	Availability of local BIM consultants or service providers	1	4	0.011	15	Minor Factors
CSF15	Industry-wide awareness and promotional campaigns	1	2	0.0215	12	Minor Factors
CSF16	Integration of BIM into national construction codes	1	2	0.0202	13	Minor Factors

4.6.1 Discussion of the Strategic Quadrants

The integrated AHP-MICMAC framework categorizes CSFs into four strategic quadrants, each demanding a distinct approach for effective BIM implementation.

Quadrant I: Strategic Drivers (High Importance, High Driving Power): This quadrant contains CSFs that are both highly important (as per AHP) and possess significant driving power (as per MICMAC). These are the highest priority factors for intervention, as actions taken here will have a profound and cascading positive effect throughout the BIM implementation ecosystem. This quadrant includes CSF2 ("Government policy and mandates," Global Rank 1, Driving Power 10), CSF3 ("Skilled and trained workforce," Global Rank 4, Driving Power 4), CSF4 ("Integration of BIM into education and training curricula," Global Rank 5, Driving Power 4), and CSF7 ("Availability of BIM standards and guidelines," Global Rank 3, Driving Power 4). The prominence of CSF2 underscores the critical role of top-down governmental directives in a public sector context, aligning with expert opinions that deemed it "non-negotiable". Similarly, the high importance and driving power of human capital development factors (CSF3, CSF4) highlight the need for robust educational reforms and training initiatives to build a competent workforce, which in turn drives other aspects of BIM adoption. The availability of clear standards (CSF7) is also crucial for guiding consistent implementation and avoiding fragmentation.

Quadrant II: Critical Outcomes (High Importance, Low Driving Power): These CSFs are highly important but have low driving power, meaning they are largely outcomes or results influenced by other factors rather than primary drivers of change. This quadrant is labeled "Monitor & Manage Results" in the strategic framework (Image 3). It includes CSF1 ("Top management support," Global Rank 2, Driving Power 3) and CSF11 ("Change management and internal communication strategies," Global Rank 6, Driving Power 3). While top management support is consistently cited as critical for any BIM initiative, its placement here suggests that it is often a

consequence of a conducive environment created by strategic drivers (e.g., government policy making BIM adoption a strategic imperative for organizations). Similarly, effective change management (CSF11) is an outcome of a well-planned implementation process, rather than a standalone driver. These factors should be closely monitored as key performance indicators to gauge the overall success of BIM implementation, but direct initial interventions should focus on the strategic drivers that influence them.

Quadrant III: Key Enablers (Low Importance, High Driving Power): This quadrant comprises factors that, while not ranked as top priorities in terms of overall importance by experts, possess high driving power. These are foundational, "enabling" factors that provide the necessary infrastructure or conditions for successful implementation. They represent the "how" for achieving the strategic drivers. This quadrant includes CSF5 ("Technological readiness (hardware, software)," Global Rank 11, Driving Power 5), CSF10 ("Clear definition of roles and responsibilities in BIM projects," Global Rank 10, Driving Power 4), and CSF13 ("Interoperability of BIM tools and software compatibility," Global Rank 14, Driving Power 4). The position of CSF5 here is particularly insightful; despite its lower AHP importance ranking, its high driving power confirms its foundational role as a prerequisite for BIM. Without adequate hardware, software, and interoperability, even the most robust policies and skilled workforces will struggle to implement BIM effectively. Similarly, clear roles and responsibilities (CSF10) are essential enablers for collaborative BIM workflows. Interventions in this quadrant are crucial for building the underlying capacity and infrastructure that supports strategic drivers.

Quadrant IV: Minor Factors (Low Importance, Low Driving Power): This quadrant contains CSFs with both low importance and low driving power. While still relevant to BIM implementation, they have a lower strategic priority compared to factors in other quadrants. These factors can be addressed after significant progress has been made on the strategic drivers and key enablers. This quadrant includes CSF6 ("Financial investment and cost affordability"), CSF8 ("Client and owner demand for BIM deliverables"), CSF9 ("Stakeholder collaboration and communication"), CSF12 ("Availability of pilot or demonstration BIM projects"), CSF14 ("Availability of local BIM consultants or service providers"), CSF15 ("Industry-wide awareness and promotional campaigns"), and CSF16 ("Integration of BIM into national construction codes"). While financial investment (CSF6) is a concern for contractors, its low driving power suggests that addressing higher-level policy and market demand factors will naturally alleviate this barrier. Similarly, while client demand (CSF8) is important, it is often a consequence of broader industry adoption driven by policy and standards.

4.7 Overall Discussion

This study employed a multi-method approach, integrating AHP, ISM, and MICMAC analyses, to identify, prioritize, and analyze the interrelationships of Critical Success Factors (CSFs) for Building Information Modeling (BIM) implementation in the public building construction sector of Addis Ababa. The findings offer unique insights into the contextual realities of BIM adoption in a developing economy, providing a strategic framework for action.

Comparing the study's findings with the literature reviewed in Chapter 2 reveals both commonalities and distinct emphases. Globally, factors such as top management commitment, skilled workforce, technological readiness, and standardization are consistently identified as critical for BIM success. This study corroborates the importance of these factors, with "Skilled and trained workforce" (CSF3) and "Availability of BIM standards and guidelines" (CSF7) emerging as Strategic Drivers, and "Technological readiness (hardware, software)" (CSF5) as a Key Enabler. "Top management support" (CSF1), while highly important, was classified as a Critical Outcome, suggesting that in the Ethiopian public sector, it might be more of a desired result influenced by broader policy rather than an initial independent driver.

A unique and supreme insight gained from the Ethiopian context is the paramount importance of "Government policy and mandates" (CSF2). This factor consistently ranked highest in importance (AHP Global Rank 1) and exhibited the highest driving power (MICMAC Driving Power 10), classifying it as the leading Strategic Driver. This finding strongly aligns with expert opinions, such as that of Expert 1, a Government Official, who stated it was "non-negotiable" for nationwide adoption. This emphasis on government mandates is more pronounced in developing economies like Ethiopia, where institutional frameworks and top-down directives often play a more significant role in driving technological adoption compared to more mature markets where market forces and private sector initiatives might be primary drivers. The literature review also highlighted the role of government mandates in countries like the UK and Singapore, but the degree of its perceived criticality in Addis Ababa is particularly striking, reflecting the centralized nature of public sector projects and the need for clear regulatory direction to overcome existing fragmentation and resistance to change.

The practical implications of the strategic framework are significant for various stakeholders in Addis Ababa:

For Policymakers (e.g., ECPMI, Addis Ababa City Administration): The framework clearly indicates that "Government policy and mandates" (CSF2) is the most potent lever for change. Policymakers should prioritize developing and enforcing clear, localized BIM mandates and procurement policies for public projects. This includes establishing national BIM standards and guidelines (CSF7) to ensure consistency and interoperability. Furthermore, investing in the integration of BIM into national construction codes (CSF16) should be a long-term strategic goal. The framework also highlights the need to foster "Technological readiness" (CSF5) concurrently, ensuring that the necessary hardware and software infrastructure are accessible and affordable, perhaps through incentives or public-private partnerships.

For Construction Companies (Contractors, Consultants, Architects, Engineers): While government policy sets the stage, companies must cultivate "Top management support" (CSF1) and implement robust "Change management and internal communication strategies" (CSF11) to ensure internal adoption. These are critical outcomes that will naturally improve as foundational drivers are addressed. Companies should also focus on developing a "Skilled and trained workforce" (CSF3) and advocating for "Integration of BIM into education and training curricula" (CSF4) by collaborating with academic institutions. Understanding the "Key Enablers" like "Clear definition of roles and responsibilities in BIM projects" (CSF10) and "Interoperability of BIM tools and software compatibility" (CSF13) will allow firms to streamline their internal processes and improve project-level collaboration.

For Educational Institutions (Universities, Technical Colleges): The study underscores the vital role of "Integration of BIM into education and training curricula" (CSF4) as a Strategic Driver. Educational institutions must urgently update their curricula to meet industry demands, providing practical, hands-on training to produce a "Skilled and trained workforce" (CSF3). This requires investment in BIM software labs, training for instructors, and fostering partnerships with industry professionals and local BIM consultants (CSF14) to bridge the gap between academia and practice. Promoting "Industry-wide awareness and promotional campaigns" (CSF15) can also help increase student and professional interest in BIM.

In essence, the integrated framework provides a holistic view, emphasizing that a successful BIM implementation strategy in Addis Ababa must be multi-pronged, starting with strong governmental leadership and policy, followed by strategic investments in human capital development and technological infrastructure, and supported by robust organizational change management.

4.7.1 Triangulation with Previous Research Findings

Triangulation in this study was applied by cross-verifying findings obtained through the Analytical Hierarchy Process (AHP), Interpretive Structural Modeling (ISM), and MICMAC analysis with the results of previous studies on BIM adoption in both global and Ethiopian contexts. The aim was to enhance the credibility and validity of the strategic framework developed.

This study found that government policy and mandates (CSF2) are the most critical driver for BIM adoption, with the highest weight in AHP (0.1987) and strongest driving power in ISM. Previous studies (e.g., Kassem & Succar, 2017; Abanda et al., 2018) similarly emphasized the necessity of clear policy frameworks and regulatory support for BIM diffusion, confirming that policy intervention is a universal success factor, particularly in developing contexts.

This research finds top management support (CSF) as a highly dependent but less influential factor, indicating it is an outcome of effective drivers such as government policies and skilled workforce. This aligns with empirical studies (Arayici et al., 2011; Eadie et al., 2013), which highlight that managerial commitment typically follows once enabling environments and clear strategies are established.

Skilled and Trained Workforce (CSF3) and Educational Integration (CSF4) as Key Enablers

In this research, human capacity factors (training and education) emerged as linkage elements, influenced by both drivers (policy, resources) and affecting outcomes (management commitment). Studies in African and Asian contexts (Olatunji, 2019) also identified skill shortages as a critical bottleneck for BIM diffusion, reinforcing that technical training and curricular integration are indispensable enablers.

The study framework classified Technological Readiness and ICT Infrastructure as a supporting enabler rather than a primary driver, depending heavily on strategic and policy factors. This contrasts with findings in developed countries (e.g., UK BIM Level 2 mandate), where technology availability was a leading enabler (Succar, 2009). This triangulation highlights contextual differences between mature and emerging construction industries.

Integrated Strategic Framework Validation using the ISM-MICMAC results triangulate with the multi-method approaches in earlier works (e.g., Gamil & Rahman, 2019; Zhao et al., 2017), which also applied structured modeling to map dependencies among CSFs. The consistency of government policy, skilled workforce, and management commitment across multiple methods and studies increases the reliability of the framework proposed in this thesis.

This triangulation demonstrates that your study findings align strongly with global literature while adding Ethiopian-specific contextual insights mainly the dominant role of government intervention and skill development needs.

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

This chapter consolidates the findings of the research, drawing overarching conclusions from the analysis. Based on these conclusions, a set of targeted recommendations is proposed for key stakeholders involved in the Ethiopian construction industry. Finally, the chapter outlines potential directions for future research to build upon the insights gained in this study.

5.1 Conclusions

The primary objective of this research was to develop a strategic framework for Building Information Modeling (BIM) implementation in the public building construction sector of Addis Ababa by identifying, prioritizing, and analyzing the interrelationships of its Critical Success Factors (CSFs). The study successfully achieved this objective through a sequential mixed-method approach, yielding several key conclusions.

The study identified sixteen CSFs through an extensive literature review and validation by industry experts. These factors span across policy, organizational, technological, human resource, and process dimensions. Their identification highlights that BIM adoption is not merely a technical issue but rather a multi-dimensional challenge requiring strategic alignment among different stakeholders.

Using AHP, the CSFs were ranked based on expert judgment. “Government policy and mandates” emerged as the most critical driver (Global Weight = 0.1987), followed by “Top management support” and “Skilled and trained workforce.” This prioritization underscores the centrality of regulatory frameworks and leadership commitment in shaping the pace and direction of BIM adoption in Ethiopia.

The ISM analysis revealed a hierarchical structure of dependencies among CSFs. At the foundational level, government policy & mandates and technological readiness(hardware, software) were positioned as the most influential drivers, while Skilled and trained workforce, Integration of BIM into education and training curricula, Availability of BIM standards and guidelines , Clear definition of roles and responsibilities in BIM projects, Interoperability of BIM tools and software compatibility, Top management support, Change management and internal communication strategies and Availability of pilot or demonstration BIM projects were identified as intermediate enablers and also Skilled and trained workforce, Industry-wide awareness and promotional campaigns, Integration of BIM into national construction codes, Financial investment and cost affordability, Stakeholder collaboration and communication and Availability of local BIM consultants or service providers were identified as outcome factors.so that this demonstrates that successful BIM implementation depends on a layered structure of interdependent factors, with policy acting as the root driver.

The MICMAC analysis categorized CSFs into four quadrants Strategic Drivers, Critical Outcomes, Key Enablers, and Minor Factors. Government policy & mandates, Skilled and trained workforce, Availability of BIM standards and guidelines and Integration of BIM into education and training curricula were identified as Strategic Drivers, while top management support and Change management and internal communication strategies was found to be a Critical Outcome. Technological readiness (hardware, software), Clear definition of roles and responsibilities in BIM projects and Interoperability of BIM tools and software compatibility acted as Key Enablers, whereas certain factors such as Availability of pilot or demonstration BIM projects , Availability of local BIM consultants or service providers , Industry-wide awareness and promotional campaigns , Integration of BIM into national construction codes , Stakeholder collaboration and communication , Financial investment and cost affordability and Client and owner demand for BIM deliverables were grouped as low-impact contributors. This classification provides clarity on where stakeholders should focus their attention and resources.

By synthesizing findings from AHP, ISM, and MICMAC analyses, the study developed a comprehensive strategic framework. The framework not only ranks CSFs but also maps their systemic interplay, offering a practical roadmap for BIM adoption. This integrated approach moves beyond simple prioritization and provides actionable insights for policymakers, contractors, consultants, and clients seeking to institutionalize BIM in Ethiopia’s public construction sector. As overall conclusion The study concludes that BIM adoption in Ethiopia is contingent upon strong government policy, committed organizational leadership, and a skilled workforce, supported by technological readiness and clear guidelines. A multi-method analysis approach has enabled a deeper understanding of how these factors interact, offering a robust and context-specific strategic framework. This research contributes to both theory and practice by providing the first empirically grounded model for BIM implementation in Ethiopia, and it paves the way for more targeted interventions to overcome existing barriers.

5.2 Recommendations

Based on the conclusions derived from the research findings, a set of comprehensive recommendations is proposed for the key stakeholders engaged in Addis Ababa's public construction industry. These recommendations are directed toward government agencies, construction enterprises, professional associations, academic institutions, and funding organizations, as they collectively shape the ecosystem required for successful BIM adoption. The aim is not only to address the most serious problems identified in the study but also to provide clear mechanisms for action that can translate research insights into practical improvements. Each recommendation emphasizes priority actions, highlights responsible stakeholders, and suggests feasible implementation mechanisms tailored to the Ethiopian public construction context. By following these targeted interventions, Addis Ababa's public construction industry will be able to overcome barriers, allocate resources more effectively, and move toward a structured, integrated, and sustainable adoption of Building Information Modeling (BIM).

A persistent problem within Ethiopia's public construction sector is the absence of consensus on the most critical factors influencing BIM adoption. This lack of clarity results in fragmented initiatives, duplication of efforts, and minimal impact on implementation outcomes. The main stakeholders responsible for addressing this problem include the Ministry of Urban Development and Construction (MUDC), public construction enterprises, professional associations, and academic institutions. It is recommended that a national BIM taskforce be established, comprising representatives from these stakeholders. This taskforce should periodically review and validate Critical Success Factors (CSFs) and maintain a centralized knowledge repository that informs policy and practice. Such an institutionalized mechanism would ensure that CSFs remain contextually relevant to the Ethiopian construction environment.

One of the most serious issues facing BIM adoption is the inefficient allocation of resources due to the absence of a clear prioritization of factors. Organizations often attempt to address multiple issues simultaneously without directing resources to the most influential drivers. The key stakeholders include government regulatory bodies, construction firms, and donor or investment agencies supporting infrastructure projects. To address this, it is recommended that clear BIM policies and regulatory mandates be established and reinforced by leadership development and awareness programs for decision-makers. This will ensure that resources are concentrated on the most impactful factors, such as government policy, top management commitment, and workforce training, rather than dispersed across less influential areas.

Another critical problem is the limited understanding of the interdependence among CSFs, which leads to fragmentary interventions that do not achieve systemic improvements. For example, training initiatives may be launched without organizational readiness or government support, undermining their effectiveness. The stakeholders involved in this challenge include training institutions, universities, consulting firms, and public project owners. The recommended mechanism is the development of a stepwise BIM implementation roadmap, informed by the ISM results. This roadmap should start with strengthening foundational drivers such as policy and human capacity development, followed by organizational readiness and technological integration. Pilot projects in flagship public building programs should be used to validate the roadmap and refine strategies before broader national rollout.

A serious problem arises from treating all CSFs as equally significant, which leads to weak focus and suboptimal investment decisions. Policymakers, funding agencies, and top management in construction organizations are the key stakeholders in this domain. The recommended mechanism is the adoption of a tiered resource allocation framework based on the MICMAC classification results. Strategic drivers, such as Government policy & mandates, Skilled and trained workforce, Availability of BIM standards and guidelines and Integration of BIM into education and training curricula, should receive the majority of institutional and financial support. Critical outcomes, such top management support and Change management and internal communication strategies, should be enhanced through leadership capacity-building. Technological enablers should be supported through subsidies or shared platforms, while minor factors can be addressed as supplementary considerations. This approach ensures that limited resources are allocated efficiently and strategically.

The overarching challenge to BIM adoption is the absence of an integrated national strategy that unifies government policy, organizational readiness, technology, and human capacity. The primary stakeholders include the Ethiopian Construction Works Corporation (ECWC), professional regulatory councils, the Ministry of Education, and private construction firms. To address this challenge, it is recommended that the proposed integrated BIM strategic framework be formally adopted as a guiding document for public sector projects and incorporated into procurement and contracting requirements. Universities should embed BIM education—including training in advanced digital tools such as custom scripting—into engineering and construction curricula. Moreover, flagship pilot projects implemented by ECWC and municipal authorities should serve as demonstrative platforms, validating the framework and showcasing the tangible benefits of BIM adoption to the wider construction industry.

5.3 Future Research Work Directions

While this study has provided a comprehensive framework for identifying, prioritizing, and structuring Critical Success Factors (CSFs) for BIM implementation in Addis Ababa's public construction sector, further research is necessary to strengthen and expand its practical impact. The following directions are proposed for future research, building on the recommendations provided in Section 5.2.

Future studies should focus on designing and testing a stepwise BIM adoption roadmap tailored to the Ethiopian context. This research could explore how government policy, institutional readiness, and technological infrastructure can be sequenced in practical phases, validated through pilot projects in Addis Ababa, and later scaled nationally.

Since prioritization of CSFs highlights the importance of efficient resource distribution, future research should examine models of cost–benefit analysis and funding mechanisms for BIM adoption. Studies can investigate how limited resources can be optimized across government, private firms, and educational institutions to maximize impact.

This research applied ISM-MICMAC to analyze interrelationships at a single point in time. Future research should adopt longitudinal approaches to track how CSFs evolve over time in response to policy shifts, technological advancements, and capacity-building initiatives. Such studies will offer dynamic insights into the systemic interplay of BIM adoption drivers.

Given the centrality of human capacity development, further studies should assess how BIM can be effectively integrated into engineering and construction curricula at Ethiopian universities. Future work could evaluate the effectiveness of different pedagogical approaches (e.g., problem-based learning, simulation-based training, or custom script programming) in producing a BIM-ready workforce.

Future research should investigate organizational behavior aspects, such as leadership culture, change management practices, and managerial attitudes toward digital transformation in construction. Such studies would enrich understanding of how top management support can be cultivated and sustained in Ethiopian public enterprises.

There is a need for empirical research that tests the proposed integrated BIM strategic framework through real-life pilot projects in Addis Ababa. Future studies could compare project outcomes between BIM-enabled and traditional construction projects, providing evidence of cost, time, and quality benefits. Comparative cross-country studies with other developing economies could also shed light on contextual similarities and differences.

Finally, future studies should investigate the development of supportive legal and regulatory frameworks, including procurement guidelines, intellectual property protection for BIM models, and standardization of data exchange. Research in this direction will provide a stronger policy backbone for the recommendations outlined in this thesis.

As a Summary These future research directions provide pathways to strengthen the evidence base for BIM adoption in Ethiopia. They emphasize policy refinement, organizational transformation, capacity building, and practical validation through pilot projects ensuring that the proposed strategic framework evolves into a sustainable and actionable national strategy.

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APPENDIX

Addis College

MSc in Construction Technology and Management Data Collection Form

AHP Survey: Prioritization of Critical Success Factors for BIM Implementation in the Ethiopian Public Construction sector

1.Introduction

Dear Expert,

Thank you for participating in this crucial stage of our research. This study aims to prioritize the Critical Success Factors (CSFs) for the successful implementation of Building Information Modeling (BIM) in Addis Ababa's public building construction sector. Your expert opinion is invaluable in determining the relative importance of these factors.

This survey uses the Analytical Hierarchy Process (AHP), a structured decision-making technique. You will be asked to compare factors against each other (pairwise comparison) to determine which is more important and by how much. The process is divided into two parts: first, comparing the main categories of factors, and second, comparing the factors within each category.

2.Respondent Information

Please provide some general information about your professional background.

Current Role / Title:	
Years of Experience in the Construction Industry:	
Years of Experience with BIM (Direct or Indirect):	

3.Instructions for Pairwise Comparison

1. For each pair of items presented below, please perform the following two steps: Decide which of the two items you believe is more important for successful BIM implementation.
2. Indicate the intensity of its importance using the 9-point scale provided below.

Please use the following scale for your judgments:

Intensity of Importance	Definition
1	Equal Importance: The two factors contribute equally to the objective.
3	Moderate Importance: Experience slightly favors one factor over another.
5	Strong Importance: Experience strongly favors one factor over another.
7	Very Strong Importance: A factor is favored very strongly over another.
9	Extreme Importance: The evidence favoring one factor is of the highest possible order.

Note: Values of 2, 4, 6, and 8 can be used to represent intermediate judgments.

4. AHP Survey - Part 1: Comparison of Main Factor Categories

In this part, please compare the main categories of Critical Success Factors. This will determine the overall weight of each category.

Pairwise Comparison of Main Categories

Factor A	Your Judgment (Place 'X' and a number from 1-9)	Factor B
Management and Organization (MO)	Which is more important, and by how much? [ ] Factor A is more important by: ______ [ ] Factors are equally important (1) [ ] Factor B is more important by: ______	Policy and Standards (PS)
Management and Organization (MO)	Which is more important, and by how much? [ ] Factor A is more important by: ______ [ ] Factors are equally important (1) [ ] Factor B is more important by: ______	Technology and Process (TP)
Management and Organization (MO)	Which is more important, and by how much? [ ] Factor A is more important by: ______ [ ] Factors are equally important (1) [ ] Factor B is more important by: ______	Training and Resources (TR)
Policy and Standards (PS)	Which is more important, and by how much? [ ] Factor A is more important by: ______ [ ] Factors are equally important (1) [ ] Factor B is more important by: ______	Technology and Process (TP)
Policy and Standards (PS)	Which is more important, and by how much? [ ] Factor A is more important by: ______ [ ] Factors are equally important (1) [ ] Factor B is more important by: ______	Training and Resources (TR)
Technology and Process (TP)	Which is more important, and by how much? [ ] Factor A is more important by: ______ [ ] Factors are equally important (1) [ ] Factor B is more important by: ______	Training and Resources (TR)

5.AHP Survey - Part 2: Comparison of CSFs Within Each Category

In this part, please compare the CSFs against each other only within their respective categories.

Category: Management and Organization (MO)

Factors being compared in this section:

- CSF1: Top management support
- CSF6: Financial investment and cost affordability
- CSF10: Clear definition of roles and responsibilities in BIM projects
- CSF11: Change management and internal communication strategies

Factor A	Your Judgment (Place 'X' and a number from 1-9)	Factor B
CSF1: Top management support	Which is more important, and by how much? [ ] Factor A is more important by: _______ [ ] Factors are equally important (1) [ ] Factor B is more important by: _______	CSF6: Financial investment and cost affordability
CSF1: Top management support	Which is more important, and by how much? [ ] Factor A is more important by: _______ [ ] Factors are equally important (1) [ ] Factor B is more important by: _______	CSF10: Clear definition of roles and responsibilities in BIM projects
CSF1: Top management support	Which is more important, and by how much? [ ] Factor A is more important by: _______ [ ] Factors are equally important (1) [ ] Factor B is more important by: _______	CSF11: Change management and internal communication strategies
CSF6: Financial investment and cost affordability	Which is more important, and by how much? [ ] Factor A is more important by: _______ [ ] Factors are equally important (1) [ ] Factor B is more important by: _______	CSF10: Clear definition of roles and responsibilities in BIM projects

CSF6: Financial investment and cost affordability	Which is more important, and by how much? [ ] Factor A is more important by: _______ [ ] Factors are equally important (1) [ ] Factor B is more important by: _______	CSF11: Change management and internal communication strategies
CSF10: Clear definition of roles and responsibilities in BIM projects	Which is more important, and by how much? [ ] Factor A is more important by: _______ [ ] Factors are equally important (1) [ ] Factor B is more important by: _______	CSF11: Change management and internal communication strategies

Category: Policy and Standards (PS)

Factors being compared in this section:

- CSF2: Government policy and mandates
- CSF7: Availability of BIM standards and guidelines
- CSF8: Client and owner demand for BIM deliverables
- CSF16: Integration of BIM into national construction codes

Factor A	Your Judgment (Place 'X' and a number from 1-9)	Factor B
CSF2: Government policy and mandates	Which is more important, and by how much? [ ] Factor A is more important by: _______ [ ] Factors are equally important (1) [ ] Factor B is more important by: _______	CSF7: Availability of BIM standards and guidelines
CSF2: Government policy and mandates	Which is more important, and by how much? [ ] Factor A is more important by: _______ [ ] Factors are equally important (1) [ ] Factor B is more important by: _______	CSF8: Client and owner demand for BIM deliverables
CSF2: Government policy and mandates	Which is more important, and by how much? [ ] Factor A is more important by: _______ [ ] Factors are equally important (1) [ ] Factor B is more important by: _______	CSF16: Integration of BIM into national construction codes
CSF7: Availability of BIM standards and guidelines	Which is more important, and by how much? [ ] Factor A is more important by: _______ [ ] Factors are equally important (1) [ ] Factor B is more important by: _______	CSF8: Client and owner demand for BIM deliverables

CSF7: Availability of BIM standards and guidelines	Which is more important, and by how much? [ ] Factor A is more important by: _______ [ ] Factors are equally important (1) [ ] Factor B is more important by: _______	CSF16: Integration of BIM into national construction codes
CSF8: Client and owner demand for BIM deliverables	Which is more important, and by how much? [ ] Factor A is more important by: _______ [ ] Factors are equally important (1) [ ] Factor B is more important by: _______	CSF16: Integration of BIM into national construction codes

Category: Technology and Process (TP)

Factors being compared in this section:

- CSF5: Technological readiness (hardware, software)
- CSF9: Stakeholder collaboration and communication
- CSF12: Availability of pilot or demonstration BIM projects
- CSF13: Interoperability of BIM tools and software compatibility

Factor A	Your Judgment (Place 'X' and a number from 1-9)	Factor B
CSF5: Technological readiness (hardware, software)	Which is more important, and by how much? [ ] Factor A is more important by: _______ [ ] Factors are equally important (1) [ ] Factor B is more important by: _______	CSF9: Stakeholder collaboration and communication
CSF5: Technological readiness (hardware, software)	Which is more important, and by how much? [ ] Factor A is more important by: _______ [ ] Factors are equally important (1) [ ] Factor B is more important by: _______	CSF12: Availability of pilot or demonstration BIM projects
CSF5: Technological readiness (hardware, software)	Which is more important, and by how much? [ ] Factor A is more important by: _______ [ ] Factors are equally important (1) [ ] Factor B is more important by: _______	CSF13: Interoperability of BIM tools and software compatibility
CSF9: Stakeholder collaboration and communication	Which is more important, and by how much? [ ] Factor A is more important by: _______ [ ] Factors are equally important (1) [ ] Factor B is more important by: _______	CSF12: Availability of pilot or demonstration BIM projects

CSF9: Stakeholder collaboration and communication	Which is more important, and by how much? [ ] Factor A is more important by: _______ [ ] Factors are equally important (1) [ ] Factor B is more important by: _______	CSF13: Interoperability of BIM tools and software compatibility
CSF12: Availability of pilot or demonstration BIM projects	Which is more important, and by how much? [ ] Factor A is more important by: _______ [ ] Factors are equally important (1) [ ] Factor B is more important by: _______	CSF13: Interoperability of BIM tools and software compatibility

Category: Training and Resources (TR)

Factors being compared in this section:

- CSF3: Skilled and trained workforce
- CSF4: Integration of BIM into education and training curricula
- CSF14: Availability of local BIM consultants or service providers
- CSF15: Industry-wide awareness and promotional campaigns

Factor A	Your Judgment (Place 'X' and a number from 1-9)	Factor B
CSF3: Skilled and trained workforce	Which is more important, and by how much? [ ] Factor A is more important by: _______ [ ] Factors are equally important (1) [ ] Factor B is more important by: _______	CSF4: Integration of BIM into education and training curricula
CSF3: Skilled and trained workforce	Which is more important, and by how much? [ ] Factor A is more important by: _______ [ ] Factors are equally important (1) [ ] Factor B is more important by: _______	CSF14: Availability of local BIM consultants or service providers
CSF3: Skilled and trained workforce	Which is more important, and by how much? [ ] Factor A is more important by: _______ [ ] Factors are equally important (1) [ ] Factor B is more important by: _______	CSF15: Industry-wide awareness and promotional campaigns
CSF4: Integration of BIM into education and training curricula	Which is more important, and by how much? [ ] Factor A is more important by: _______ [ ] Factors are equally important (1) [ ] Factor B is more important by: _______	CSF14: Availability of local BIM consultants or service providers

CSF4: Integration of BIM into education and training curricula	Which is more important, and by how much? [ ] Factor A is more important by: _______ [ ] Factors are equally important (1) [ ] Factor B is more important by: _______	CSF15: Industry-wide awareness and promotional campaigns
CSF14: Availability of local BIM consultants or service providers	Which is more important, and by how much? [ ] Factor A is more important by: _______ [ ] Factors are equally important (1) [ ] Factor B is more important by: _______	CSF15: Industry-wide awareness and promotional campaigns

Conclusion

Thank you for taking the time to complete this important survey. Your input is essential to the success of this research and will contribute significantly to developing a strategic framework for BIM adoption in Ethiopia.

Addis College

MSc in Construction Technology and Management Data Collection Form

An Interpretive Structural Modeling (ISM) Approach: Survey on the Interrelationships of Critical Success Factors for BIM Implementation in the Ethiopian Public Construction sector

1.Introduction for the Expert

Dear Expert,

Thank you for your continued support of this research. In the previous stage (AHP Survey), we prioritized the Critical Success Factors (CSFs) for BIM implementation. In this second stage, our goal is to understand how these factors relate to and influence one another. This will help us build a hierarchical model (using ISM) and identify the most influential drivers of change (using MICMAC analysis).

Your expertise is essential for mapping the complex network of relationships between these CSFs.

2.Respondent Information

Please provide some general information about your professional background.

Current Role / Title:	
Years of Experience in the Construction Industry:	
Years of Experience with BIM:	

3. Instructions for Completing the Matrix

For each pair of factors, please determine the nature of their relationship by asking the guiding question:

'Does Factor i help achieve or influence Factor j?'

Based on your answer, please place one of the following four symbols (V, A, X, O) in the corresponding cell in the matrix provided in Section 5.

Contextual Relationship Symbols (VAXO)

Symbol to Enter	Definition of Relationship (i = row factor, j = column factor)
V	Factor i influences Factor j (but j does not influence i).
A	Factor j influences Factor i (but i does not influence j).
X	Factor i and Factor j influence each other (bidirectional influence).
O	Factor i and Factor j are unrelated (no significant influence).

You only need to fill in the white cells in the upper-right half of the matrix. The shaded cells are not required.

4. List of Critical Success Factors (CSFs)

CSF1: Top management support

CSF2: Government policy and mandates

CSF3: Skilled and trained workforce

CSF4: Integration of BIM into education and training curricula

CSF5: Technological readiness (hardware, software)

CSF6: Financial investment and cost affordability

CSF7: Availability of BIM standards and guidelines

CSF8: Client and owner demand for BIM deliverables

CSF9: Stakeholder collaboration and communication

CSF10: Clear definition of roles and responsibilities in BIM projects

CSF11: Change management and internal communication strategies

CSF12: Availability of pilot or demonstration BIM projects

CSF13: Interoperability of BIM tools and software compatibility

CSF14: Availability of local BIM consultants or service providers

CSF15: Industry-wide awareness and promotional campaigns

CSF16: Integration of BIM into national construction codes

5. Structural Self-Interaction Matrix (SSIM)

For each white cell, please enter V, A, X, or O to define the relationship between the row factor (i) and the column factor (j).

Factors	CSF1	CSF2	CSF3	CSF4	CSF5	CSF6	CSF7	CSF8	CSF9	CSF10	CSF11	CSF12	CSF13	CSF14	CSF15	CSF16
CSF1																
CSF2																
CSF3																
CSF4																
CSF5																
CSF6																
CSF7																
CSF8																
CSF9																
CSF10																
CSF11																
CSF12																
CSF13																
CSF14																
CSF15																
CSF16																

6. Completion

Thank you for dedicating your time and expertise to this detailed analysis. Your input is fundamental to constructing an accurate model of the dynamics of BIM adoption in Ethiopia.