Utilization Assessment on Building Information Modelling (BIM) In Ethiopia, A Case Study in Addis Ababa

Yared Getachew

A Thesis Submitted to the department of Civil Engineering,

College of Civil Engineering and Architecture

Presented in Partial Fulfilment of the Requirement for the Degree of Master's in Construction Engineering and Management

Office of Graduate Studies

Adama Science and Technology University

June, 2025

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Advisor: Lemma Beressa (PhD)

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DECLARATION

I hereby declare that this Master's Thesis entitled "Utilization Assessment on Building Information Modeling (BIM) In Ethiopia, A Case Study in Addis Ababa" is my original work. That is, it has not been submitted for the award of any academic degree, diploma, or certificate in any other university. All sources of materials that are used for this thesis have been duly acknowledged through citation.

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ABSTRACT

Building Information Modeling (BIM) has emerged as a transformative collaboration process in the global construction industry, enabling enhanced spatial planning, design accuracy, construction efficiency, and facility management. When effectively implemented, BIM mitigates communication barriers, fosters shared knowledge, and serves as a reliable decision-making tool throughout a project's lifecycle. Despite its global adoption, BIM utilization in Ethiopia's construction sector remains young, with slow uptake attributed to limited awareness, high implementation costs, and insufficient technical expertise. This study evaluates the current status of BIM adoption in Ethiopia, focusing on awareness levels, practical applications, and key challenges. A field survey was conducted in Addis Ababa using structured questionnaires distributed via stratified random sampling to construction industry stakeholders. Findings reveal that while professionals demonstrate awareness of BIM, its application is predominantly restricted to design phases, hindered by low client demand, financial constraints, and limited software proficiency. The study underscores the need for policy interventions to promote BIM integration, including workforce training, government-led initiatives, and academic curriculum enhancements. The BIM integration framework in Addis Ababa emphasizes assessing existing buildings, collecting accurate data using advanced tools like 3D laser scanning and GIS, and creating as-built BIM models for lifecycle management. These digital twins will be integrated with facility management systems to enable real-time monitoring, efficient maintenance, and sustainable retrofitting through energy modeling. Capacity-building programs, supportive policies, and pilot projects support scalability, aiming to expand BIM's impact through initiatives like city-wide digital twins and public-private partnerships. Recommendations emphasize raising awareness among construction firms and advocating for public-sector mandates to accelerate BIM adoption.

Keywords: Building Information Modeling (BIM), AEC industry, adoption challenges, construction technology.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LISTS OF ACRONYMS

AEC	Architecture, Engineering, and Construction
BIM	Building information modeling
CAD	Computer Aided Design
CDE	Common data environment
CI	Construction industry
CP	Construction project
IAI	International Alliance for Interoperability
ICT	Information and communication technology
IFCs	Industry Foundation Classes
IPD	Integrated Project Delivery
MEP	Mechanical, electrical, and plumbing
PI	Performance indicator
PMBOK	Project Management Body of Knowledge
ROI	Return on investment
2D	Two-dimensional
3D	Three-dimensional
4D	Four-dimensional
5D	Five-dimensional
6D	Six-dimensional
7D	Seven-dimensional
8D	Eight-dimensional

CHAPTER ONE

1. INTRODUCTION

1.1. Background

In the past several decades, transformation brought about by technology has enhanced several industries, notably in the quality, productivity, and variety of products offered. In the Architecture, Engineering, Construction (AEC) industry, tools of technology are extensively used in the design, construction, and operation of buildings and other infrastructure assets. With building information modelling (BIM), construction and design teams can fully leverage the technological resources available to them. By consolidating all relevant multidisciplinary construction and design documents into a single repository, the BIM process facilitates the development and administration of data across the entire architecture, engineering, and construction project lifecycle (Jung and Joo, 2011).

BIM, as a progressive methodology in the AEC sector arose at the end of the 20th century, enables integrated planning and holistic design approaches, which can potentially facilitate better industry performance, allowing to foresee and prevent errors as well as optimize processes to provide better and more sustainable solutions throughout the assets' lifecycle (Azhar, 2011).

Capturing programmatic data, analyzing energy performance, and even evaluating costs, a virtual model developed in BIM can accomplish all these things. Also, BIM software is fully capable of generating conventional drawings like plans and 3D renderings. View "extraction" of the model can also be performed, and therefore, "drawing" generation is no longer manual. So, all documents necessary for seamless interaction and efficient collaboration between the members of the design and construction teams, as well as documents for permits, are always up-to-date and accurate with every design iteration. A virtual 3D model is not only a graphical design but also a virtual database which required for a building project to be built virtually before being built physically. Though there is doubt regarding how traditional construction management techniques fit together. Hence, construction management (CM) systems can adopt BIM as an example model for one of the initial strides in implementing 3D technologies in construction, which began as 3D solid modelling in the late 1970s. At this period, the manufacturing industry conducted product design, analysis, and simulation of 3D models of products. The manufacturing industry realized, spent more resources on technology, and seized the “potential benefits of integrated analysis capabilities, reduction of errors, and the move toward factory automation”. They worked together with modelling tool providers to reduce and eliminate the technological software setbacks. Recently, various BIM tools have become readily available throughout the construction industry. This is a reward of the construction industry’s dedication to Building Information Modelling for the last 20 years (Eastman, 2011).

The construction industry has come to a point to realize the true benefits of technological advancement. The labour efficiency gap can be closed via the Building Information Modelling concept. Therefore, it is the intention of this project to study BIM and its tools to determine the benefits and setbacks it poses to construction managers at risk (Fadeyi, 2017).

BIM involves digitally representing the essential characteristics of a building. It serves a facility’s life cycle, starting from an idea and outlasting the structure's eventual demolition, and also provides a wealth of knowledge that can aid in making informed decisions for the entire span of the building. Which focuses on collaboration and integration of stakeholders at different phases of the life cycle is the peculiar feature of BIM. On the other hand, some define BIM as an intelligent 3D model-based process that gives architecture, engineering, and construction professionals the insight and tools to more efficiently plan, design, construct, and manage buildings and infrastructure (Kymmell, 2008).

Applying the BIM approach helps to realize a much more significant use of computer technology in the design, engineering, construction, and running of built facilities. BIM stores, maintains, and exchanges data using thorough digital representations of the building information models instead of documenting information in drawings. This method greatly enhances the handover of building information to the operator, the coordination of the design activities, the integration of simulations, the setup and control of the construction process, and so on. By reducing the manual re-entering of data to a minimum and enabling the consequent re-use of digital information, laborious and error-prone work is avoided, which in turn results in an increase in productivity and quality in construction projects (Azhar et al., 2012).

1.2. Statement of the Problem

As many Ethiopian and foreign researchers have tried to state that the Ethiopian construction industry sector is one to watch because of its rapid growth, there are many barriers to its effectiveness and efficiency. In addition to design errors and clashes, project overrun, low productivity, low building quality, the poor satisfaction of stakeholders /client/users and shortage or unauthenticated data for facility management during maintenance stage are the major barrier to reach to the intended level of the industry growth (Arayici et al., 2012). This is where BIM becomes essential.

While the global construction industry is rapidly advancing and becoming increasingly efficient, Ethiopia has not yet achieved the desired level of progress in this sector. Reasons for cost and time overruns of projects are attributed to design incompleteness, design changes, scope changes, changes in volume of work, poor initial estimation of completion time, force majeure, and other reasons. As can be noted from this study, most of the reasons arise at earlier stages of the project cycle (gaps in strategic project planning and preparation) thus showing more serious gaps related to project feasibility/planning, design and tender documents equally important gap is associated with ineffective contracts implementation management that includes risks management and performance monitoring practices (Asmerom Taddese, 2016).

Most of or projects are either delayed or terminated due to cost, deign, poor construction performance in accordance to the planned scheduling and many others so, we need to asses our adoption of Building Information Modeling technology concepts. This research will try to assess the utilization and obstacles that BIM is facing in the Ethiopian construction industry and will suggest applicable recommendations in order for BIM to succeed in the Ethiopian construction sector.

1.3. Research objectives

1.3.1. General objective

The General objective of this research paper is to broadly assess the utilization of building information modeling in Ethiopian construction, per the rate of implementation, and if there are challenges that inhibit the industry from using building information modeling, and also to assess key elements that will help the industry.

1.3.2. Specific objectives

This research paper will try to meet three different specific objectives, which are:

- To assess the application of building information modeling in the project management system planning and design phase.
- To investigate the utilization of building information modeling as an auditing tool and contrast it with traditional auditing of project management progress.
- To develop a Framework for BIM Integration with existing buildings and assess which building information modeling software is implemented.

1.4. Significance of the study

This study assesses the current utilization of BIM in Ethiopia in accordance with the rate at which our AEC offices are implementing and integrating the technology into their work format and investigates the critical challenges in implementing BIM in our construction industry. Furthermore, introducing building information modeling to the industry will help to control and audit the progress of the current mega projects to finish them according to the design, time frame, and cost, which will boost the construction industry sector significantly. In addition, it will manage to integrate facility maintenance and management in the design stage.

In general, incorporating BIM into the Ethiopian construction industry has a positive effect on the quality of our projects and sets clear accountability for the post-construction phases. As the technology is new and progressing rapidly in the world and our country, this study will add some value and will invite more researchers to this area.

1.5. Scope of the study

This study targeted the ongoing utilization of building information modeling and its key attributes in the Ethiopian construction sector. It tried to investigate and point out the challenges and benefits that building information modeling presents to the Ethiopian Construction industry development. Specifically, a case study was conducted at the Ethiopian Construction Design and Supervision Works Corporation, as well as in selected architectural offices.

CHAPTER TWO

2. LITERATURE REVIEW

2.1.Background of BIM

Construction projects are becoming much more complex and difficult to manage (Alshawi and Ingirige, 2003). One complexity is the reciprocal interdependencies between different stakeholders, such as financing bodies, authorities, architects, engineers, lawyers, contractors, suppliers, and trades (Sears et al., 2008). As a response to the increasing complexity of projects, information and communication technology [ICT] has been developing at a very fast pace (Taxén and Lilliesköld, 2008).

During the last decade, a major shift in ICT for the construction industry has been the proliferation of BIM in industrial and academic circles as the new Computer Aided Design (CAD) paradigm. BIM is currently the most common term for a new way of approaching the design, construction, and maintenance of buildings. It has been defined as “a set of interacting policies, processes, and technologies generating a methodology to manage the essential building design and project data in digital format throughout the building's life-cycle” (Succar, 2009).

BIM is an acronym that can stand either for “Building Information Modeling” or “Building Information Management.” This means more “Building Information modeling” Via project data management. These two words are related to each other since BIM stands for a whole process of design, construction, and operation starting from a digital Model and makes use of object-oriented information to manage and sustain the whole lifetime process in the building (AEC) sector. The most crucial point is realizing why BIM is so crucial and what it is used for. BIM serves purposes beyond design or visual aid. It is a technique allowing the creation of a shared data model. The model is available to all the participants, including the managers, construction firms, property owners, and building designers. In simpler words, BIM is a set of Technologies, Digital Processes, and Standardization policies for the digital representation of the built environment (Lee and Borrmann, 2020).

The Technologies are: the digital equivalents of the real-world physical objects, and a digital database (common data environment) of the BIM model elements. Lately, BIM has been making significant advances in the construction industry. While it may seem new to many, the ideas and technologies behind BIM have been evolving for more than fifty years (Silva and AMORIM, 2011).

The idea of BIM is not ascribed to one person but rather reflects a rich history of invention spanning the United States, Central and Northern Europe, all the way to Japan. Interestingly, also is the fact that some of BIM's past is entwined with the Cold War. All these engaging stories come down to the race to create the perfect collaborative solution to disrupt the 2D CAD workflows (Bergin, 2011).

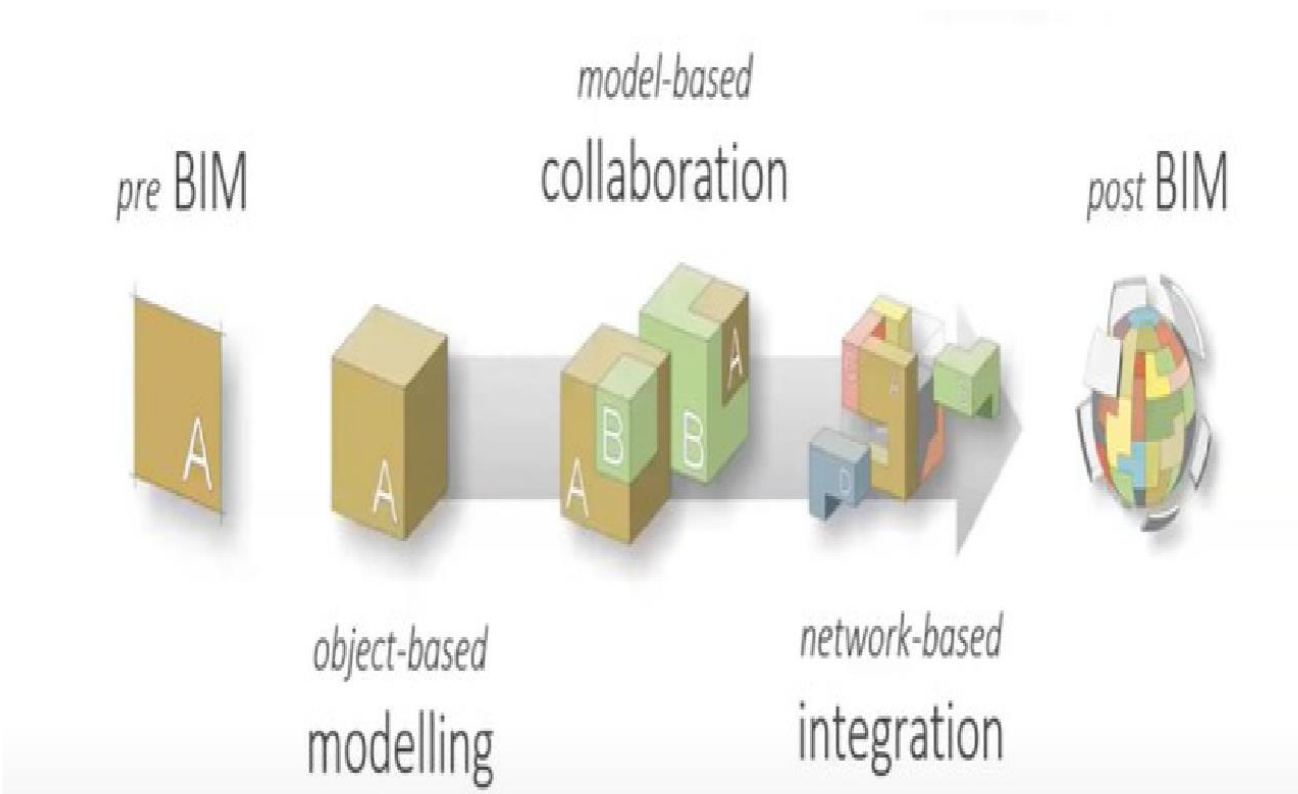

Figure 2.1: BIM stages of adoption (Miceli et al., 2017)

BIM is 'the concept of relating data to geometrical objects that form a digital representation of building component assemblies' (Holzer, 2015). In the last ten years, many countries have recognized the capabilities and benefits of BIM and have begun to adopt BIM in the Construction industry. According to the NBS (Thrower, 2021) report, BIM Adoption in the UK reached 73% in 2020, a considerable improvement from 13% in 2011. Thanks to its extensive application and ongoing development, BIM has started to reflect a management approach more than only a technology.

2.2. Application of BIM

The theoretical framework of BIM promotes understanding of this technology in the AEC sector through multiple research perspectives. BIM is recognized as an effective tool for eliminating design errors and reducing costs and time (Alwisy et al., 2012). However, from a technological perspective, certain organizational factors equally important, if not more so, than BIM adoption itself, have often been overlooked in research. As noted by (Ahuja et al., 2016), there is a lack of studies that explore BIM through the lens of organizational variables. This gap limits a comprehensive understanding of the technology's implementation and impact. BIM has evolved beyond a digital construction tool to become a comprehensive management method essential for modern project management, particularly in complex construction environments where coordination between multiple stakeholders is critical.

Recent studies highlight BIM's transformative potential in bridging the gap between design intent and construction execution. The technology enables real-time collaboration between architects, engineers, and contractors through shared digital models that reduce interpretation errors and change orders (Alwisy et al., 2012). This collaborative environment is particularly valuable in large-scale projects where traditional communication methods often lead to information silos and coordination challenges.

2.2.1. Integration of building information modeling and project management

The project lifecycle context reveals that a project constitutes a temporary endeavor with defined phases, including starting, preparing, carrying out, and ending (Coleman and Bourne, 2018). Traditional project management typically concludes at project delivery, whereas BIM extends through the entire building lifecycle. This full lifecycle encompasses raw material extraction, manufacturing, construction, operation and maintenance, demolition and disposal, and reuse or recycling (Ngwepe and Aigbavboa, 2015), creating opportunities for sustainable design and circular economy practices.

Current construction planning remains manual and time-intensive, relying on bar charts, CPM network diagrams, and time-changes diagrams. These conventional methods lack capabilities for visualizing activity sequencing and execution patterns (Metkari and Attar, 2015). BIM-enabled virtual models address these limitations by recording programmatic data, generating automatic 3D renderings, maintaining always-updated documentation, and simulating construction before physical implementation, thereby reducing costly on-site modifications.

The integration of BIM with project management methodologies has shown particular promise in risk mitigation. By enabling clash detection during the design phase and providing accurate quantity takeoffs, BIM helps identify potential issues before construction begins (Brown et al., 2023). This proactive approach to risk management contrasts sharply with traditional methods, where problems are often discovered during construction, leading to delays and budget overruns.

Regarding project delivery methods, BIM enhances all major approaches, including Design-Bid-Build, Construction Management at Risk, Design/Build, and Integrated Project Delivery (IPD). Key applications include 4D BIM for schedule integration, cost estimation via quantity extraction, subcontractor coordination, and as-built model handover (Sacks et al., 2018). The technology's ability to maintain a single source of truth throughout the project duration significantly improves decision-making accuracy and reduces disputes among stakeholders.

The BIM process utilizes Design Models developed by architects and engineers, and Construction Models developed by contractors. These federate into a unified model for clash detection, marketing visualization, and facility maintenance (Lowe and Muncey, 2009). The literature demonstrates BIM's role in transforming information management from document-based paradigms to integrated database systems, enabling better team collaboration (Fazli, Fathi et al., 2014). This shift represents a fundamental change in how construction professionals approach information sharing and project coordination.

Emerging applications of BIM in facility management demonstrate its long-term value proposition. Building operators utilizing BIM models for maintenance planning report significantly improvements in asset tracking and lifecycle cost management (Patacas et al., 2015). This extended use case underscores BIM's potential to deliver value throughout a building's operational life, far beyond the construction phase.

According to the literature, project teams need to be better integrated, and everyone involved has to work together. Additionally, it demonstrated the necessity of switching from the document paradigm to the Project Integrated Database paradigm in order to handle information. The information analyses pointed in the direction that BIM could be the tool that allowed this better integration of teams and of information (Fazli et al., 2014).

Table 2.1: BIM capabilities for project management (Wang and Chen, 2023)

	Project Life Cycle					
	Stage 1 Preparation and Briefing	Stage 2 Concept Design	Stage 3 Spatial Coordination	Stage 4 Technical Design	Stage 5 Manufacturing and Construction	Stage 6 Handover
	Starting Phase	Preparing Phase			Carrying Out Phase	Ending Phase
BIM Capabilities for Project Management	Collaboration and Communication Based on 3D Visualization					
	Site Analysis					
	Phase Planning					
		Cost Estimation (QuantityTake-Off)				
		3D Modelling (Architectural, Structural, MEP)				
		Engineering Analysis (Structural, Lighting, Energy, Mechanical, Other)				
		Sustainability Analysis				
		Design Review				
			Clash Detection			
					Site Utilisation Planning	
					Construction System Design	
					Digital Fabrication	
					Record Model	

2.3. BIM Adoption

Though the overall economic benefits of BIM on a theoretical level are comprehensible, its implementation in the field of construction has been dealt with in slightly different ways. There are already numerous examples of what a correctly used BIM approach might potentially offer to the construction process in terms of economic advantage. To enable the acceptance and deployment of BIM by organizations, designers, and managers, an understanding of the elements that drive and impede BIM utilization is required. Factors influence BIM adoption at the individual, organizational, and institutional levels. These high-level implementation areas are strategies and policies, methods and approaches for adopting BIM that correspond to the overall company objectives for competitive positioning, operational excellence, and efficient delivery (Doumbouya et al., 2016).

BIM processes and model management tools are combined with enterprise systems to produce information in a collaborative setting across the organization and project teams (Son et al., 2015). In order to make BIM adoption more effective, the whole process should be divided into stages, with the targets of each stage depending on the project type (Gu and London, 2010).

2.3.1. Factors Influencing the Adoption of BIM

The decision to adopt BIM involves complex interactions between technical, organizational, and behavioral factors. Key enablers identified in architectural practice include strong top management support, subjective norms within professional networks, compatibility with existing workflows, and practitioners' computer self-efficacy (Becerik-Gerber and Rice, 2010). These factors collectively shape behavioral intentions toward BIM adoption through perceived usefulness and ease of use, as predicted by technology acceptance models.

Conversely, significant barriers persist, particularly technical complexity in software implementation, challenges in project scheduling integration, and substantial upfront financial investments (Arayici et al., 2011). The construction industry's fragmented nature further complicates adoption, as firms must adapt BIM implementation strategies to their specific business models and project types (Doumbouya et al., 2016).

Successful BIM implementation necessitates comprehensive organizational changes, including workflow redesign, staff training programs, and revised responsibility matrices (Azhar et al., 2008b). The transformation extends beyond technology adoption to encompass new collaborative processes and information management protocols. When properly executed, these changes yield measurable benefits at both project and organizational levels, justifying the implementation costs (Volk et al., 2014).

Emerging research emphasizes the importance of developing standardized implementation frameworks that address these multidimensional challenges while accommodating varying organizational contexts. Such frameworks could significantly accelerate industry-wide BIM adoption by providing clear roadmaps for overcoming common barriers while maximizing the technology's strategic value.

2.4. Building Information Modeling Aspects

2.4.1. Integrated Project Delivery System

Integrated Project Delivery represents a transformative approach that unifies multidisciplinary teams, including project managers, designers, engineers, and systems specialists, into a cohesive collaborative process (Rokooei, 2015). This methodology shifts focus from individual objectives to collective project outcomes, optimizing value through enhanced efficiency across all project phases, from conceptual design to facility handover. The construction industry has increasingly recognized IPD as a solution to fragmented project delivery, particularly for complex projects requiring high levels of coordination among numerous stakeholders.

The synergy between IPD and BIM creates a powerful framework for construction management, enabling teams to overcome traditional communication barriers and information silos. BIM tools serve as the technological foundation for IPD by enabling teams to communicate, visualize, and analyze complex project information holistically, while providing a shared platform for model-based coordination. By consolidating detailed inputs from all stakeholders into an integrated model, this approach significantly improves team productivity, reduces conflicts during construction, and enhances decision-making throughout the project lifecycle (Rokooei, 2015). The combination of IPD's collaborative framework with BIM's technological capabilities represents a paradigm shift in project delivery, where information integration drives performance improvement at every stage.

Key advantages of BIM-based IPD include comprehensive project tracking and assessment capabilities, streamlined conflict resolution processes, data-driven decision-making support, and enhanced execution coordination. These benefits are particularly evident in large-scale projects where multiple disciplines must work concurrently, as the integrated approach minimizes rework, improves schedule reliability, and enhances overall project quality. Recent case studies demonstrate that projects using BIM-enabled IPD approaches can achieve up to 20% reduction in project duration and 15% cost savings compared to traditional delivery methods (Lowe and Muncey, 2009).

2.4.2. Unique Language and Interoperability Standards

Effective project management requires standardized terminology, clear communication protocols, and robust data exchange mechanisms (Institute, 2021). The construction industry has addressed these needs through global initiatives like building SMART, formerly known as the International Alliance for Interoperability, which develops and maintains open standards for BIM implementation across software platforms and project phases (Wright, 2009). These standards have become increasingly important as projects involve more international teams and complex supply chains.

The industry foundation classes (IFC) specification represents a critical advancement in BIM implementation, serving as an open, neutral data format that enables consistent representation of building information across different software platforms and throughout all project phases, from feasibility studies to operations and maintenance (Rokooei, 2015). This interoperability framework includes a comprehensive data schema covering interdisciplinary building information, support for full project lifecycle information management, a neutral format for seamless software-to-software exchange, and continuous development to address evolving industry needs. The development of these standards reflects the industry's recognition that data interoperability is fundamental to realizing BIM's full potential, ensuring that information retains its integrity and usefulness as it moves between stakeholders and across project phases.

Recent advancements in IFC standards now support more sophisticated data exchange requirements, including 4D scheduling information, 5D cost data, and performance parameters for sustainability analysis (Institute, 2021)These developments are particularly crucial for supporting circular economy principles in construction, as they enable accurate tracking of material properties, embodied carbon, and deconstruction information throughout a building's entire lifecycle. As BIM adoption grows globally, the importance of these interoperability standards continues to increase, making them an essential component of modern construction information management.

2.4.3. Technical Aspects of BIM

BIM offers numerous technical capabilities that significantly enhance project management effectiveness. These advanced features, which continue to evolve through ongoing development, can be categorized into several key functional areas (Lahdou and Zetterman, 2011). Each aspect contributes uniquely to improving construction project outcomes through digital transformation.

Clash Detection and Resolution

One of BIM's most valuable technical capabilities involves identifying and resolving geometrical design inconsistencies between different disciplines' plans. When architectural, structural and mechanical electrical and plumbing (MEP) designs overlap or conflict, BIM software automatically detects these clashes during the virtual modeling stage (Rokooei, 2015). This proactive identification allows teams to modify designs before construction begins, reducing costly field changes and rework. Beyond purely functional conflicts, BIM also enables aesthetic evaluation, ensuring the final built environment meets both technical and visual design requirements.

Constructability Analysis and Risk Mitigation

BIM facilitates comprehensive constructability reviews by allowing project teams to virtually examine building elements from multiple perspectives. Team members can identify potential construction challenges, elevate critical issues through formal Requests for Information, and visualize problems from optimal vantage points (Rokooei, 2015). The combination of detailed visual models with collaborative markup tools enables thorough investigation of constructability issues, leading to more effective risk mitigation strategies before ground is broken.

Advanced Performance Analysis

The analytical capabilities of BIM extend far beyond basic modeling, enabling sophisticated performance evaluations that inform better decision-making. By linking building information models with specialized analysis tools, project teams can assess energy consumption patterns, evaluate material performance, and optimize spatial configurations (Azhar et al., 2012). These analytical functions include lighting simulations to evaluate natural and artificial illumination, mechanical system performance modeling, and acoustic analysis to ensure proper sound transmission and attenuation throughout the facility.

Time and Cost Management (4D & 5D BIM)

BIM's integration of scheduling (4D) and cost (5D) data represents a transformative advancement for project controls. Project managers can visualize the construction sequence over time, understanding how each phase will progress and interact with other project elements (Azhar et al., 2012). This temporal modeling enables more accurate time estimation during early project stages and allows evaluation of multiple construction sequencing alternatives. Similarly, 5D cost integration provides reliable budget forecasting by linking model components with current cost data, enabling rapid evaluation of design alternatives and their financial implications.

Model Integration and Data Coordination

The true power of BIM emerges when multidisciplinary models are combined into a unified, coordinated dataset. This integration allows all project team members to interact with a comprehensive digital representation that incorporates architectural, structural, and MEP systems (Eastman, 2011). The federated model serves as a single source of truth throughout the project lifecycle, coordinating design development, analysis activities, and construction operations while maintaining data integrity across all disciplines.

Quantity Takeoff and Procurement Support

BIM's automated quantity extraction capabilities provide significant advantages for cost estimation and procurement processes. The model generates accurate, consistent quantity takeoffs that inform decision-making during design development and support procurement activities (Azhar, 2011). Because these quantities are directly derived from the virtual model, they can be quickly updated as designs evolve, ensuring cost estimates remain current. The seamless integration between model quantities and cost databases enables faster, more reliable estimation compared to traditional manual methods.

Object-Based Modeling Advantages

Unlike conventional CAD systems that use basic geometric elements, BIM utilizes intelligent objects that carry rich data attributes. This object-oriented approach allows complex buildings to be decomposed into manageable components, each with defined properties and relationships

(Eastman, 2011). The resulting model provides a clear project scope definition, supports more accurate estimation, and enables better construction planning by treating building elements as discrete, data-rich entities rather than simple geometric representations.

Collaboration and Communication Enhancement

Perhaps BIM's most significant technical contribution is its ability to foster collaboration among diverse project stakeholders. The shared model environment creates a common framework for input, modification, and analysis, improving communication between project managers, architects, engineers, and contractors (Kelly et al., 2013). This collaborative approach reduces disputes, minimizes information silos, and ensures all team members work from consistent, up-to-date project information throughout all phases of design and construction.

2.4.4. Comparison of BIM Capabilities with PMBOK Knowledge Areas

The capabilities of BIM in construction projects exhibit strong alignment with the Project Management Body of Knowledge (PMBOK) framework, demonstrating BIM's comprehensive value as a project management tool. This correspondence manifests across multiple knowledge areas, beginning with integration management, where BIM serves as a unifying platform that consolidates documents, plans, and stakeholder contributions into a coordinated system (Institute, 2021). The integration extends beyond document management to include real-time synchronization of project data across all disciplines, ensuring all stakeholders work with current information. This dynamic coordination capability addresses one of PMBOK's fundamental challenges, maintaining consistency across distributed project teams and evolving project requirements.

BIM's object-oriented environment enables effective scope management through its inherent capacity to categorize building elements into logical groups, mirroring PMBOK's scope definition processes. The parametric nature of BIM objects allows for automatic updates across all views when changes occur, significantly reducing the scope creep common in traditional projects. Recent advancements in BIM software now incorporate machine learning algorithms that can predict potential scope deviations based on historical project data, adding a proactive dimension to scope management (Wang et al., 2024). This predictive capability represents a significant evolution beyond traditional PMBOK approaches, offering project managers new tools for maintaining project boundaries.

The technology's 4D (time) and 5D (cost) functionalities directly support PMBOK's time and cost management knowledge areas, providing dynamic visualization of project phasing and financial implications. Modern BIM platforms integrate with enterprise resource planning (ERP) systems to provide real-time cost data feeds, enabling more accurate cash flow projections and resource allocation. A 2023 study of large-scale projects demonstrated that teams using BIM-integrated cost management reduced budget variances by 37% compared to traditional methods (Hussain et al., 2023). This level of integration exemplifies how BIM can enhance traditional PMBOK processes through technological augmentation.

While BIM's constructability analysis addresses many construction risks, its clash detection capabilities specifically enhance quality management by identifying and resolving both soft (logistical) and hard (physical) conflicts during the design phase. The human resource aspects of PMBOK find their counterpart in BIM's collaborative environment, which fosters team building through shared model access and coordinated workflows. Emerging cloud-based BIM platforms now incorporate social collaboration features similar to enterprise social networks, facilitating more natural communication patterns among team members (Lee et al., 2020). This evolution in collaboration tools demonstrates how BIM continues to adapt to address fundamental project management challenges identified in the PMBOK framework.

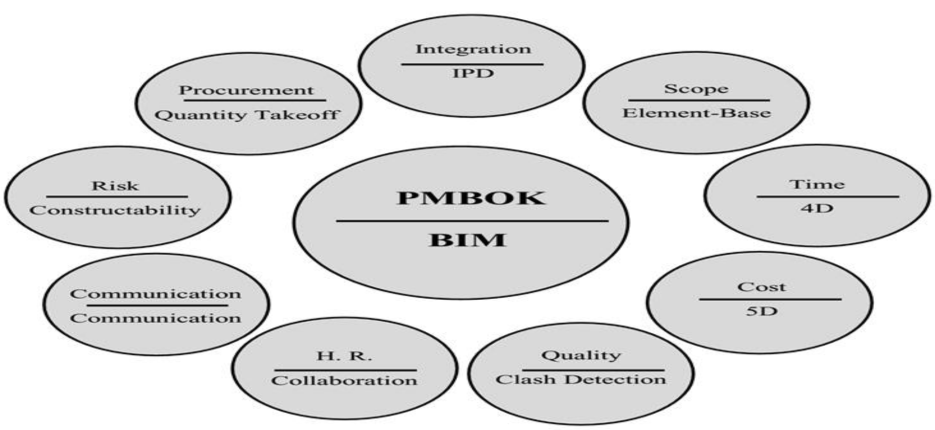

Figure 2.2: PMBOK knowledge areas Vs. BIM roles in construction PM

2.5. Traditional Cost Estimating and BIM for Construction Cost Control

Accurate cost control fundamentally depends on precise quantity takeoffs, which are critical for analyzing productivity and financial performance (Monteiro and Martins, 2013). BIM enhances this process through model-based quantification standards developed by Building Smart, particularly through IFC that facilitates information flow. The development of IFC4.3 in 2023 introduced enhanced quantification standards specifically designed for cost management, including improved classification systems for materials and labor (Weber-Lewerenz and Traverso, 2023). These enhancements address previous limitations in granularity that affected cost estimation accuracy for specialty trades and complex building systems.

However, IFC implementation faces challenges including incomplete adaptation to local requirements and dependency on software-specific data handling (Monteiro and Martins, 2013). Regional variations in construction practices, measurement standards, and cost structures create significant hurdles for global standardization. A recent survey of international AEC firms revealed that 68% still maintain custom cost databases alongside IFC-based systems to accommodate local practices (Global BIM Survey, 2023). This dual-system approach undermines some of BIM's potential efficiency gains, highlighting the need for more flexible standardization frameworks.

Effective cost control requires dynamic comparison of actual versus estimated costs throughout construction. BIM's potential to integrate cost with time factors through well-implemented IFC standards remains partially unrealized, with persistent issues including data errors and omissions during implementation (Patacas et al., 2015). The emergence of block chain-based cost tracking systems integrated with BIM models shows promise in addressing these reliability concerns by creating immutable records of cost transactions (Wang & Li, 2023). These technical challenges, combined with unanswered questions about BIM's comparative advantage over traditional methods, indicate that fully realizing BIM's cost control potential requires both technological advancement and organizational change management.

2.5.1. Traditional and BIM-based projects in the design phase

Traditional 2D CAD vs. BIM information flow

BIM can refer to either a Building Information Model or the process of Building Information Modelling. The term "Building Information Model" describes a multi-dimensional representation of a building that compiles data about interconnected components. While it might seem similar to a regular 3D model, a BIM model contains detailed, "smart" information beyond just a visual representation. In contrast, a 3D model serves only as a geometric visualization tool without embedded data.

When people talk about BIM as "Building Information Modelling," they are referring to the process of using the model and the data it holds to simulate and facilitate various tasks within the project (Eastman 2011). One of BIM's most significant advantages, often overlooked, is its role as a process rather than just a software tool. It enables and necessitates collaboration among all stakeholders throughout the project lifecycle (Azhar, 2011).

A common issue in traditional projects is the inefficient flow of information, leading to delays and errors. In conventional 2D CAD-based projects, information exchange is often fragmented, with miscommunications and gaps between the various players and project phases. In contrast, BIM projects allow for a more dynamic and integrated information flow. Information is shared in real-time, and stakeholders can interact with the "live" version of the building model, reducing the reliance on outdated data and improving collaboration. This seamless sharing helps design teams work together more effectively, allowing them to evaluate changes instantly and assess their impact on the entire project, rather than encountering errors, rework, or delays that come from working in isolation.

2.6. Levels and Dimensions of BIM

2.6.1. Levels of BIM

The maturity of BIM adoption in any construction project is measured through four distinct levels: Level 0, Level 1, Level 2, and Level 3. At **Level 0**, the use of CAD is limited to the creation of basic plans and drawings. This level does not allow for collaboration or collective decision-making among team members, making it outdated. Today, both developing and developed nations typically work above this level.

Level 1 introduces 3D CAD modeling for conceptual designs, while 2D CAD is used for drafting and documentation. At this stage, the handling and sharing of information are conducted through a Common Data Environment (CDE), following standards such as BS 1192:2007.

Level 2 BIM advances the process by enabling a collaborative environment where all project stakeholders use 3D CAD. However, these team members work on separate models instead of a single integrated model. This level is mandatory in several developed countries due to its effectiveness in saving time and costs, and minimizing rework through better data management.

Level 3 BIM is characterized by full collaboration, where all team members work on a single, shared project model. This version, also referred to as Open-BIM, allows for real-time access and alterations by any project participant. Security and data integrity are ensured through clauses that address potential clashes throughout the project lifecycle (Fazli, Fathi et al., 2014).

2.6.2. Dimensions of BIM

BIM goes far beyond traditional three-dimensional drawings common in CAD. A well-implemented BIM model can include various levels of detailed information.

3D BIM provides a visual representation of building models in three dimensions, offering clarity during the initial stages of a project. It also helps in detecting clashes between different construction elements, improving collaboration (Charef, 2022).

4D BIM adds the dimension of time to the 3D model, enabling a visual simulation of the project's timeline. This allows project teams to optimize schedules by monitoring daily requirements for resources such as equipment, labor, materials, and time (Fazli, Fathi et al., 2014).

5D BIM integrates cost information into the 4D model, providing real-time estimates of costs and allowing for more accurate cost and time predictions. It also facilitates the review of design changes and identifies potential cost-saving opportunities (Cho and Gibson Jr, 2001).

6D BIM is an emerging dimension that incorporates sustainability considerations, such as energy analysis, into the model. This addition enables project teams to track energy consumption and carbon emissions, promoting more sustainable building practices (Charef, Alaka et al., 2018; Khahro, Kumar et al., 2021).

7D BIM extends the functionality further by including operations and facility management data, enhancing the building's long-term use and maintenance. Finally, **8D BIM** integrates safety information into the model, allowing for a more comprehensive approach to safety management throughout the project (Raza et al., 2023).

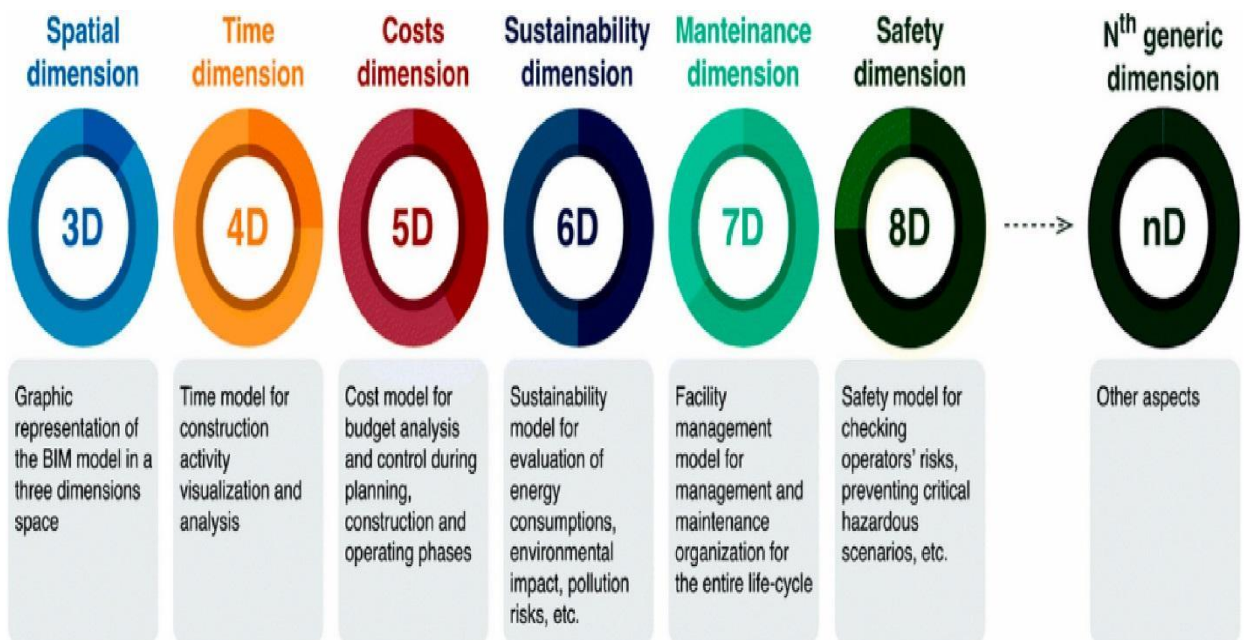

Figure 2.3: Numerous dimensions of BIM models with their brief features

2.7. Perceptions and expectations of BIM

With the increase in the quest for facilities management and multi-disciplinary collaborative decision making for sustainable design and construction of infrastructures, the adoption of BIM is witnessed to be increasing day by day (Khahro et al., 2021). Various perceptions for and expectations for BIM in comparison with the current practices of CI (Construction industry) can be viewed from three main perspectives: product, process, and people (Gu and London, 2010).

2.7.1. In terms of product

BIM is recognized as a technological advancement that benefits various disciplines, but expectations surrounding its use differ across fields. Designers typically see BIM as an improvement over traditional 2D CAD modeling, while project managers and contractors view BIM primarily as a tool for managing and organizing information that supports decision-making. While there is some overlap in these perspectives, the full integration of both aspects remains immature and unviable. Interestingly, many studies, with a few exceptions, place more emphasis on BIM's role as an enhancement to 2D CAD rather than as a data management tool (Gu and London, 2010).

2.7.2. In terms of process

When approached as a process, the integration of BIM will demand substantial changes to current workflows in the construction industry. Creating integrated building models requires enhanced communication and collaboration between various disciplines. With multiple parties contributing to a single model, the development approach will need to evolve. Additionally, standardized protocols for assigning roles and responsibilities during design reviews and approvals will become essential. While previous experience with data management may be beneficial, a new database tailored to the unique needs of each project and team structure will be necessary (Gu and London, 2010).

Furthermore, the success of BIM-based projects could be at risk if issues related to model ownership and business models are not addressed according to the specific needs of the construction industry. BIM models can be managed in-house or outsourced to external service providers. In the case of outsourcing, legal contracts must ensure data security and client satisfaction (Gu and London, 2010).

2.7.3. In terms of people

As construction projects become more complex and technologies continue to evolve, new roles and their interactions within the industry are being considered. In particular, the role of a dedicated BIM manager is expected to become crucial in large-scale projects. To ensure effective collaboration, all team members and stakeholders will need adequate training and knowledge to participate actively in a dynamic work environment (Gu and London, 2010).

2.8. Advantages of BIM

In recent years, BIM has garnered significant attention in the AEC industry. Despite its popularity, there remains considerable confusion regarding its role and potential benefits for contractors. A common misconception is that BIM is merely a technological tool or that it is only related to 3D modeling, even though 3D models are a key component of BIM. In reality, BIM is a comprehensive process used to create and manage project information, which results in a Building Information Model, a digital representation that captures every detail of the physical project. Although BIM is typically associated with design and preconstruction stages, it offers advantages throughout the entire project lifecycle, even after construction is finished. By enabling virtual construction before physical building begins, BIM helps eliminate many inefficiencies and challenges that typically arise during the construction phase. Below are the top 10 benefits of BIM in construction (Bryde et al., 2013).

Enhanced Collaboration and Communication

BIM models facilitate improved collaboration and version control compared to traditional paper drawings. Cloud-based platforms like Autodesk's BIM 360 allow team members from all disciplines to collaborate effortlessly on the project. The BIM 360 ecosystem makes it possible to share models and coordinate planning in real-time, ensuring that everyone involved in the design process has access to the latest project updates. With mobile access, teams can review models and drawings on-site, ensuring that they have up-to-date information during construction (Grilo and Jardim-Goncalves, 2010).

Model-Based Cost Estimation

Many AEC companies have discovered that involving estimators early in the planning phase leads to more accurate construction cost predictions. This has spurred the adoption of model-based cost estimation, also referred to as 5D BIM. Tools like Autodesk's Revit and BIM 360 Docs automate the complex and time-consuming task of quantifying and assigning costs, allowing estimators to focus on more important factors, such as identifying potential risks and construction assemblies (Grilo and Jardim-Goncalves, 2010).

Preconstruction Visualization

BIM enables the visualization of an entire project before construction begins, allowing stakeholders to plan and explore different aspects of the project in the preconstruction phase. Space-use simulations and 3D visualizations give clients a clear idea of what the space will look like, allowing for necessary adjustments before construction starts. This thorough planning helps avoid costly and time-consuming modifications later (Bryde et al., 2013).

Improved Coordination and Clash Detection

BIM improves coordination among trades and subcontractors by identifying potential conflicts between MEP systems, as well as structural components, before construction starts. With tools like Autodesk’s BIM 360 Glue, automated clash detection helps avoid costly errors by ensuring that electrical conduits, steel beams, and doorways don't interfere with each other. By detecting clashes early, the need for rework is minimized and last-minute changes and surprises on-site are reduced (Grilo and Jardim-Goncalves, 2010).

Cost Reduction and Risk Mitigation

Research by McKinsey indicates that 75% of companies using BIM reported positive returns on their investments. BIM can significantly reduce costs in various ways. For instance, closer collaboration with contractors can lower risk premiums, insurance costs, and reduce the chances of disputes. Better project oversight during the planning phase leads to more prefabrication, less material waste, and reduced labour costs. Many companies leverage BIM and related construction technologies to minimize risks and costs. Real-time collaboration and centralized data repositories like BIM 360 Docs ensure that teams always work with the most current information, further reducing the likelihood of errors and delays (Hammad, Rishi et al., 2012).

Improved Scheduling and Sequencing

Many of the benefits of BIM not only help save money but also reduce project timelines by preventing delays in construction schedules. BIM enables simultaneous design and documentation, and allows quick adjustments to be made in response to changing site conditions. This leads to more accurate and effective schedule planning, with improved coordination increasing the likelihood that projects will be completed on time or even ahead of schedule (Bryde et al., 2013).

Increased Productivity and Use of Prefabrication

BIM can instantly generate production drawings and data for manufacturing, facilitating greater use of prefabrication and modular construction methods. By designing and constructing components off-site in controlled environments, waste is reduced, efficiency is enhanced, and labor and material costs are minimized.

Safer Construction Sites

BIM plays a crucial role in improving safety on construction sites by identifying potential hazards early, allowing for proactive planning and risk management. By visualizing the project and logistics before physical work begins potential safety issues can be addressed in advance. This preemptive approach, supported by visual risk analysis and safety assessments, ensures a safer construction process (Rokooei, 2015).

Improved Construction Quality

The reliability of a well-coordinated BIM model directly contributes to better building quality. By using shared BIM tools, experienced team members can collaborate effectively throughout the project, ensuring better control over design and construction decisions. This allows for early identification of structural flaws and testing of construction methods. Additionally, visualizations help improve aesthetic choices, such as optimizing natural light flow within the building. During construction, reality capture technology can further enhance accuracy (Bryde et al., 2013).

Better Facility Management and Building Handover

BIM's benefits extend beyond construction into the operational phase, providing long-term value for building management. An accurate digital record of building information created during design and construction can be integrated into building maintenance software for use throughout the building's lifecycle. Tools like Autodesk's BIM 360 allow contractors to link BIM data from the construction phase directly to building operations, improving the efficiency of building handovers. As a result, BIM has become an indispensable tool that enhances project success at every stage of the lifecycle (Kelly et al., 2013).

2.9. Challenges to the Utilization of BIM

Participants in the building process are constantly challenged to deliver successful projects despite tight budgets, limited manpower, accelerated schedules, and waste (Mesároš et al., 2018). The AEC industry has long sought to adopt techniques to decrease project cost, increase productivity and quality, reduce project delivery time, and eliminate waste (Azhar et al., 2008b). One of these techniques is BIM. (Azhar et al., 2008a) said that BIM has recently attained widespread attention in the AEC industry. However, there are several problems when implementing BIM in the fragmented construction industry and which are connected with many different barriers hindering effective adoption of BIM (Lindblad, 2013).

Despite the great benefits of BIM, there is still no clear strategy for its widespread use in the future (Ghaffarianhoseini et al., 2017). There exists a vast variety of classifications in different studies with regard to barriers to implementing BIM.

Legal and Contractual Issues: Although BIM technical issues have been highly considered in recent years and considerable energy has been spent on these areas, "maturity of the legal body of BIM as well as its contractual configuration is more unsophisticated than its technical aspects (Sardroud et al., 2018). (Abdirad, 2015)" This deficiency has a unique influence on contractual conditions, and there is a challenge that restricts the duties of legal concerns associated with BIM implementation. Therefore, an acceptable substrate for applying BIM in contract conditions of projects should be designed or added.

The Need for Regulations

There is a pressing need for global regulations and coordinated frameworks to establish common standards for BIM implementation. Such regulations would help reduce conflicts, standardize practices, and provide a clear path for resolving disputes (Kiviniemi and Codinhoto, 2014).

Risks in BIM Contractual Agreements

Poorly defined BIM contractual agreements, coupled with a failure to implement BIM correctly, can pose significant risks to project success. BIM contracts need to address two main categories of risks:

1. **BIM Behavioral Risks**: These include issues related to collaboration, the efficiency of coordination, and the development of shared project information.
2. **BIM Technological Risks**: These involve challenges related to the reliability of information, model accuracy, management and maintenance of the model, and issues regarding ownership of the BIM data.

Financial Considerations

Financial and investment factors play a critical role in the success of any project, and they become even more significant when implementing emerging technologies like BIM. As discussed in the "cultural" section, the incomplete or partial adoption of BIM often creates uncertainty among investors and stakeholders. This section addresses two key financial questions: 1) is the high initial investment in BIM technology justified? 2) What is the expected return on investment (ROI)?

Adopting new technology, such as BIM, requires an upfront financial commitment. Most of the investment is allocated towards purchasing software, upgrading hardware, training personnel, and hiring specialists. The primary challenge is justifying and explaining these expenses to stakeholders. A key point to consider is whether these costs should be treated as part of the project budget or as part of a broader organizational transformation. Determining whether these costs are seen as simply software purchases and training or part of a more extensive business process change is crucial for justifying the initial investment (Hardi and Pittard, 2015). The ROI, a common concern for investors, can be evaluated by comparing earnings to costs (Azhar, 2011).

Resistance to Change

Currently, only a small fraction of companies are familiar with BIM and using it to benefit their projects. Many others continue to follow traditional methods, avoiding BIM because they perceive it as an underdeveloped technology with limited capabilities. These companies also view BIM as overly complex, leading them to prefer non-BIM tools for project execution. A significant barrier is the lack of knowledge and training. Engineers and companies are skeptical about learning BIM and believe that training employees in this new system would be costly. Additionally, the absence of trained personnel and the difficulty in convincing other stakeholders to bear the implementation costs further complicate the adoption of BIM (Sardroud, Mehdizadehtavasani et al., 2018).

Lack of Collaboration among Project Stakeholders

Successful BIM-based projects require strong collaboration among all team members. The effectiveness of a project depends on the cooperation of everyone involved, as working together ensures the project's success. A lack of collaboration from any stakeholder can significantly hinder the project's progress. Generally, BIM implementation in construction projects demands more integrated and cooperative approaches to project delivery (Teo, Ofori et al., 2016).

Demand-Related Barriers

The construction industry was not initially prepared to adopt BIM, and demand for the technology remained low. The uncertainty about BIM's immediate benefits, particularly during the planning phase, led to insufficient demand for its use. Additionally, many professionals didn't perceive BIM as a time-saver when compared to traditional drafting methods, further limiting its demand. Interoperability issues also complicated matters, making BIM adoption even more challenging. Although less frequent, other barriers, such as issues related to processes, management, awareness, expertise, project scale, technology, skills, training, contracts, and standards, were also identified as significant obstacles to the effective implementation of BIM (Ghaffarianhoseini et al., 2017).

2.10 BIM Software Programs

Building Information Modeling is the future of the construction industry, with many countries at various stages of integrating BIM into their legislation. Although the concept of information modelling in civil engineering has been around for over thirty years, it continues to evolve rapidly and is still considered innovative. The construction and civil engineering sectors generally acknowledge the need for BIM and the potential benefits it offers (Bouška, 2016).

Autodesk Revit

Revit is widely used BIM software that enables users to create, edit, and view building models in a 3D environment. It is one of the most popular BIM programs and is used by architects, engineers, and construction professionals around the globe. By using Revit to generate 3D BIM models, miscommunication is reduced, and the creation of construction documents and visualizations is enhanced (Nizam and Zhang, 2015).

Plannerly – The BIM Management Platform

Plannerly is a web-based tool that simplifies BIM management by breaking down the process into three steps: 1) Plan, 2) Scope, and 3) Verify. These steps ensure that BIM requirements are effectively managed from beginning to end. Plannerly is unique in its focus on efficient BIM and information management for design and construction projects. It is among the simplest BIM tools available and comes with templates for documents such as EIRs and BEPs, meeting essential ISO 19650 standards out of the box. The platform integrates well with other BIM software, such as Autodesk Revit, BIM 360/ACC, and IFC files, allowing for smooth data transfer between different tools (Plannerly, 2024).

Trimble Connect

Trimble Connect is a cloud-based platform that centralizes the management, viewing, and sharing of construction data. It plays a significant role in design coordination and project management, especially in civil infrastructure projects. Trimble Connect helps improve project quality and productivity by providing a secure repository for project data, allowing team members to access and update information from anywhere. Its robust collaboration tools ensure that project teams can stay connected and work together efficiently (Kravchenko, 2020).

Revizto

Revizto is a cloud-based BIM solution designed to enhance communication and project coordination across architecture, engineering, and construction teams. It facilitates seamless workflows between 3D and 2D models, allowing team members to collaborate effectively. Revizto's key features include clash detection, issue tracking, and change management, all integrated within a unified platform. Additionally, it offers tools for real-time mark-ups, file sharing, and format conversion, further enhancing communication and coordination (Nizam and Zhang, 2015).

BIMCollab

BIMCollab is an online tool for model coordination and clash detection, enabling AEC professionals to collaborate on BIM projects. It offers features like real-time collaboration, model comparisons, and visualizations. With BIMCollab, users can interact with BIM models in real-time, helping to resolve issues quickly and avoid conflicts. It also provides tools for issue tracking, version management, and mark-ups, making it easier for teams to stay aligned and maintain project consistency (Vargas et al., 2023).

Dalux

Dalux is cloud-based BIM software for construction project management. It helps manage all aspects of a construction project, from progress tracking to cost management, scheduling, and resource allocation. Dalux also provides access to BIM data analytics for valuable project insights. The software allows for real-time collaboration on both 2D and 3D models and offers tools for managing construction documents, including version control, document libraries, and comment features (Plannerly, 2024).

Graphisoft ArchiCAD

Graphisoft ArchiCAD is a BIM/CAD application that combines building information modeling with traditional 2D CAD. Known as one of the first true BIM implementations, ArchiCAD offers a wide range of tools for architectural design, including project collaboration, MEP engineering, energy analysis, and construction documentation. It also includes powerful rendering and presentation features, making it easy to produce high-quality visuals that showcase the design vision. ArchiCAD is widely used for designing not only buildings but also structures and even entire cities (Waas, 2022).

CHAPTER THREE

3. RESEARCH METHODOLOGY

Research methodology is the process of finding answers to research objectives. It is a concrete step that a researcher needs to undertake during his or her research journey to answer their research questions.

3.1. Description of the study area

The research is conducted in the central region of Ethiopia, which is located in the capital of Ethiopia, which is called Addis Ababa. According to the 2024 population data of Addis Ababa, there are 5,704,000 people and its area is 527 km². The specific offices where the research was based in Addis Ababa are the Ethiopian Construction Design and Supervision Works Corporation and in G1 architectural offices.

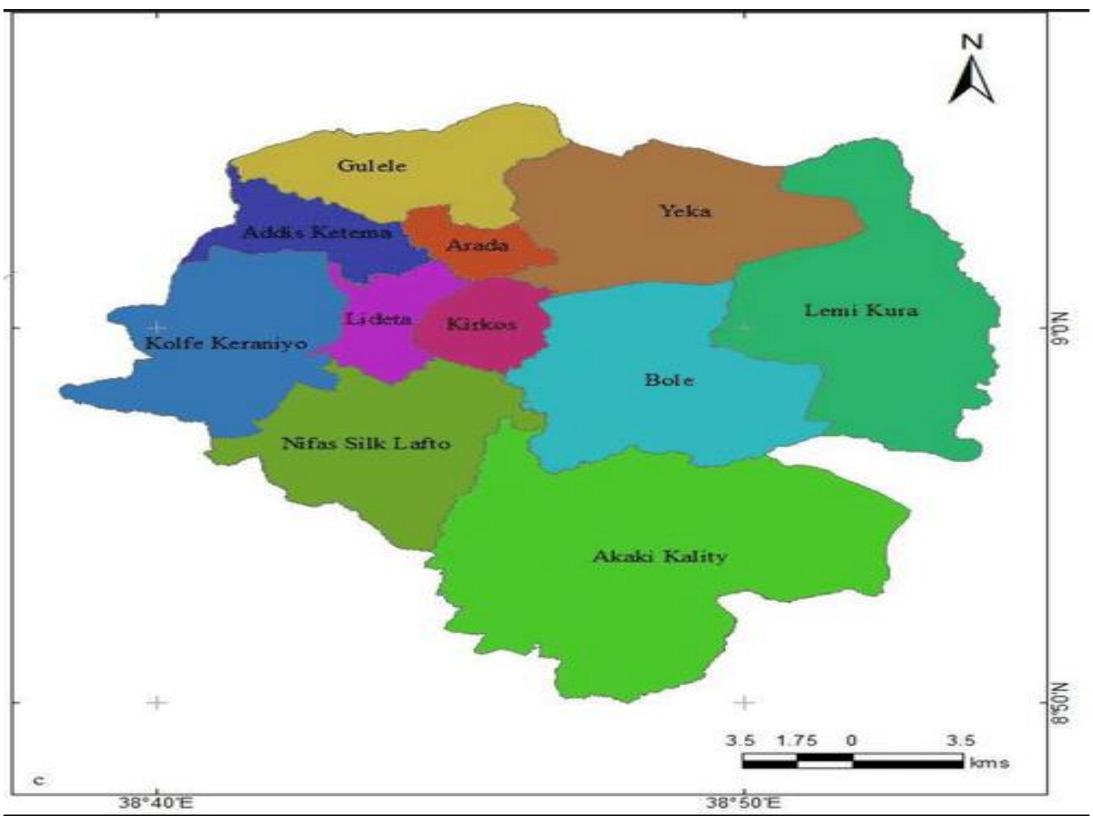

Figure 3.1: Location map of the study area

3.2. Research Design

The research strategy consisted of initiating clarity on the problem through an unstructured literature review, archival study, and formal conversation with practitioner experts in the industry, then building the research design. Next, using the study strategy developed, the data and information sources were identified. After identification of the data/information sources, the instruments of research were selected according to the data/information sources, and appropriate document sources were examined.

A document study of relevant articles was conducted to create a solid knowledge of the history, developments, practices, tools, barriers, and software in the construction and BIM implementation. The paper used books, journals, articles, online searches, and archival records.

The research was a mixed research methodology. Mixed methods research is a research approach that uses a mixed-methods approach, and the qualitative and quantitative approaches in attempts to come to answers to research questions. The philosophical rationale for choosing this method is the ability for researchers to assemble different quantitative/qualitative data so that they can have a greater understanding of the topic being studied. The questionnaire was designed to identify and address the stated objectives.

An attempt was made to collect information from the relevant population to examine and assess the use of BIM in our construction project management and using questioners we established if BIM is even being used as an Auditing Tool, compared it with the traditional and to assessing which BIM software's enhances the use of BIM and to overcome the obstacles of successfully using BIM.

3.3. Study Variables

The variables of study investigated in this research are 1) the benefit of BIM in implementation, 2) the performance index of BIM, 3) the applications of BIM in our project management system, and 4) the types of building information modeling software used in our system.

3.4. Data Type and Sources

This research has utilized both primary and secondary data sources. The primary data source was a structured questionnaire to answer the specific objectives, which had been distributed through mail and hard copy amongst a qualified pool of candidates to evaluate the use of and barriers to adopting BIM, as well as personal observation. The secondary data source was adopted from a robust literature review to determine the up-to-date usage, benefits, barriers, software efficiencies, and knowledge on BIM adoption from literature in the area of BIM.

3.5. Data Collection Technique

In this research, different methods of data collection, such as observation, interview, and questionnaire (both structured and unstructured), have been used. The technique that was used in this research is described as follows:

Questionnaire Method

In this research, the questionnaire method is used, allowing respondents to independently provide their answers to the questions. The survey questionnaire included structured and unstructured questions. Both types of questions were designed to receive responses from the options provided to answer the stated specific objectives one and two, while also allowing the questions to include the respondents' attitude and express their feelings honestly.

Interview Method

In this case, face-to-face interviews and telephone interview was used to achieve specific objective three and collect primary data, particularly data on current utilization of building information modeling in Ethiopian construction industries and how it’s being applied.

Observation

In this method, data has been collected directly from the field by the researcher, and it is a systematic view of the occurrences. In this case, drawings, designs, and any found at the time construction phase will be observed and analyzed to draw a given conclusion.

3.6. Study Population and Sample Size Determination

The target populations of the study are the professionals (Engineers, architects, Quantity surveyors…) in the construction offices, which were mentioned above, and who are aware of the concept that is building information modeling. It takes too long and it is too costly, involving a study like this, to test each individual from the entire population. Consequently, small portions of a unit sample were selected to represent the relevant characteristics of the complete unit. The researcher will follow the rationale of the entire population, which is also called the sample size formula (Naing et al., 2006).

To achieve an acceptable sample size, from a total of 78 active architectural consulting offices, this equation was used:

$$\mathbf{n} = \frac{\frac{z^2 \times p(1-p)}{e^2}}{1+(\frac{z^2 \times p(1-p)}{e^2 N}} \quad \textbf{........................} \text{ Equation 1 sampling method}$$

n is the sample size,

z is the z-score associated with a level of confidence =1.645

p is the sample proportion, expressed as a decimal = 50% = 0.5

e is the margin of error, expressed as a decimal = 10% = 0.1

N is the population size = 78

$$\mathbf{n=} \frac{\frac{1.645^2 \times 0.5(1-0.5)}{0.1^2}}{1+(\frac{1.645^2 \times 0{,}5(1-0.5)}{0.1^2 * 78}} \mathbf{=37.9}$$

From the total population of grade one architectural consulting offices working in Addis Ababa's building sector. Using the above formula with a 10% margin of error yields a sample size of 38. Each of the selected 38 sample-size offices was surveyed by questionnaire.

3.7. Research Measurement

In order to identify the status and current performance of BIM application in our project management system was based on performance indicators, and to rate management techniques, the respondents to the survey were asked to take the appropriate rating on the scale against each performance statement reflecting their opinion on the level of satisfaction. Each respondent was asked to rate the degree of opinion and attitude a response to each item of the management techniques, and their performance in terms of 5 levels using the Likert-type Scale. The numbers that were assigned to the agreement or degree of application of the techniques (i.e., 1, 2, 3, 4, and 5) do not imply that the interval scales are equal and do not indicate absolute quantities. The numbers are only numerical labels. Please refer to the scale, see Table 3.1.

Table 3.1: Likert scale

Scale	1	2	3	4	5
Assigned scale	Strongly disagree	Disagree	Neutral	Agree	Strongly agree

3.8. Data analysis and interpretation

Data analysis involved systematically accessing and organizing the interview transcripts, completed questionnaire, field notes, and other materials collected to better understand the respondents' subjective experiences. The qualitative data have been organized and presented as narratives. Different software packages, such as SPSS and Excel that allow for the descriptive analysis and statistical analysis of the data using mean, frequencies, and percentages were used. Finally, the data has been processed and presented.

3.9. Validity and Reliability

Reliability is the total internal consistency measure. If alpha equals 0.70, the value is accepted. Validity is the technical term for the objectivity and credibility of a research project. All through the collection and analysis of data, validation of the data collection will take place. Validity is strength of research as it defines the correctness of information from the point of view of all the stakeholders of the research. In this research contextual argument for knowledge construction through the logical process of brainstormed group thinking needs to be solidified for concrete validity (Weston, et al., 2001).

The reliability test used Cronbach's alpha coefficient of internal consistency, and evaluated the reliability test. Therefore, the survey presents twenty (20) factors as generated for factors to assessing the performance of current water supply projects from key performance indicators references. Cronbach’s alpha is computed using equation 2

$\alpha = K/K{-}1\ [1 - \Sigma S2y/S2x]$ .... **Equation 2**

Where: -

- α = Cronbach’s coefficient
- K = Number of items
- ΣS2y = sum of item variance
- S2x = Variance of total score

Interpretation

Interpreting ALPHA for Likert scale question, Cronbach’s alpha

Table 3.2: Cronbachs alpha interpretation

Cronbach’s alpha(α)	Internal consistency
0.9 and above	Excellent
0.8 – 0.89	Good
0.7 – 0.79	Acceptable
0.6 – 0.69	Questionable
0.5 – 0.59	Poor

Having 20 numbers of items:

$\alpha = 20/20{-}1\ [1 - 26.5/132.62] = 0.84$

With a coefficient of **0.84**, the results, as they are shown in Table 4, suggest that the data are trustworthy, internally consistent, and hence acceptable.

3.10. Ethical considerations

In this study, ethical aspects were first that the data collectors informed the participants of the study's purpose, and participants in the study agreed to participate voluntarily. Even after the interviews commenced, or questionnaires started being filled in, participants were informed they had the right to skip any question they did not wish to answer, or to withdraw from the study. In order to maintain confidentiality, participants were given pseudonyms, and/or luminary coding concealed the identity of their questionnaire responses.

CHAPTER FOUR

4. RESULT AND DISCUSSION

The findings of the analyses and their interpretations are provided in this chapter. The trends and overall performances of the variables are shown under the descriptive statistics. The variables are described using statistical tools such as tables, charts, and graphs.

4.1. Questionnaire Response Rates

From the total sample size, a total of 35 respondents were achieved. From which three respondents' data was missing, two of the respondents didn't even return the questionnaire format, and one respondent's questionnaire had been filled out incorrectly, so I had to mark the respondent's questionnaire invalid. Generally, I had a 92% success rate of respondents from the total sample size.

4.1.1. Respondents Profile

The target populations of the study are the professionals (Engineers, architects, designers, and others) in the construction offices. Of which 11 are architects, 7 are structural engineers, 1 is a sanitary engineer, 2 are resident engineers, 12 are designers, and 2 are classified themselves in the other category.

Table 4.1: Profession profile of the respondents

Profession

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Architect	11	31.4	31.4	31.4
	structural designer	7	20.0	20.0	51.4
	sanitary engineer	1	2.9	2.9	54.3
	resident engineer	2	5.7	5.7	60.0
	Designer	12	34.3	34.3	94.3
	Other	2	5.7	5.7	100.0
	Total	35	100.0	100.0	

Of the total respondents, 62.9% are BSc. graduates and the rest, which means 37.1 % are MSc graduates, which shows the research focus group was skilled and educated professionals.

Table 4.2: Educational status of the respondents

Educational Status

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Bsc	22	62.9	62.9	62.9
	Msc	13	37.1	37.1	100.0
	Total	35	100.0	100.0	

According to the questionnaire survey all almost all the respondents are beginner and intermediate, with a total of 97.1%, which leads to only 2.9% being expert. This shows that BIM implementation is at the infant stage of its development in our country.

Table 4.3: Proficiency of the respondents

Proficiency

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Beginner	8	22.9	22.9	22.9
	Intermediate	26	74.3	74.3	97.1
	Expert	1	2.9	2.9	100.0
	Total	35	100.0	100.0	

4.2. Application of Building Information Modeling

Most of the construction offices have started to use building information modeling, but when we see the rate of the application, it’s at the early stage of development and still the old system is in use. From the collected survey, we can see that mostly building information modeling system is being applied mainly on the design stage of the construction. And also when we come to building information software’s the main software utilized is Autodesk Revit, and some also use Graphisoft ArchiCAD, and only one respondent used lumenRT software. In addition to this, the offices still use both paper-based and computerized communication systems, and the data shows that there are still errors and omissions occurring.

Table 4.4: Stages of using BIM software

Stages of using BIM software

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	At the feasibility stage	11	31.4	33.3	33.3
	During concept development	7	20.0	21.2	54.5
	After the design is complete	15	42.9	45.5	100.0
	Total	33	94.3	100.0	
Missing	System	2	5.7		
Total		35	100.0		

Information Exchange: The design team must communicate with one another. Misinformation leads to a lack of communication, which in turn causes poor design quality, missed deadlines, and design errors. As clearly shown on the bar graph, 48.57% of the respondents used both paper-based and computer-based information exchange mechanisms. The other 20% and 31.43% of the respondents used computerized and paper-based, respectively.

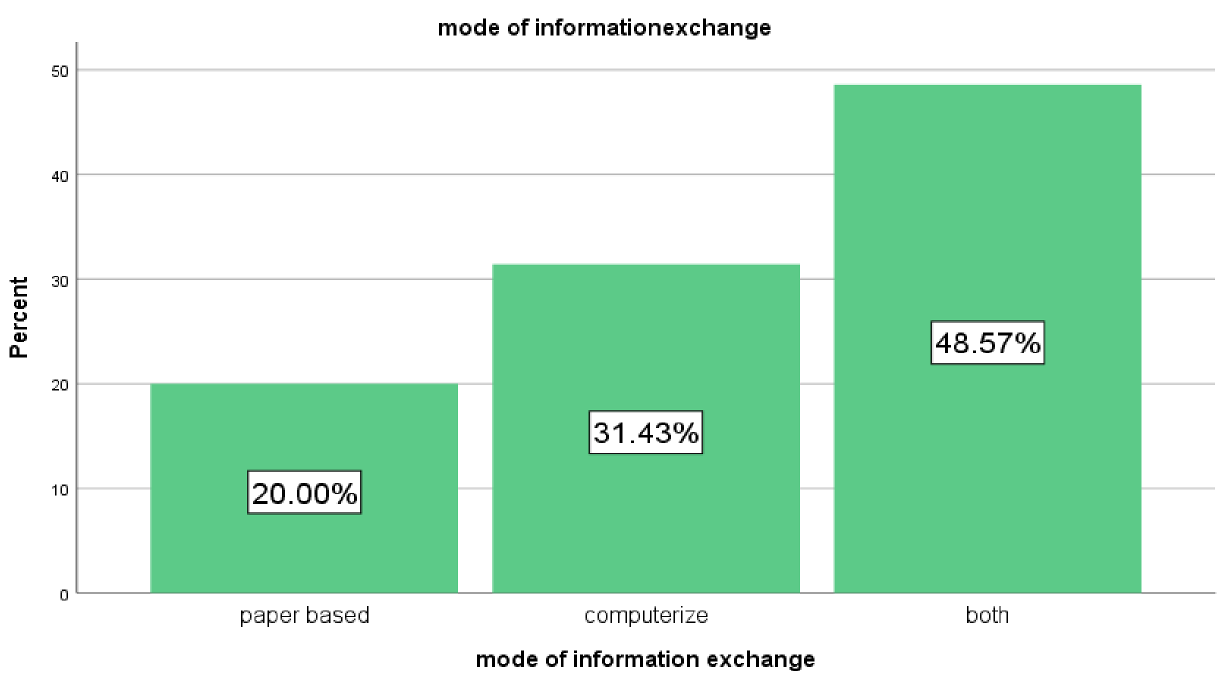

Figure 4.1: Information exchange system

Level of BIM application: As was tried to elaborate on in the previous chapter BIM project goes beyond the standard three-dimensional drawing typical of the CAD approach. So, according to the feedback I gained, only 5.7% of the respondents use the 4^{th} dimension of BIM, which is when time is added to a 3D BIM model in order to give effectiveness to the construction project timeline. The other 94.3% of respondents only use the 3D stage of BIM. The following graph illustrates the respondent's feedback.

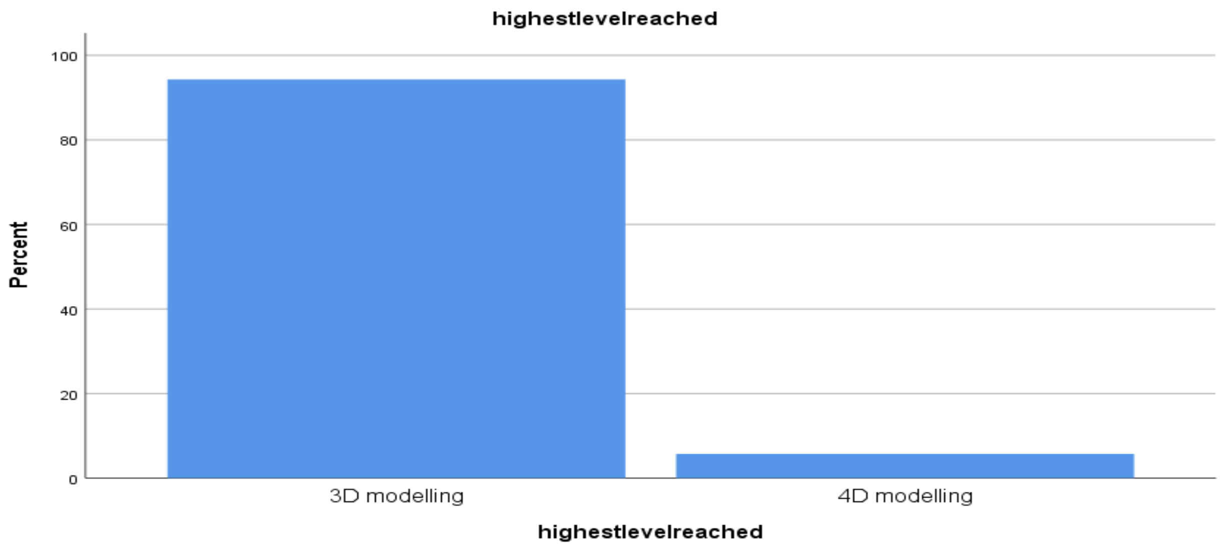

Figure 4.2: Highest level of BIM dimension of the respondents

As stated above, the building information modelling is at the infant stage of application development in the construction industry in accordance with our project management. From the key parameters which were listed on the questionnaire survey as Likert scale, these three parameters were outstanding.

Table 4.5: Client demand for BIM software to be used

The client has a strong demand for a BIM software application

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	strongly Disagree	5	14.3	14.3	14.3
	Disagree	17	48.6	48.6	62.9
	Neutral	12	34.3	34.3	97.1
	Agree	1	2.9	2.9	100.0
	Total	35	100.0	100.0	

The above table clearly shows that most clients are not demanding BIM software to be utilized on their project, which will hinder the growth of building information modelling applicability or integration in our project management system.

As many researchers and the media state, Ethiopia is undergoing a major renovation in the construction sector, which gives a big boost to our construction industry to adopt new technologies like the one I am researching. But according to the respondents' data, the government is not pushing enough to utilize the BIM system in our construction industry.

Table 4.6: Government use of BIM in public sectors

The Government is using BIM for public sector work

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Disagree	9	25.7	25.7	25.7
	Neutral	12	34.3	34.3	60.0
	Agree	14	40.0	40.0	100.0
	Total	35	100.0	100.0	

The other factor that was assessed through the survey questionnaire was “the overall cost of BIM affects its utilization”. In consonance with the outcome of the gathered data, for certain that the overall cost of BIM had an impact on the adoption and growth of BIM application in our PM system. The overall cost includes the cost of the software, educational cost (training cost) up and up-and-running cost. According to our data, 60% of the respondents agree that the overall cost impacts the utilization of building information modeling, where 40% were neutral. The following pie chart shows the detailed results of the respondents.

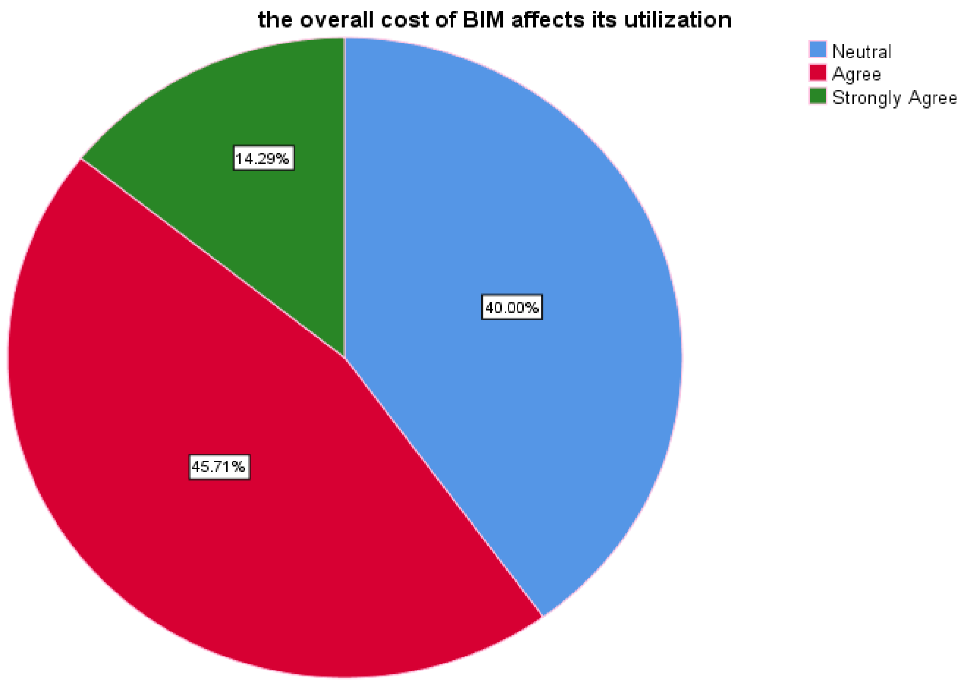

Figure 4.3: The overall cost of BIM affects its utilization

BIM allows stakeholders to collaborate in real time, ensure everyone is on the same page regarding project timelines, costs and requirements and after construction, BIM models can be used for facility managements, allowing owners to efficiently manage and maintain their buildings these to parameter index has gained a wide agreement on the scale, having 91.4% and 80% agreement of the respondents respectively. This shows the basic concept of building information modeling is being incorporated with the professionals, which will help our effort to upgrade the utilization of BIM in our construction industry and project management system.

4.2.1. Analysis summary of the application of Building Information Modeling

The application of building information modeling in our project management is as early as its infant stage of development, as I tried to find out through a structured and unstructured questionnaire survey. I found out that BIM is being applied at the design stage of the construction process, mainly at the feasibility stage and the detailed design stage. According to my findings from the respondents' data, the highest level the respondent's organization has reached in application of BIM on a project was 3D modeling having a total of 94.3% in a visual illustration of building models in three dimensions which gives a clear and concise idea of design in initial stages of CPs. 3D models also serve the purpose of clash detection for various construction stakeholders, and only 5.7% were adopting 4D, which integrates time and 3D.

The information exchange system gained from the gathered data was that 48.57% of the respondents used both paper-based and computer-based information exchange mechanisms. The other 20% and 31.43% of the respondents used computerized and paper-based, respectively. Data shows that there are still errors and omissions occurring in the paper-based information exchange system.

Even if the respondents have a good concept of building information modeling and hear more and more about BIM these days, they have encountered challenges in implementing BIM in their workflow. The main challenges were that most clients are not demanding BIM software to be utilized on their project, gathering 62.9 % of disagreement, 34.2% of neutral, and 2.9% of agreement on the client is demanding the application of BIM on their projects. On the other hand, for the challenge of the government on implementing BIM in public sector works, I had only a 40% agreement, in which 25.7% disagreed, and the remaining 34.3% were neutral. The other factor that was assessed through the survey questionnaire was "the overall cost of BIM affects its utilization". In consonance with the outcome of the gathered data, for certain that the overall cost of BIM had an impact on the adoption and growth of BIM application in our PM system. The overall cost includes the cost of the software, educational cost (training cost), and up-and-running cost. According to our data, 60% of the respondents agree that the overall cost impacts the utilization of building information modeling, where 40% were neutral.

4.3. Utilization of BIM as an auditing tool

As mentioned above in the literature review section, building information modeling can be utilized as an auditing tool of a construction process, in a way of to control the timeline, cost, and sustainability of the construction phases, which are integrated in the building information dimensions step by step from 2D up to 8D. In consonance with the generated data from the respondents, most of the respondents have the basic knowledge that building information modeling can enforce and be used as an auditing tool in a better way than the traditional paper-based monitoring system. According to this performance indicator parameter, "auditors can use BIM to assess the quality of construction works by comparing the digital model with the actual built environment, identifying any deviation from the specified standard." The following result was gained: 65.7% total agreement and 28.6% were neutral, where the rest disagreed.

Table 4.7: BIM as an auditing tool

Auditors can use BIM to assess the quality of construction works by comparing the digital model with the actual built environment, identifying any deviation from the specified standard.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Disagree	2	5.7	5.7	5.7
	Neutral	10	28.6	28.6	34.3
	Agree	17	48.6	48.6	82.9
	Strongly Agree	6	17.1	17.1	100.0
	Total	35	100.0	100.0	

However, when it comes to the application of building information modeling as an auditing tool, the result obtained is poor. Even if the respondent's profile and concept knowledge is good on building information modeling, Most of the respondents have disagreed that BIM is being used as an auditing tool. As a performance index, I added "BIM is utilized as an auditing tool in your organization," and 77.1% of the survey data shows BIM is not yet being applied as an auditing tool to monitor and control the construction process.

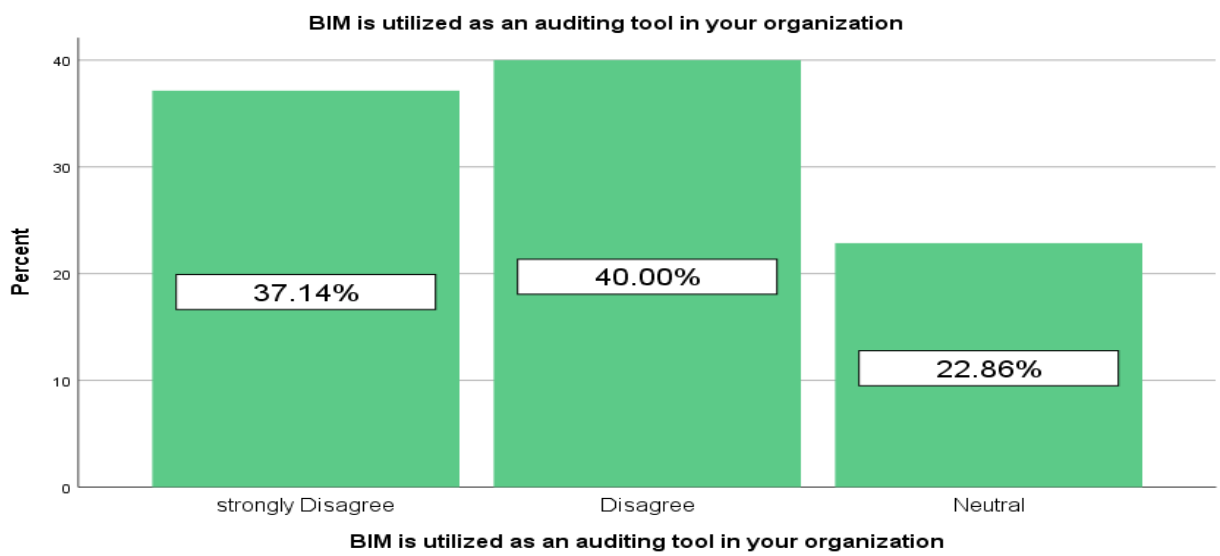

Figure 4.4: Utilization of BIM as auditing tool

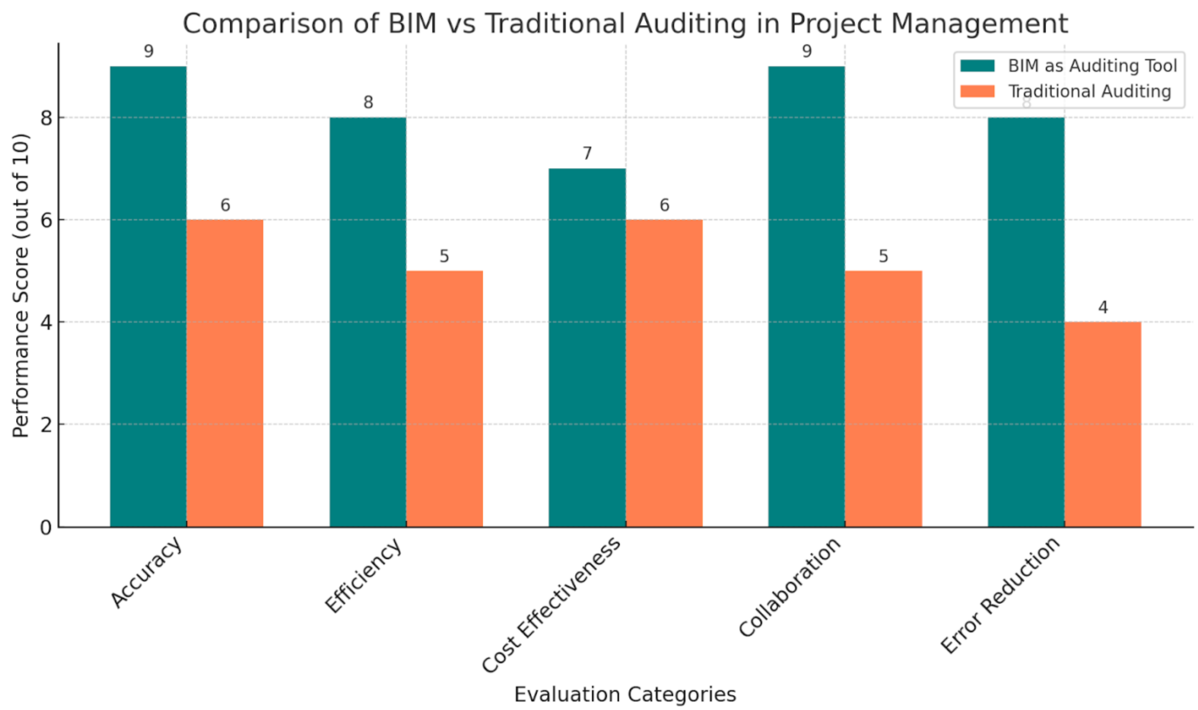

Figure 4.5: Comparison of BIM vs. Traditional auditing in project management

The comparison graph provides a clear illustration of the advantages of using BIM as an auditing tool over traditional auditing methods in project management. Across key performance metrics, accuracy, efficiency, cost-effectiveness, collaboration, error reduction, visualization, integration, and scalability, BIM consistently outperforms traditional approaches. While traditional methods may still have relevance in smaller, less complex projects, the efficiency, accuracy, and collaboration offered by BIM make it the preferred choice for modern project management, especially for large-scale and intricate developments. For project managers in Ethiopia and beyond, the adoption of BIM could transform auditing processes, leading to better project outcomes and enhanced stakeholder satisfaction.

4.3.1. Analysis summary of utilization of BIM as an auditing tool

In consonance with the generated data from the respondents, most of the respondents have the basic knowledge that building information modeling can enforce and be used as an auditing tool in a better way than the traditional paper-based monitoring system. However, when it comes to the application of building information modeling as an auditing tool, the result obtained is poor. Even if the respondent’s profile and concept knowledge is good on building information modeling, Most of the respondents have disagreed that BIM is being used as an auditing tool.

77.1% of the survey data shows BIM is not yet being applied as an auditing tool to monitor and control the construction process.

4.4. Framework for BIM Integration with Existing Buildings in Addis Ababa

4.4.1. Preliminary Assessment of Existing Buildings

The initial step in integrating BIM into existing buildings involves a comprehensive assessment of their current state and available documentation. Conducting surveys is essential to classify buildings based on type, whether residential, commercial, or industrial, and their specific usage. This classification helps identify buildings with the highest potential for BIM benefits, such as heritage structures or facilities requiring frequent maintenance. Reviewing architectural drawings, structural designs, and maintenance records further establishes a foundation for BIM modelling. This phase highlights the importance of understanding the unique characteristics of each building to tailor BIM applications effectively.

4.4.2. Digital Data Collection

Accurate data collection is critical for creating reliable BIM models. Advanced tools such as 3D laser scanning, drones, and photogrammetry are invaluable for capturing detailed building geometry. These technologies ensure precise representation of existing structures. On-site inspections complement this data by documenting materials, conditions, and systems that are not easily captured by digital tools. Moreover, integrating Geographic Information System (GIS) data provides contextual information, such as the building's urban setting, which enhances the usability of BIM for broader applications like city planning.

4.4.3. BIM Model Creation

Once data is collected, the next phase involves developing BIM models that accurately represent the existing buildings. These models, known as as-built models, incorporate architectural, structural, and MEP components. Ensuring interoperability is crucial, and using open file formats like IFC facilitates seamless data exchange among stakeholders. This step establishes a digital twin of the building, serving as a central repository for all project-related information and a foundation for future modifications or maintenance.

4.4.4. Integration with Facility Management Systems

BIM extends its utility beyond design and construction by integrating with facility management systems. Linking BIM models with Computer-Aided Facility Management (CAFM) or Building Management Systems (BMS) enables real-time monitoring of building conditions. Maintenance schedules, asset data, and performance metrics can be embedded within the BIM model, creating a dynamic tool for managing the building lifecycle. Additionally, dashboards provide stakeholders with accessible insights into the operational status of buildings, facilitating informed decision-making.

4.4.5. Training and Capacity Building

For successful BIM integration, it is imperative to equip professionals with the necessary skills. Training programs focusing on tools such as Autodesk Revit, ArchiCAD, and Navisworks enable architects, engineers, and facility managers to harness BIM's full potential. Workshops and collaboration with local universities can further disseminate knowledge, emphasizing the benefits of BIM in renovation and facility management. This focus on capacity building ensures that the workforce is prepared to manage and sustain BIM enabled workflows.

4.4.6. Policy and Regulatory Framework

A supportive policy environment is essential for scaling BIM adoption. Collaborating with city authorities to establish guidelines for digitizing existing buildings ensures alignment with local regulations. Standards for data sharing, model accuracy, and building classification create a uniform approach to BIM integration. Furthermore, legal frameworks addressing data security, ownership, and intellectual property safeguard stakeholder interests, promoting trust and widespread adoption.

4.4.7. Pilot Projects for Key Buildings

Pilot projects provide practical demonstrations of BIM's benefits. Selecting key buildings, such as government facilities, hospitals, or schools, allows stakeholders to focus on specific challenges like energy optimization, safety management, or structural retrofitting. These projects serve as test cases for refining BIM methodologies. Documenting outcomes showcases BIM's value, encouraging its broader implementation across similar projects.

4.4.8. Sustainable Integration

BIM's potential to enhance sustainability is a significant driver for its integration. Energy modelling and simulations enable the optimization of building performance, while retrofitting older buildings with green technologies aligns with global sustainability goals. BIM-driven analytics monitor resource consumption, providing actionable insights to reduce waste and improve efficiency. This emphasis on sustainability positions BIM as a tool for not only operational efficiency but also environmental stewardship.

4.4.9. Monitoring and Continuous Improvement

Ensuring the long-term success of BIM integration requires ongoing monitoring and refinement. Developing Key Performance Indicators (KPIs) allows stakeholders to measure BIM's impact on building operations and maintenance. Regular feedback from users helps identify areas for improvement, ensuring the BIM model remains up-to-date and relevant. Encouraging periodic updates to reflect modifications or renovations maintains the model's accuracy and utility.

4.4.10. Scaling Up

Finally, scaling BIM integration across Addis Ababa necessitates strategic initiatives. Creating a digital twin of the city by combining BIM models with urban data enables holistic urban planning and management. Incentivizing property owners to adopt BIM fosters widespread usage, while public-private partnerships can provide funding for large-scale initiatives. This phase underscores the potential of BIM, extending its benefits from individual buildings to the urban ecosystem as a whole.

BIM software includes computer-aided design products used commonly within the architecture and construction industries. BIM software offers a model-based process for designing and managing buildings and infrastructures, going beyond construction drawings to generate a digital representation of the functional properties of a facility. Even if the world is offering lots of software these days, here in our country, the construction sector is limited to some software only. From my report of the questionnaire forwarded the respondents gave back that Autodesk Revit is the most popular one, having a percentage of 88.57%. This makes it widely used software in our construction offices, where Revit is an established BIM design software that enables users to create, edit, and view building models in a three-dimensional environment. It is one of the most popular BIM software programs on the market and is used by BIM architects, BIM engineers, and construction professionals worldwide.

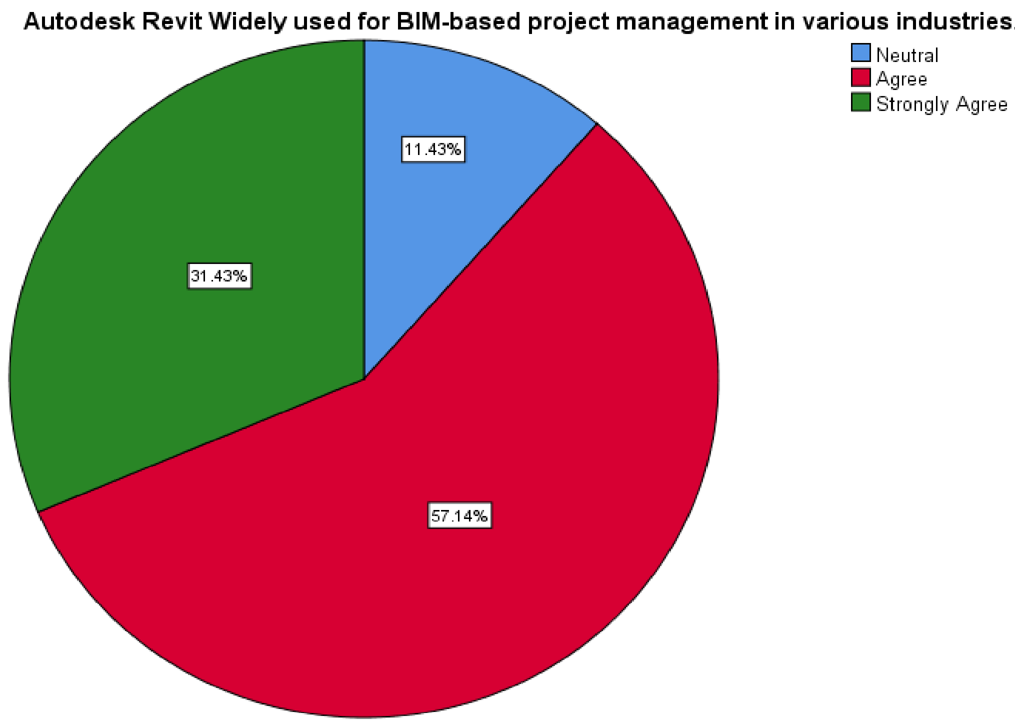

Figure 4.6: Autodesk Revit widely used BIM software

The result from the field shows as to adding other building information modelling software would enhance the BIM software application and increase the effectiveness of BIM with surpassing its obstacles, having 65.7% agreeing, 28.6% sharing neutral context, and 5.7% disagreeing.

Table 4.8: Using other software rather than Revit to enhance BIM effectiveness

Using software other than Revit will enhance the application of BIM effectiveness

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Disagree	2	5.7	5.7	5.7
	Neutral	10	28.6	28.6	34.3
	Agree	14	40.0	40.0	74.3
	Strongly Agree	9	25.7	25.7	100.0
	Total	35	100.0	100.0	

Effective BIM implementation requires a skilled workforce familiar with BIM tools and processes. The lack of expertise and adequate training can hinder the successful adoption and utilization of BIM. The main reason for not adopting other software like Graphisoft archiCAD and BIMcollab is mainly a lack of training and expertise in the construction industry system pool, in which it had an 80% agreement value from my respondents, as expressed through the following graph.

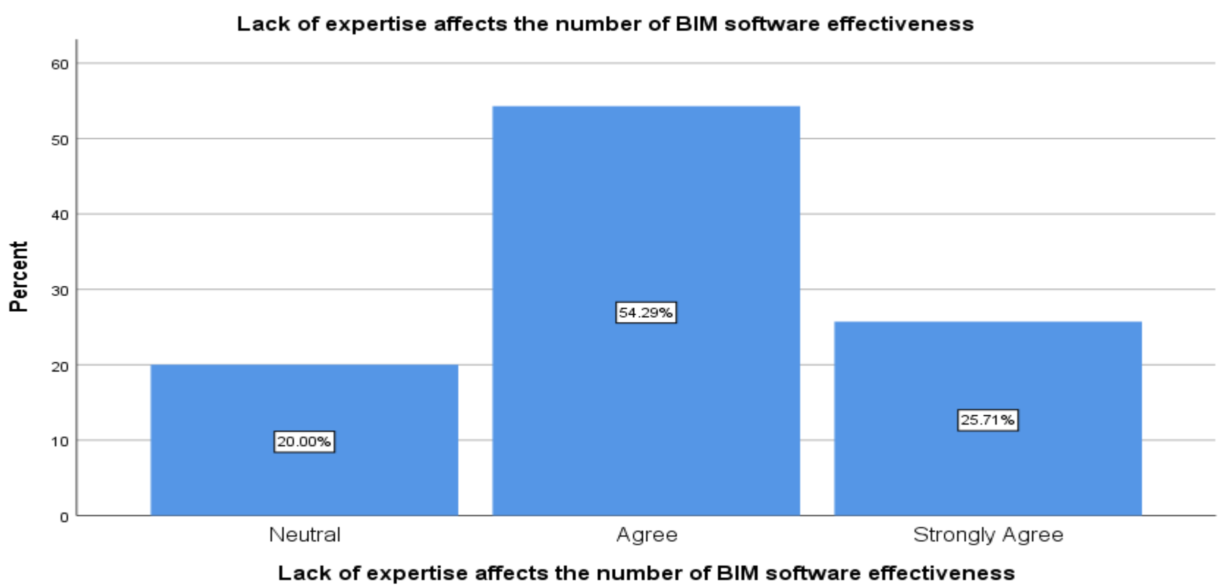

Figure 4.7: Lack of expertise affecting the effectiveness of BIM software

4.4.11. Analysis Summary of BIM software to enhance its application

The framework for BIM integration in Addis Ababa focuses on assessing existing buildings to identify those suitable for BIM, followed by accurate data collection using advanced tools like 3D laser scanning, drones, and GIS. As-built BIM models will be developed using interoperable formats to serve as digital twins for lifecycle management. These models will be integrated with facility management systems for real-time monitoring and efficient maintenance.

Capacity building through training programs and policy development ensures a skilled workforce and a supportive regulatory environment. Pilot projects in key buildings demonstrate BIM's benefits, while its sustainability potential is leveraged through energy modeling and retrofitting. Continuous monitoring, regular updates, and scaling initiatives, such as city-wide digital twins and public-private partnerships, aim to extend the advantages of BIM across Addis Ababa's urban ecosystem.

From my report of the questionnaire forwarded the respondents gave back that Autodesk Revit is the most popular one, having a percentage of 88.57%. This makes it widely used software in our construction offices, where Revit is an established BIM design software that enables users to create, edit, and view building models in a three-dimensional environment. It is one of the most popular BIM software programs on the market and is used by BIM architects, BIM engineers, and construction professionals worldwide**.** Other BIM software, such as BIMcollab and Graphisoft ArchiCAD, had poor application usage in the respondents' offices. For the successful implementation of BIM, people/professionals have the main role. BIM comes up with new professional categories like BIM manager, BIM coordinator. As a result, in this research, finding an expert/BIM professional is a main challenge. Since BIM is infancy stage in Ethiopia, it's difficult to find BIM professionals in the industry.

CHAPTER FIVE

5. CONCLUSION AND RECOMMENDATION

Conclusion

The study sought to illustrate the utilization assessment of BIM in Ethiopia, specifically in Addis Ababa. The last ten years have seen a very rapid advancement in BIM technology. Large-scale construction projects in industrialized nations have made extensive use of it, demonstrating the significant advantages that come with BIM implementation. However application of building information modelling is at an infant stage in our project management system.

According to the research application of BIM is mainly used for the design process of the construction phase. The main reasons for not applying building information modelling extensively are that the clients are not demanding the application of BIM in their projects, which may occur due to a lack of knowledge of the benefits of BIM from the client side. The other challenge was that even the government is not imposing that much in order for BIM to be implemented extensively. And also, setting up cost includes hardware, software, and designers' training cost were also an issue for the better application of BIM in our project management system.

Building information modelling can be used as an auditing tool for a construction process, allowing for the control of the budget, schedule, and sustainability of the phases of construction that are gradually included in the building information dimensions. However, the research data shows that it leans towards the poor scale when we come to using BIM as an auditing tool for the project management system.

The framework for BIM integration in Addis Ababa emphasizes evaluating existing buildings to determine their suitability for BIM, followed by precise data collection using advanced technologies such as 3D laser scanning, drones, and GIS. Interoperable as-built BIM models will be created to function as digital twins, facilitating effective lifecycle management. These models will seamlessly integrate with facility management systems, enabling real-time monitoring and optimized maintenance processes.

When it comes to using BIM software to enhance the application of BIM and overcome the obstacles of BIM effectiveness, the number of software options is very limited, according to the research. Autodesk Revit is the most widely used BIM software in Ethiopia, whereas other software like BIMCOLLAB, Graphisoft ArchiCAD, Delux, and others are not being implemented that much. To overcome the obstacle of BIM effectiveness, more BIM software's lack of Software interoperability issues, infrastructure, and expertise on BIM should be resolved.

Generally, as the research indicates, the utilization of building information modeling is at the initial stage of its growth.

Recommendations

As a developing country, there are lots of construction developments, so a wider framework of laws and regulations is needed to structure the usage of BIM throughout the chain of services and professionals involved in the building process, as the construction industry adopts the BIM technology. And the government should play a bigger role in promoting BIM to the construction office sector by enforcing construction offices to extensively adopt BIM. Encouraging offices that are actively involved in BIM implementation will serve as an inspiration and eye-opener for other offices involved in the building process. Also, the government should revise academic courses in order to incorporate BIM in its curriculum to have more expertise and well-educated professionals in BIM.

Since the client plays a crucial part in the success of any project, the stakeholder office should collaborate and involve clients in all design decisions, and raise awareness about BIM applications. Implementing a structured change management process can help manage resistance. This includes clear communication, setting realistic expectations, and providing support throughout the transition.

Implementing BIM does incur costs, but conducting a thorough cost-benefit analysis can provide a clearer understanding of the long-term benefits of BIM. Highlighting cost savings, improved project efficiency, and reduced rework can justify the initial investment. And also establishing a dedicated BIM team with a mix of experienced professionals and new talent can foster knowledge transfer and create a robust support system within the organization.

Selecting BIM tools and platforms that support interoperability is essential. Ensuring that software solutions can integrate seamlessly with other tools in the BIM ecosystem minimizes data silos and enhances collaboration.

Recommendation for further studies

In the aspect of recommendation for further studies, this study mainly focused only the utilization assessment of building information modelling, so it opens up for further topics like change management and BIM application, and also design sustainability using BIM and many others.

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APPENDIX

Adama Science and Technology University

Department of Civil Engineering, School of Civil Engineering and Architecture Office of Graduate Studies

Questionnaire and Interview prepared for research purposes entitled with "Utilization Assessment on Building Information Modelling (BIM) In Ethiopia, A Case Study in Addis Ababa"

Prepared by: Yared Getachew

Questionnaire

Dear Sir/ Madam

This is a questionnaire designed for research purpose at Adama Science and Technology University in Partial Fulfillment of the Requirements for the Degree Master of Science in Construction Engineering and Management. The objective of this questionnaire is to obtain information to conduct a thesis entitled **''Utilization Assessment on Building Information Modelling (BIM) In Ethiopia, A Case Study in Addis Ababa"**. The data collected and the information to be answered in this questionnaire will be used for academic research purposes only. All specific companies and interviewee information will always be kept confidential. Only a generalized analysis of the information contained within this completed questionnaire will be utilized in the research process.

Instruction

Please answer, rate, and tick (✓) the questionnaire by choosing the appropriate choices. The questionnaire and data collection contain two parts. Part one contains the company and respondent's general information, and part two deals with the specific, objective-oriented questions. I realize that there are numerous demands on your time; however, your involvement is a vital requisite for my research. Therefore, I kindly request your valuable cooperation to respond to me with the provided information data given in the questionnaire survey, and return the questionnaire paper as soon as possible. Thank you in advance for your cooperation and honesty in providing me with your valuable response.

Sincerely

Yared Getachew

Email; yadayenatu@gmail.com

Phone No: **+251 910897862**

Section 1: General profile of the respondent

Please give your response to the following questions by writing your answers in the space provided or by putting marks (√) in your choice rectangle shown for questions having a choice.

1.1 Name of company /Optional/ ……………………………..

1.2 Educational status?

☐ Diploma ☐ BSc ☐ MSc ☐ PHD and above

1.3 What's your profession at the company?

☐ Architect ☐ Structural designer ☐ Sanitary engineer

☐ Resident Engineer ☐ Designer

☐ Other; Please Specify………………………………………………………………

1.4 How long have you worked on Building Information Modelling?

☐ 0 – 1 years ☐1- 3 years ☐3 – 5 years

☐5 – 10 years ☐ over 10 years

1.5 How would you rate your proficiency with BIM tools and software?

☐ Beginner ☐ Intermediate ☐ Expert

Section 1.2 Building information management (BIM) application impacts

1.6 Do you use any BIM software for project management?

☐ Yes ☐ No

1.7 If yes, at what stage do you use BIM software for project management?

☐ At the feasibility stage ☐ during the concept development

☐ After the design is complete

1.8 At what stage of the construction process does your company apply the BIM design review?

☐ At design stage ☐ At preliminary detail design stage

☐ At developed planning stage ☐ At detail design stage

1.9 What mode of information exchange exists between each design stage?

☐ Paper Based ☐ Computerized ☐ Both

1.10. If you use paper-based information exchange, how often do errors and omissions occur?

☐ Very frequently ☐ frequently

☐ Sometimes ☐ Never

1.11 What is the highest level your organisation has reached in the application of BIM on a project?

☐ 2D Modelling ☐ 3D Modelling ☐ 4D Modelling

☐ 5D Modelling ☐ 6D Modelling ☐7D Modelling

1.12 When producing drawings, which of the following tools do you mainly use?

☐ Autodesk Revit ☐ Autodesk AutoCAD ☐ Graphisoft ArchiCAD

☐ Other; Pleas Specify ……………………………………………………………….

Section 2: Building information modeling (BIM) application (aimed to assess the application of building information modeling in our project management system)

You are kindly requested to tick (√) your responses in the provided space for the appropriate answer. Hence, tick on **Strongly Agree=5, Agree=4, Neutral=3, Disagree=2, or Strongly Disagree=1** on the BIM application indicators on project management.

Performance indicator	**Description of building information modeling**	**Level of BIM utilization assessment**				
		1	**2**	**3**	**4**	**5**
Adopting BIM	You hear more and more about BIM these days					
	BIM is extensively utilized in your organization					
	BIM enhanced the efficiency of project planning and scheduling compared to the traditional method in your experience.					
	Any challenges or obstacles can be encountered in implementing BIM into your workflow					
	There are specific phases in a project lifecycle where BIM can be predominantly used					
	Clients have a strong demand for BIM software applications					
	BIM allows stakeholders to collaborate in real time, ensuring everyone is on the same page regarding project timelines, costs, and requirements					
	The Government is using BIM for public sector work					
	Adopting BIM will have unnecessary extensive work compared to traditional paper-based work					
	The overall cost of BIM affects its utilization					
	After construction, BIM models can be used for facility management, allowing owners to efficiently manage and maintain their buildings					

Section 2.1: BIM performance indicator for auditing project management and software effectiveness (aimed to investigate the utilization of BIM as an auditing tool and contrast it with traditional auditing of project management progress, and BIM software enhances the application of BIM and overcomes the obstacles of BIM effectiveness.)

Performance indicator	Description of building information modeling	Level of BIM utilization assessment				
		1	2	3	4	5
BIM as an auditing tool and software, and its effectiveness	BIM facilitates change management by documenting and visualizing changes to the project throughout its lifecycle.					
	BIM is utilized as an auditing tool in your organization					
	BIM enables auditors to track project progress by comparing the as-built condition with the original plan and schedules.					
	Benefits of BIM are not tangible enough to warrant its use as an auditing tool					
	Auditors can use BIM to assess the quality of construction works by comparing the digital model with the actual built environment, identifying any deviation from the specified standard.					
	Autodesk Revit is widely used for BIM-based project management in various industries					
	Graphisoft ArchiCAD and BIMcollab are being used in your company currently					
	Lack of expertise affects the effectiveness of BIM software					
	Using software other than Revit will enhance the application of BIM effectiveness					

Section 3:

In this section, the respondents are requested to express their opinion on the overall BIM application, BIM being used as an auditing tool compared to the traditional way, and BIM software enhancing the application of BIM and overcoming the obstacles to BIM effectiveness.

1. How would you define Building Information Modeling (BIM)**? ………………………**

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2. What are the primary benefits of using BIM in construction projects?

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3. What other BIM software have you used in your company, and what benefits have you acquired?

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4. How does BIM facilitate collaboration among different stakeholders in a construction project?

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5. What communication tools or methods are utilized alongside BIM to ensure effective coordination?

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6. In what ways has BIM improved the efficiency of your projects (e.g., time savings, cost savings, fewer errors, etc.)?

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7. Have you conducted any assessments or studies to measure the performance of BIM implementation in your projects?

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8. What training or educational resources are provided to staff members to enhance their BIM skills?

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9. What are your future plans regarding the utilization of BIM in upcoming projects?

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10. Are there any specific features or functionalities that you believe could be improved in existing BIM tools/software?

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Interview questions

1. Full name
2. Job description in the company
3. What is your current level of familiarity with Building Information Modelling (BIM) technology?
4. How extensively is BIM integrated into your construction projects?
5. Can you provide examples of how BIM has improved project outcomes or efficiency in real-world scenarios?
6. How has BIM software interoperability challenged other software tools?
7. Have you previously utilized BIM for auditing or performance measurement purposes in construction projects?
8. What are your expectations regarding the effectiveness of BIM as an auditing tool for performance measurement in the construction industry?
9. What key performance indicators (KPIs) are critical for evaluating construction project performance?
10. In what way has BIM software enhanced the visualization of project design and data?
11. Can you discuss common challenges encountered during the BIM implementation process and how they can be overcome?