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The Practice and Benefits of Building Information Modeling (BIM) In Ethiopian Construction Industry

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A Research Project Work Submitted to the School of Graduate Studies of Addis Ababa University in Partial Fulfillment of the Requirement for the Degree of Master of Arts in Project Management

Advisor: Wubeshet Bekalu (PhD)

Addis Ababa University, School of Commerce
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ADDIS ABABA UNIVERSITY COLLEGE OF BUSINESS AND ECONOMICS

SCHOOL OF COMMERCE DEPARTMENT OF

PROJECT MANAGEMENT

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STATEMENT OF DECLARATION

I, Dula Alemu Dinku, declare that the project work titled "The Practice and Benefits of Building Information Modeling (BIM) In Ethiopian Construction Industry" is the result of my effort and that all sources of materials used in the study have been properly acknowledged except the research advisor's advice and suggestions, I have developed this research entirely on my own. This research has not been submitted for any degree at this or any other institution. It is provided as part of a Master of Arts in Project Management degree program.

Dula Alemu Dinku

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Addis Ababa, Ethiopia

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ABSTRACTS

The practice and benefits of Building Information Modeling (BIM) technology are studied in countries that utilize the technology well. Associated with the newness of the technology in developing countries, little is known about the practice and benefits of it in developing countries like Ethiopia. Hence, this study aimed to investigate the practice of BIM and its associated benefits by taking a case study of a public building in which BIM technology is tried to be practiced against the internationally accepted BIM practice standards. Primary data were collected using questionnaires from research participants identified for this study, interviews of key informants, and focus group discussions with a team that took part in BIM practice. Moreover, relevant literature is used to support the data synthesis process and these data are used for data triangulation purposes. The findings of the study revealed that BIM practice in Ethiopia involves various stakeholders including institutions (government, clients, contractors, consultants, and professionals in the Architecture, Engineering, and Construction industry. The Government of Ethiopia through its many offices including the Construction Management Institute, the Federal Government Building Construction Project Office, the Ethiopian Construction and Works Corporation, and the Ethiopian Standards Institute is playing the leading role in adopting and practicing BIM. Moreover, the study noted that there is growing awareness, and ambition/interest to adopt and practice BIM technology, and the practice of BIM in Ethiopia is in its infant stage and is slowly growing. Moreover, the author recommended that introducing seamless system adoption models, transition plans and integrated BIM planning and implementation strategies need to be developed by learning from other countries' best experiences.

Key Words: *Building Information Modeling, Construction Project Management*

Contents

LIST OF FIGURES

Acronyms

AEC - Architecture, Engineering, and Construction

AIR - Asset Information Requirements

BEP - BIM Execution Plan

BS1190 - BIM Standard 1190

BIM - Building Information Modelling

CIC - Construction Industry Council, Hong Kong

CMI - Construction Management Institute

CAD - Computer-Aided Design

CDE - Common Data Environment

E.C - Ethiopian Calander

ECC - Ethiopian Construction and Works Corporation

EIR - Exchange Information Requirement

FGBCPO - Federal Government Building Construction Project Office

5D - Five Dimensional

4D - Four Dimensional

GDP - Gross Domestic Product

IPD - Integrated Project Delivery

IT - Information Technology

ISO - Internation Organization of Standards

OIR - Organizational Information Requirements

PIM - Project Information Model

PIR - Project Information Requirement

3D - Three Dimensional

Two Dimensional (2D)

CHAPTER ONE: INTRODUCTION

This section deals with the introduction of the study. This section aims to introduce the motivations, context scope, and limitations of the study. Accordingly, this section presents the background of the study, background of the organization, statement of the problem, research objectives, research questions, scope of the study, the significance of the study, limitations of the study, and structure of the report.

1.1 Background of the study

Proper project information processing and management are the backbone of every project. The success of any project relies on the ability of project teams to get access to the needed information and support their projects with informed decision-making. Like every project, the success of construction projects heavily relies on properly planning, executing, monitoring, and evaluating projects. All these processes are best achieved by adopting the right information management and utilization systems that allow collaboration among professionals from the Architecture, Engineering, and Construction (AEC) disciplines.

The traditional construction management system is less collaborative and significantly relies on project managers` expertise and experiences that are not well documented to help continuous professional learning and advancement, and asset management which is vital as the project transitions into the operation stage. Hence, it is limited in terms of properly scheduling tasks; schedules in traditional project management are wrong seventy percent of the time (Hardin & McCool, 2015). Moreover, it has limited room to accommodate changes which makes it prone to defects and reworks that have the potential to delay projects and incur additional costs. Besides, it has drawbacks in allowing easy communication and prompt modification among project partakers, and it focuses on the results rather than the process (Sacks et al., (2017). Yet, the hard fact is what produces the results are the processes. Thus, the processes need to be well guided to help each decision made yield the required outcomes from the inception to the last lifecycle of construction projects.

Studies reveal that the global construction industry is shifting from traditional information processing to a more modern and sophisticated data-supported and collaborative construction practice and management. The global construction management experience over the last half-century reveals that efforts have been made to optimize information management and efficiency in construction projects

(Agenda, 2016). Yet, the contribution of many of the efforts to improving planning, design, and implementation of projects is limited since its focus is product optimization and reducing wastage (Francis & Thomas, 2020).

Building Information Modeling (BIM) is the recent “state of the art” construction information management process that allows 3D visualization through federated 3D models developed with inputs from AEC industry professionals` collaboration to manage all construction project processes from its inception to the final facility management stage. It helps in scheduling, cost estimation, and construction simulation besides harmonizing the professional contributions of various professionals whose contributions are vital in realizing construction projects.

In the course of BIM`s application and usage, the process has contributed to construction process optimization and smooth information flow among various stakeholders. Moreover, its cloud-based live collaboration tool and information exchange enabled the system to fix potential errors that might incur additional costs, delay projects, or affect the quality before going to construction sites. Though experiences of BIM practice in countries that adopted the system early and practiced the system for so long have shown higher maturity allowing them to claim the highest possible benefits the system could offer, little is known about the practice and benefits of the system in countries that are late in adopting the system.

1.2 Background of the Industry

The Ethiopian Construction Industry is an active industry supporting the country`s development ambitions. Ethiopia has a vision of achieving a status of lower-middle income country by 2025, and one of the cornerstones of the country`s development is believed to be the construction sector (Donnenfeld et al., 2017). Hence, the country is undertaking various development projects across the country. As a diplomatic and administrative capital strategically located in the Eastern part of Africa, Addis Ababa is under significant development and reconstruction which gave the construction industry a prime position in the city`s development. The construction boom in the city involves the private sector, government, and international investors and It is supporting many lives within the capital. In 2022, the Ethiopian Construction market was estimated at $54.8 billion and this number is expected to grow by eight percent between 2024 and 2027 (Saraswati, et al., 2022).

However, there is significant doubt about the efficiency of construction projects in the country. The construction practice in the country is majorly dependent on traditional construction management which is limited in terms of allowing collaboration among stakeholders. Hence, it is prone to resource wastage and delayed project delivery.

1.3 Statement of the Problem

Ethiopia is one of the countries that is late to practice the Building Information Modeling system. Studies show that the Ethiopian construction industry is at the early stage of implementing the BIM process (Belay et al., 2021). Thus, how the system is being practiced and the benefits of the BIM process in the context of the country`s construction experience, are less known which affects the motivation of stakeholders to contribute in adopting and developing the system. Moreover, the system requires initial capital investment to buy equipment, software, and cloud service, and train staff to effectively use the system. Since the system is a new experience with less proof of achievement in the country`s construction industry, this would limit the interests of the private sector, professionals in the AEC industry, government, and clients. Anything that requires investment of resources needs a warranty of not investing in vain and anyone in a position of investing in the process wants to know the practice and practical benefits of the system to assess whether the investment is worthwhile. Edw3x qa1`

Hence, it is critical to document the practice and gains of the process to draw lessons about the challenges and potentials of the BIM practice and understand how to contextualize the system so that it can address local needs and claim benefits the system could offer. Understanding how the system is practiced, the challenges in properly practicing it, and the benefits the system offers in the context of local experiences would guide decisions made to invest in the development of the system or not invest, and improve the system`s performance. Thus, the outcomes of this research can assist stakeholders gathered around the construction industry including the government, investors/developers, and construction professionals in understanding the system, their roles, and advantages of the system better and better position themselves in the adoption and development of BIM.

1.4 Research Objectives

The overall objective of this study is to explore the real practice and benefits of BIM systems. Accordingly, the research aims.

1. To investigate BIM practice in light of institutional, legal, and professional preparedness
   1.1. To understand how is BIM Planned and implemented

1.2. To identify stakeholders involved in BIM planning and Implementation

1.3. To describe the roles of various stakeholders

1.4. To investigate the challenges perceived in planning and implementing BIM

2. To explain the benefits of the BIM practice in optimizing processes and reducing wastage

2.1. To explain the contributions of BIM in enhancing project quality, timely and on-budget completion of projects

1.5 Research Questions

3. How is the practice of Building Information Modeling (BIM)?

1.5. How is BIM Planned and implemented?

1.6. Who are the stakeholders in BIM planning and Implementation?

1.7. What are the roles of various stakeholders?

1.8. What are the challenges in planning and implementing BIM?

4. What are the benefits of Building Information Modeling (BIM)?

4.1. What are the contributions of BIM in enhancing project quality, and timely and on-budget completion of projects?

4.1.1. What are the contributions of BIM in enhancing project quality?

4.1.2. What are the contributions of BIM in enhancing the timely completion of projects?

4.1.3. What are the contributions of BIM in enhancing on-budget completion of projects?

1.6 Scope of the Study

This research is limited to the study of the practice and benefits of Building Information Modelling (BIM) in the context of the Ethiopian construction industry. Although a lot of topics could be studied about BIM experiences in Ethiopia, the study focuses on investigating how the BIM system is planned and implemented in various public buildings and in what ways the planning and implementation of the system benefit stakeholders gathered around BIM planning and implementation. In line with this, the study endeavors to grasp how the government, contractors, consultants, and clients are contributing to BIM adoption and to what extent the practice of BIM helped the various stakeholders involved in the process to claim benefits of the process.

Since the majority of the efforts made to practice BIM are within Addis Ababa, geographically, the study is limited to the study of BIM practice on building constructions within Addis Ababa, Ethiopia.

Temporally, the study tries to cover the practice of BIM in building constructions since the early introduction of the system in Ethiopia up to the start of this study.

1.7 Significance of the Study

The result of this study is expected to raise awareness about the practice of BIM shading light on how the system is practiced against the globally accepted BIM practice standards, the level of maturity of BIM practice, and the benefits claimed from BIM implementation. Moreover, the study helps to identify areas of improvement and provide recommendations on how to fill the perceived gaps in planning and executing BIM to claim the best possible benefits of the system.

Accordingly, the findings and recommendations of this study can help stakeholders concerned including the government, the clients, the contractors, and the consultants, to better position themselves by understanding their roles in new ways, and what they can do better to enhance the practice and benefits of the BIM process. Understanding the practice and the benefits well enables stakeholders to base their stand about BIM adoption on a firm foundation. The significance of this study extends beyond stakeholders directly involved in the construction process. Moreover, it can help policy experts in the construction industry to focus on important aspects of BIM practice while formulating BIM adoption and execution policies, regulations, directives, and manuals.

Besides, it is hoped that lessons gained from this study complement the existing little knowledge available about BIM practice in Ethiopia, and also inspire other researchers to study the subject in such a way that it fits the local context.

1.8 Limitations of the Study

Shortage of time, limitedness of cases to be studied and geographical concentration of available cases are the limitations of this study. The BIM system in Ethiopia is yet in its early stages. This limits the amount of lessons taken from the implementation of the system. Moreover, the unwillingness of research participants to give detailed information on the planning and implementation of BIM is another limitation expected in the research as some of the information needed for this study might be considered to be a threat to their continued role in the BIM planning and implementation process. Hence, this may require incorporating questions that help to meet the research objectives without causing any threat of exposing one`s private information.

1.9 Structure of the Report

This study has six chapters. The first chapter introduces the subject to be studied and also provides the background introduction, giving an insight into the questions, objectives, scope, and significance of the study. The second chapter reviews the literature on the practice and benefits of the BIM process. The third chapter states how the study is conducted and what methodology is used. Chapter four deals with the findings and discussions of the study, highlighting the practical experience of BIM practice in Ethiopia and associated benefits, particularly in achieving the set schedule, budget, and quality requirements along with analysis and interpretation of the findings of the study. Finally, chapter six provides a conclusion and important recommendations.

CHAPTER TWO: LITERATURE REVIEW

2.1 Introduction

This section illustrates the findings of a review of relevant works of literature. The section is arranged in such a way that the flow of pertinent ideas cascades from the general to specific contents of a literature review to ease contextual understanding and positioning of this study. Accordingly, the review begins by presenting findings of a literature review on the broader construction industry and its economic contribution. The section continues to explain construction project management practices in traditional and modern styles. Moreover, the review covers information flow and exchange in traditional and modern construction project management. Finally, the section is concluded by introducing relevant findings of a review on Building Information Modelling.

2.2 Theoretical framework

Building Information modeling is a modern technology and the result of technological advancement. According to Straub (2009), Adoption theory studies individuals and their choices to accept or reject a given technology. Besides, it is a unique individual construct and complex social development process that relies on people`s perception of technology. Hence, understanding theories and models underpinning new technology adoption has paramount importance in properly assessing the adoption of BIM in Ethiopia. Accordingly, this section presents three theories the author believed to be critical in investigating the practice and benefits of BIM in the Ethiopian construction industry. The three technology diffusion-related theories are the Technology Acceptance Model, the Concerns-Based Adoption Model, and the United Theory of Acceptance and Use of Technology.

2.2.1 Technology Acceptance Model

The technology acceptance model was introduced in 1986 and It is still a widely used theoretical model in the Information Systems field. Most studies on the Technology Acceptance Model utilize general-purpose systems, office systems, Communication Systems, and specialized business systems to assess the level of acceptance of new technologies (Lee, et al., 2003). According to Masrom (2007), the perception of ease of use and usefulness of technologies determine technology acceptance.

2.2.2 Concerns-Based Adoption Model

The concerns-Based Adoption Model deals with cognitive concerns and how an individual's concerns influence his or her integration of innovation. It provides a unique perspective on facilitating adoption through the perspective of the adoptees. Its goal is to ease the problems of diagnosing group and individual needs during innovation adoption. The concerns-based Adoption Model is based on the assumption that change is a process, not an event to be accomplished by individuals which is a highly personal experience. Moreover, It sees change as something involving involves developmental growth and to be best understood in operational terms, and whose focus should be on individuals, innovations, and context. These assumptions form the basis of the three components of the concerns-based model: stages of concern, levels of use, and innovation configuration (Straub, 2009).

2.2.3 United Theory of Acceptance and Use of Technology

The United Theory of Acceptance and Use of Technology is a recent instrument, which is a synthesis of eight existing models of technology acceptance — including the Technology Acceptance Model (Oshlyansky et al., 2009). It focuses on specific innovation, rather than the adoption environment which is given attention in the above two models. The theory includes four key determinants of use (performance expectancy, effort expectancy, facilitating condition, and social influence) and four moderators of individual use behaviors (description, gender, age, experience, and voluntariness of use) (Straub, 2009).

2.3 Construction industry

The construction industry is known for being a capital-intensive industry. A study conducted by Anaman, K. A., & Osei-Amponsah (2007) on the relationship between construction activity and national economy, using time series data between 1968 and 2004 in Ghana reveals a causality between increased construction activity and an increase in macro-economy expressed by a Gross Domestic Product (GDP) level (Anaman & Osei-Amponsah, 2007). Besides, the construction sector is one of the major contributors to the global economy. It accounts for one-tenth of the world's GDP (Styhre, 2009).[1] Led by China, the United States, and India which account for 57% of the global growth, the world`s construction volume is expected to grow by 85% to become $15.5 trillion by 2030 (Robinson, 2015). However, the contribution of the construction industry to the national economy varies from country to country based on the level of countries` engagement in construction.

Between 1985 and 2005, Construction was the third GDP contributor in France, Germany, Italy, Spain, the United Kingdom, and the United States (Rossi & House, 2007). In some countries, its contribution is not less than one-tenth. In the United Kingdom, Construction has been the major contributor accounting for about ten percent of the nation`s economy (Kumar, 2015). The GDP share of construction in Spain grew from seven percent to ten percent between 1985 and 2005 (Rossi & House, 2007). Between 2002 and 2007, the GDP share of the Turkish construction sector increased by 11.6% annually to become 6.5% in 2007 (Balaban, 2012).

However, due to the complex nature of construction and associated tasks, the construction industry is subject to defects that have economic and other implications. These defects could be wastage, decreased efficiency, over budget or under budget, and frequent accidents (Rajab, 2022) which would lead to deteriorated quality, cost overrun, or time overrun probably leading to project failure. For instance, between 1964 and 2004, construction productivity in the United States of America decreased by twenty percent, contrary to increased productivity in other sectors. Yet, in 2014, construction generated about 33.5% of all waste across Europe contributing only 5.4% GDP share in the region (Baldwin, 2019).

Hence, the need for advanced construction project management to address such challenges the industry is suffering from is undeniable. In line with this, emerging technologies have the potential to support construction project management practices by enabling project teams to detect and address pertinent challenges early on in project undertaking.

2.3.1 Construction project management

Construction project management is a field of specialization within a project management discipline that focuses on the management of all activities of construction projects from their inception to the final project delivery. It is an important component of the productivity and effectiveness of construction projects (Mandičák, et al.,2020).

Under the leadership of the Construction Project Manager, management of construction projects involves various stakeholders including professionals from the Architecture, Construction, and Engineering fields, clients, contractors, sub-contractors, consultants, and regulators. Hence, the effectiveness of construction project management relies on the quality of information flow and exchange among various stakeholders which are the actors and backbones of well-informed decision-making.

2.3.1.1 Information Flow and Exchange in Construction Project Management

The quality of information flow and exchange determines the responsiveness of project communication management, project scope management, project integration management, project procurement management, project risk management, project quality management, project time management, project cost management, project human resource management, and project stakeholder management. However, challenges associated with derailed information flow and exchange are obvious in construction projects associated with the level of complexity of construction projects and the multiplicity and diversity of stakeholders involved in the process. The most common challenge associated with information flow is inconsistencies in what various stakeholders understand about the project and try to deliver (Gutierrez, 2017).

Defects in information flow and exchange in the construction project management context negatively affect projects undertaken. For instance, inadequate information flow and interoperability issues during operations and maintenance phases in construction projects within the United States cost nearly $10 billion annually (Newton, 2004; cited in Azhar et al., 2012). Hence, a project team working to deliver a project effectively needs to plan for effective means of information flow and exchange in which roles are assigned, and schedules and means of communication are planned well in advance.

2.2.1.1.1 Information flow and processing in traditional construction project management

Tradition construction project management is the foundation for a more advanced project management practice. However, it has limitations that need to be addressed to make sure that all stakeholders gathered around the construction project claim the expected benefits. It stresses on the project delivery. It is less of process driven, but more of a ‘get it done’ industry. Hence, this mindset has created challenges that should be corrected (Gutierrez, 2017). Besides, studies have documented various challenges associated with traditional construction management including cost overrun, time overrun, and deterioration of quality (Abdullah et al. 2009).

Moreover, traditional construction is known for being rigid in terms of communication, cooperation, and integration (O. Zwikael, 2009; cited in Azhar et al., 2012)) which are the foundations of successful project practice. Hence, it has a limited role in BIM-based construction projects. Thus, stakeholders of the construction industry need to work towards using more advanced technologies to ease communication, collaboration, and integration among partakers of a project.

2.3.1.1.2 Information flow and exchange in modern construction project management

Linked with technological advancement and digitalization of the world, information flow and exchange have shown significant advancement over the past decades. Accordingly, construction Project Management has benefited from advanced information flow and exchange. Hence, construction practices in some countries have shifted from traditional construction and adopted modern practices. In line with this, Computer-Aided Design (CAD), Lean construction project management, and Building Information Modeling (BIM) are a few of these efforts that have helped the construction industry to redress some of the challenges perceived in the traditional construction labor productivity issue (Karatas & Budak, 2023). However, the transition to Computer-Aided Design (CAD) did not change the common construction process, except fast tracking execution (Ganah, & Lea, 2021). Besides, the lean construction process has shown remarkable results in optimizing processes and reducing wastage. Lean construction practice is a system of production to reduce the wastage of materials, and time and achieve the highest possible production level. The philosophy of lean construction is based on the following 11 principles: 1. Reduction of non-value-adding activities. 2. Increasing value of outputs 3. Reduction of variability. 4. Reducing cycle time. 5. Simplification through minimizing the number of steps, parts, and linkages. 6. Increasing output flexibility. 7. Increasing transparency of processes. 8. Focusing on the complete process. 9. Building a culture of continuous improvement in the process. 10. Balancing flow improvement with conversion improvement. 11. Benchmarking (Rajab, n.d.). The roles of both Computer-Aided Design (CAD) and Lean construction project management in improving the performance of the construction industry are noteworthy. Yet, the issues associated with communication, collaboration, and integration remained prominent challenges owing to more classic solutions.

2.3.2 Building Information Modeling

Building information modeling is a digital approach to construction project management. Digitalization eases many of the tiresome and manual workflows by introducing flexibility, collaboration, and integration among stakeholders of the construction project (Baldwin, 2019). Moreover, BIM has both technology and process components that are shaping the construction industry. The technology component enables early detection and correction of design, construction, or operational problems by illustrating the project to be undertaken in a simulated environment, whereas, the process eases collaboration and integration of the roles of various stakeholders (Chen et al., 2017).

Besides, based on the maturity of BIM practice in the construction industry, BIM applications are classified into four hierarchical categories ranging from the lowest level, Level 0 to the highest, Level 3. Level 0 BIM uses unmanaged CAD, probably 2D as a tool of data exchange. Level 1 is characterized as a managed CAD with a common data environment (CDE) as a tool of collaboration with some structured data format. Level 2 BIM is more advanced than level 0 and level 1, and it BIM managed 3D environment. It may be 4D and 5D data used to develop schedule and cost estimation respectively, whereas, level 4 is an open process with a data integration feature and collaborative model server as a management tool (Kumar, 2015. Thus, the benefits the BIM process offers vary based on the maturity of BIM practice in construction projects in various locations and contexts.

2.3.2.1 Building Information Modeling Practice

Compared to conventional design approaches, the practice of BIM requires more thoughtful solutions and a better understanding of other disciplines (Özkoç, et al., 2021). Thoughtfulness and understanding other disciplines aid in establishing effective communication, and a collaborative work environment. The overall BIM practice requires technologies, structures, and protocols that can guide the planning and implementation of BIM. The first set of requirements under technology includes the acquisition of software, hardware, and networks used as a medium of information exchange and collaboration. The structure component includes leadership, infrastructure, human resources, and products and services. The protocols required include contractual, regulatory, and preparatory frameworks that govern BIM practice (Succar, 2009). Hence, professionals practicing BIM need to be aware of existing standards including the ISO 19650. ISO 19650 is a standard governing BIM practice`s information management from project initiation to the last life cycle of a built asset (Godager et al., 2022). Figure 1 illustrates the BIM workflow.

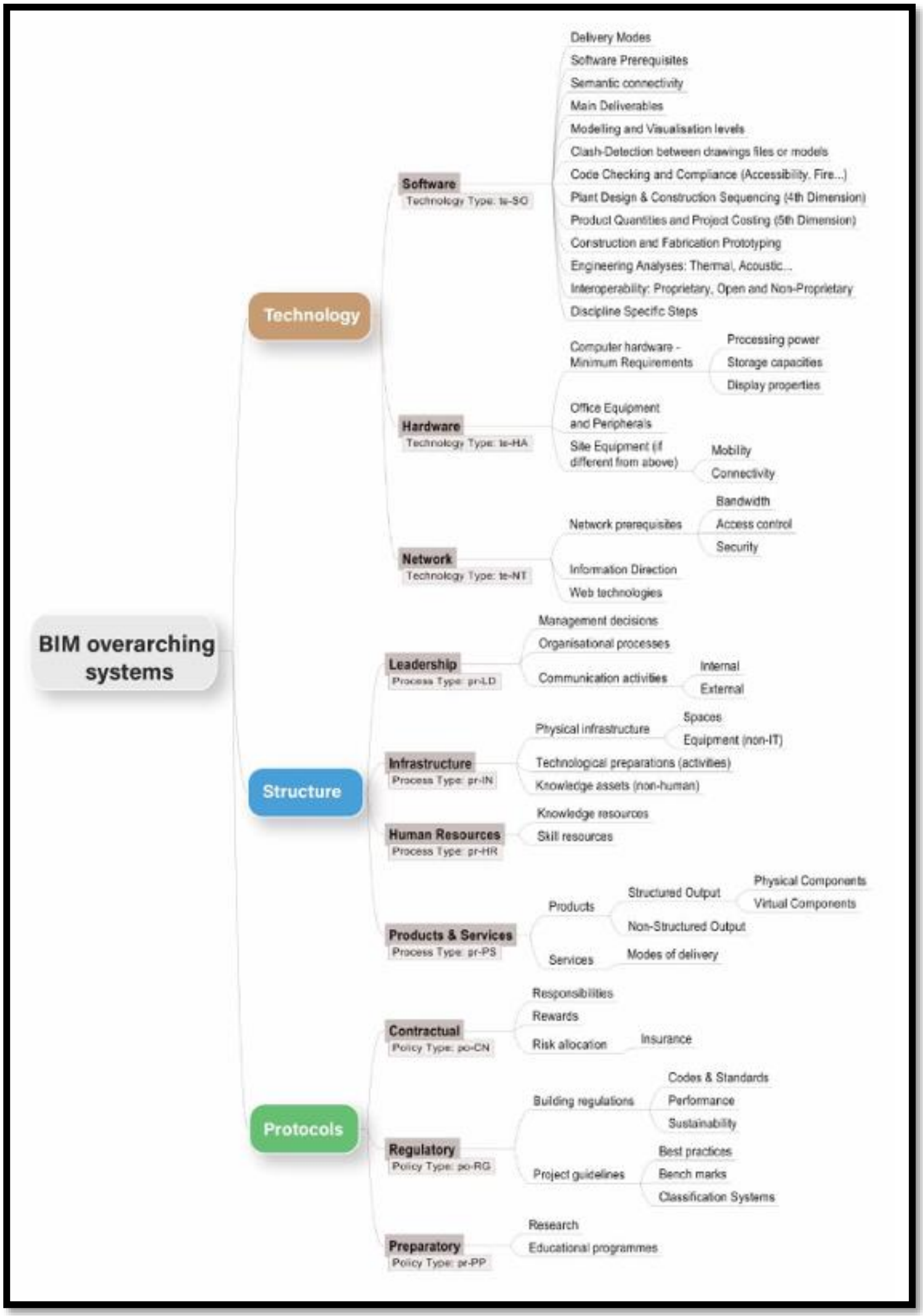

Figure 1: The BIM workflow (Succar, 2009).

The practice of BIM passes various stages involving different tasks contributing to project success. The primary requirement as part of the BIM application is understanding the client's specifications to plan for the production of information at each stage of the project and designate the party in charge to deliver information to the right stakeholders which is called 'planning the planning'. Exchange information requirement (EIR) is a requirement of information dictating how information is shared and exchanged among various stakeholders on which the project Information Model (PIM) is based. EIR is a product of Organizational Information Requirement (OIR), Asset Information Requirement (AIR), and Project Information Requirement (PIR). The output of this challenging stage is the Project`s BIM Execution Plan (Baldwin, 2019). Figure 2 illustrates information requirements and information models.

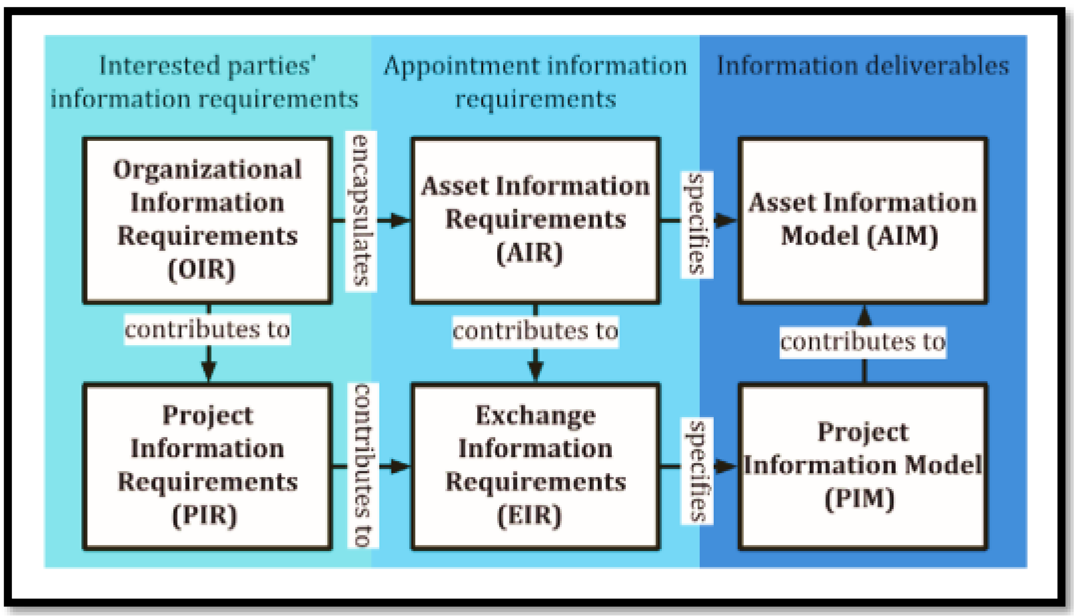

Figure 2: Various information requirements and information models, (according to ISO 19650)

Moreover, BIM can be integrated with a Geographic Information System (GIS) to ease site selection that meets certain requirements set out including technical and financial factors, decreased cost of utility planning and demolition, and Minimize risks linked to hazardous materials (Azhar et al.,2012).

BIM workflow according to ISO 19650 follows an eight-stage process. The Primary stage is Assessment and Need which is conducted by the client group to understand their needs and expectations. This stage is critical in preparing tender documents before they are sent to suppliers.

The second stage is invitation to tender which is to be conducted by the client. In an ideal BIM practice, the CDE used has a list of suppliers and suppliers are given access to tender documents on the CDE. The third stage is the tender response by suppliers including the lead appointed party which is to be identified on the next stage Appointment stage. The tender response includes pre-appointment BEP, risk register, and mobilization plan. At this stage, the suppliers show their capability to deliver the project using BIM technology. The fifth stage is the mobilization stage where the appointed parties mobilize resources needed to deliver the project. The parties train or hire their staff to fill skill gaps and mobilize finance and other resources aiding project success. The sixth stage is the collaborative information production stage which involves staff of appointed parties. Information model deliverer and Project close-out are the seventh and eighth steps requiring collaboration among appointed and appointing parties (EFCA, n.d). Figure 3 shows the BIM Workflow according to ISO 19650

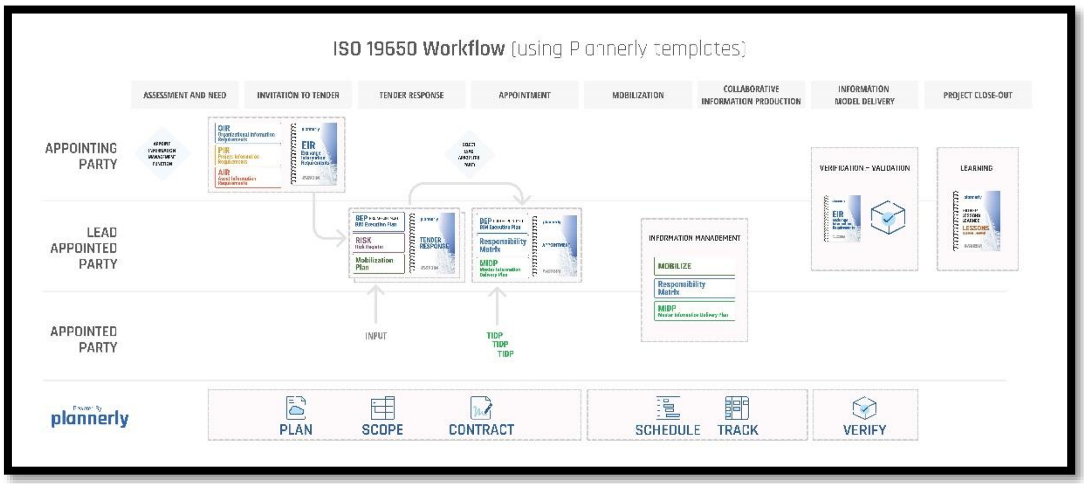

Figure 3: BIM Workflow according to ISO 19650

BIM practice requires a Common Data Environment (CDE) that allows the exchange of information among various stakeholders. Work in Progress is visible and accessible to the originator or task teams only. Each task team collaborates to finalize works in progress and produce outcomes to be shared by other team members outside the task teams. Once a task team`s outcomes are reviewed and approved to be shared by the task team`s coordinator, the information is shared so that other task teams that are given access and need the outcomes, get access to the shared information. Then, information authorized to be used in design for either construction or asset management is published. The final set of information is information that is archived for audit trail purposes. This information is important for future projects as it contributes to an advanced understanding of critical matters if the company has similar projects (EFCA, n.d). Figure 4 shows the structure of CDE.

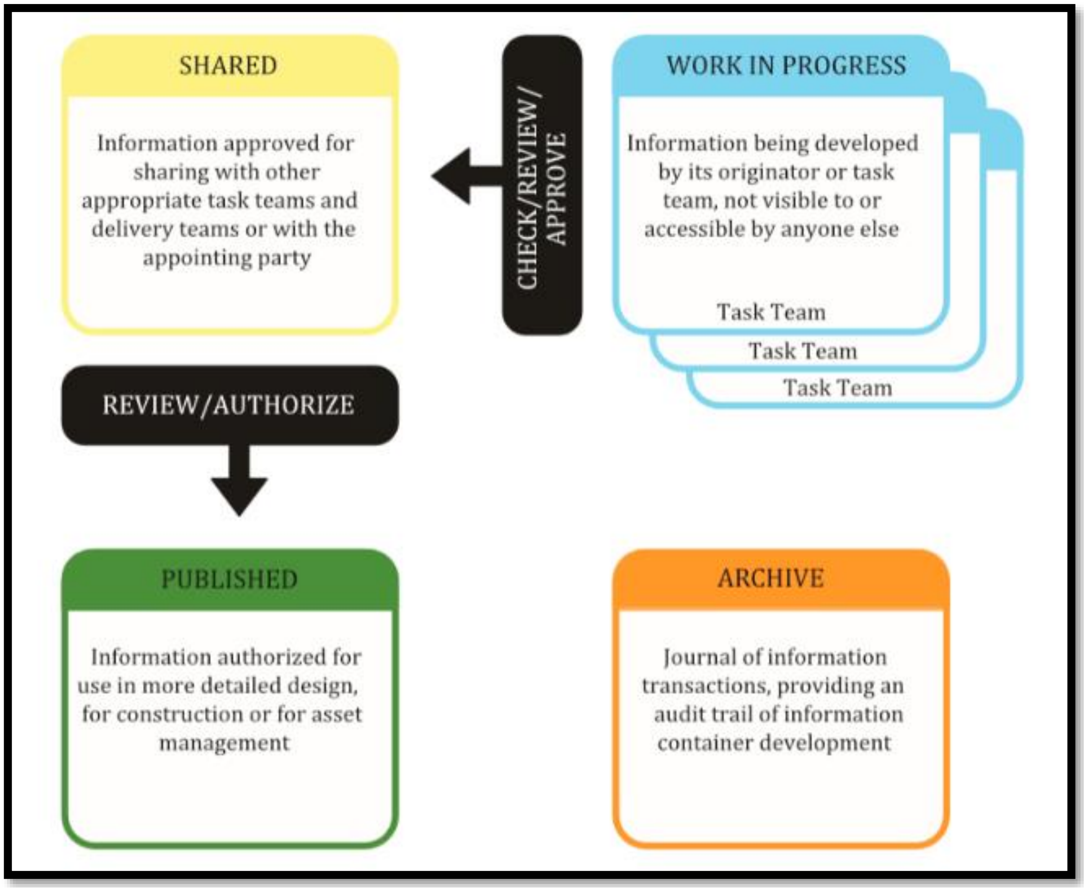

Figure 4: The structure of a Common Data Environment, (Source: according to ISO 19650)

2.3.2.1.1 Building Information Modeling Practice in Various Contexts

The introduction of BIM is attributed to Charles M. Eastman, who was a professor of Design and Computer Science at Georgia Institute of Technology (Karatas & Budak, 2023) and is considered to be the father of computer-aided design and BIM. Besides, BIM inception is also associated with the parametric modeling research conducted in the United States of America in 1970 and Europe in 1980, though, its implementation in the Architecture-Engineering-Construction (AEC) industry started in the mid-2000s (Azhar et al., 2012). Till 2015, the United Kingdom, Singapore, Norway, Finland, South Korea, and Denmark were the countries that made BIM a mandatory requirement in their countries` construction industry (Ganah & Lea, 2021). Yet, in recent years, BIM adoption globally has shown promising results. Though the acceptance was slow during the earliest stages of its development, now many countries adopted the system and have made it a mandatory requirement governing the construction practice. BIM adoption in North America was estimated to be sluggish during the early stages of BIM introduction, according to Smart Market Report, "Business Value of BIM in North America", BIM acceptance increased from 28 percent in 2007 to 74 percent in 2012 (Hardin & McCool, 2015).

However, BIM adoption in developing countries has been sluggish. The challenges in BIM adoption in developing countries are associated with limited IT infrastructure, financial competency of construction firms, poor collaboration among stakeholders, lack of BIM courses in universities, and cultural barriers (Ghaffarianhoseini et al., 2017; Kekana et al., 2020). Besides, legal and contractual processes, organizational and government-related barriers are identified (Belay et al., 2021). Yet, many developing nations are working to catch up and improve their BIM uptake in the Construction Industry (Olawumi & Chan, 2019). Despite its low adoption in developmental projects, in recent years, BIM has gained widespread acceptance across developing countries, particularly in Asia. (Ismail et al., 2017; Olawumi & Chan, 2019).

2.3.2.2 Building Information Modeling Stakeholders

BIM has various success factors that indicate the potential and performance implications of the technology. One of these success factors of the BIM process is the early involvement of stakeholders. Stakeholder involvement supports an Integrated Project Delivery (IPD) that has recently emerged as a companion of a BIM system. IPD engages stakeholders from various backgrounds including (construction management, trades, fabrication, supply, and product manufacturing expertise together with design professionals and the owner) early in the construction process to come up with a design with optimal quality, affordability, constructability, timeliness, aesthetics, and seamless flow of lifecycle management (Azhar et al., 2012).

The application of BIM involves various stakeholders including a BIM Manager in charge of managing integration, collaboration, and communication within a project team that would aid the achievement of BIM goals. Hence, a BIM Manager has an active role in facilitating communication, delegating roles, monitoring information flow, and leading important decisions. A BIM Manager is symbolized as a T-shaped person: a generalist with in-depth knowledge in a relevant particular field. Most BIM Managers have a background in IT or CAD. Yet, it is recommended that a BIM Manager would be someone with a Construction Project Management background who can understand and identify the core businesses of an organization (Baldwin, 2019).

Moreover, as the main stakeholder of a construction project, Project Contractors can use BIM to produce quantity takeoff and cost estimation, identify design errors through clash detections, analyze construction planning and constructability, verify, guide and track construction activities, prefabricate and modularize, plan for safety, Value engineering and implementation of lean construction concepts and communicate with project owner, designer, subcontractors and workers on site (Azhar et al., 2012).

2.3.2.3 Benefits of Building Information Modeling

There has been ongoing debate on the value of BIM since the introduction of BIM. However, as the number of countries that adopted the system and made it a legislated requirement of their construction practices has increased, the discussion has shifted towards how can it be successfully exercised to unlock the benefits the system provides (Leica Geosystems, n.d). Even though awareness about the importance of BIM has grown and the system has become a mandatory requirement in some countries, its value is not fully realized, and understanding of it is still inconsistent (Gutierrez, 2017).

Furthermore, the benefits of BIM for different users are different. It can enable project owners to assess and evaluate building design, building performance and maintainability, and financial risks early on the project planning stage to ensure project requirements are met. Moreover, it helps owners to get access to compiled information in one place and effectively use 3D renderings to market the project. Besides, Project Designers can use BIM to design better designs by rigorously analyzing digital models and visual simulations and receiving more valuable input from project owners. Furthermore, they can use it for incorporating sustainability features in building design to predict its environmental performance, better code compliance via visual and analytical checks, analyze forensics to graphically assess potential failures, leaks, and evacuation plans, and quickly produce shop or fabricate drawings (Kymel, 2008). Besides, Project contractors can use BIM to benefit from high profitability, better customer service, cost and schedule reduction, better quality production, informed decision-making; and better safety planning and management. Facility managers can also benefit from the rich information compiled by different phases of construction (Azhar et al., 2012).

Besides, possible benefits of BIM in different phases of construction can be studied through relevant application of the system in various phases. BIM in the Preconstruction Phase can serve to conduct quantity surveys and detailed cost estimates, site coordination, and constructability analysis. Based on the study conducted by Stanford University`s Center for Integrated Facilities Engineering on 32 major projects, the accuracy of the BIM estimate was reported to reduce time by 3% to 80% (Lu et al., 2014). Furthermore, contractors can plan for safety, and logistics, develop traffic layouts, and identify potential hazards at the job site using 3D or 4D site coordination models (Asnafi, 2016). Besides, in the Construction Phase, BIM can be used to monitor Project progress with the aid of 4D phasing plans and meet trade coordination depending on change orders and punch list information in the BIM models, whereas, the facility management stage utilizes project information collected through planning, design, and construction to make facility management efficient (Azhar et al., 2012). A 3D model that has rich information that supports analyses and facilitates fabrication, involves more decisions and incorporates more effort than producing the current set of construction documents (Sacks et al., 2018). The following figure summarizes the benefits of BIM practice if well practiced.

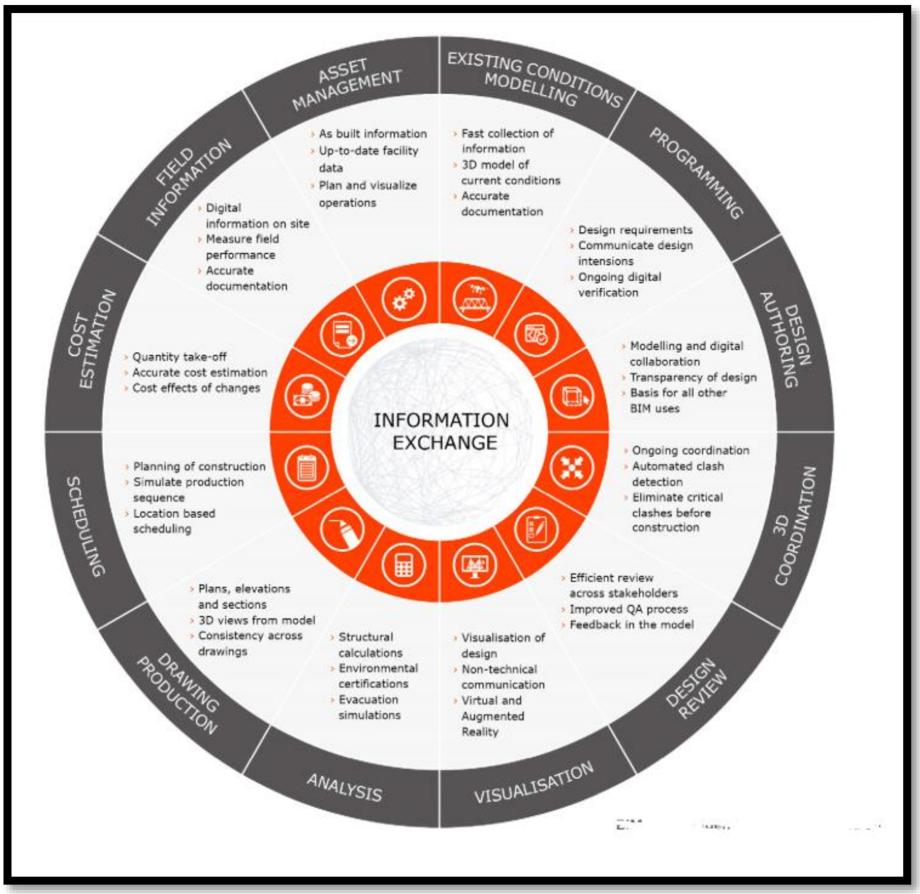

Figure 5: BIM benefits according to consulting engineers (courtesy of COWI)

2.3.2.4 Risks and Challenges of Building Information Modeling

Besides the promised benefits and potentials of the BIM Process, the application of BIM is prone to imminent risks. The risks associated with the system can be seen divided into two broad categories, namely technology-related risks, and Process-related risks (Azhar et al., 2012). Moreover, many studies identified the interoperability problem to be the main inevitable barrier to collaborative BIM environments and suggested the application of different data exchange methods to address the challenge (Sacks et al., 2018).

2.4 Literature Gap

The acceptance and practice of BIM are growing globally. And, this led countries to make the technology a mandatory requirement in their countries` construction practice. Though the practice and benefits of BIM in Construction Project Management in countries that have been using the system for a relatively longer time are well captured, the practice and benefits of the system in developing countries are less known. Hence, this study investigates the practice and benefits of BIM implementation in construction projects taking a case study of construction project management supported by BIM technology, in the Ethiopian capital Addis Ababa.

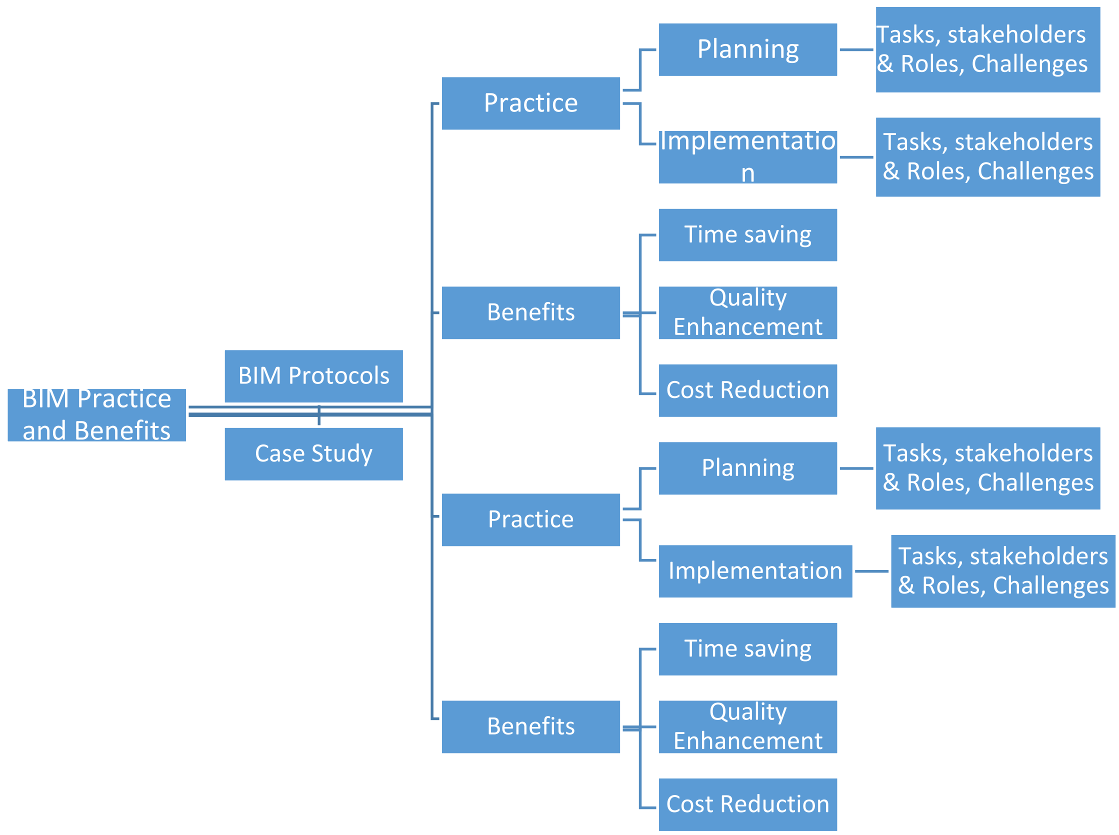

Figure 6: Conceptual framework of the study

CHAPTER THREE: RESEARCH DESIGN AND METHODS

3.1 Introduction

This section shows a clear roadmap used to meet the research objectives. Accordingly, the section covers the research design and methodological approaches followed to undertake this study. It starts by reminding the purpose of this study and continues by briefing various sections of the research design. Finally, the section illustrates the reliability, validity, and ethical considerations used in the study.

3.2 Research Design

A qualitative research design is used to understand the practices and tangible benefits of BIM planning and execution in the construction industry of Ethiopia. Qualitative design is interested in gathering detailed information about a complex phenomenon through engaging research participants (Ellis & Hart, 2023). The study tried to connect the practice of BIM with its pertinent benefits. It uses a case study method to capture the details, procedures, approaches, planning, implementation, and gains of the BIM practice. A case study is an in-depth research of a single unit through which the scholars bring to light something less known (Gerring, 2004). Though it doesn`t help to generalize results to a larger number of cases, It may provide a causal relationship between variables in a single case.

A case study method is suitable to understand the intricate details of BIM practice and associated benefits. Moreover, based on the responses of participants, it allow the researcher or data collectors to pose follow-up questions and get additional information previously not thought about. Accordingly, the research design includes the procedure for the case study, site selection, selection of participants, instrumentation, data collection, and analysis.

Through the use of a case study approach, the study attempts to gain an in-depth understanding of the subject of the study from the perspective of the major part-taker of BIM planning and Implementation and meet the research objectives by using interviews, open-ended questions, and focus group discussion. Hence, participants are vigilantly selected based on their experience of planning and implementing BIM in the context of the Ethiopian construction industry.

In a case study, the researcher identifies potential cases that could be studied to meet the research objectives. Then, the researcher develops certain criteria including representativeness of data, relevance, ease, and convenience of the cases to filter out relevant cases to be used for the study purpose. Once specific cases are identified, endeavor to get acquainted with what is already known about the cases that followed. This endeavor might be based on a literature review, media reports, or grey literature which enable the researcher to have a basic understanding of the cases under study. Acquaintance with what is already known would guide the development of research questions (Heale, 2018). Then, the researcher administers a pilot interview to test the questionnaire prepared to gather relevant data. Including important modifications to the questionnaire, the main data collection proceeds to gather data on which the study is based.

Semi-structured interviews supported by open-ended questions are used to ease data inquiry. With the permission of participants, the data are recorded and transcribed based on thematic coherence, and nature of the respondents, and their contributions. The interview questions are critical for assessing and understanding the practical experiences of different actors in the BIM and what the system offered them as advantages.

The data collection is conducted in four sections; the first section engages project managers and BIM managers who have had roles of preparing and implementing a BIM execution plan of selected cases, the second section involves contractors who have the prime role of implementing BIM execution plan prepared by professional form the AEC industry, the third section engages consultants who take part in the project either representing the client or the contractors, and the fourth section hosts clients who are the owners of the project and whose needs have to be met. The questions ask about the practical experiences of relevant actors in the BIM execution plan and the practical benefits obtained as a result of implementing BIM-based project management. Accordingly, the actors explain their roles, experiences, achievements, and benefits of using BIM as a construction project management technology. Particularly, important data on relevant procedures, approaches, methods, stakeholders, and their roles in the preparation and implementation of the BIM execution plan are gathered. Moreover, the contribution of BIM-based construction project management in balancing and meeting the targets is linked with the triple constraints of construction project management; time, cost, and quality. In line with this, critical data can aid in understanding the practice of and benefits of BIM with a particular emphasis on the 10 areas of the Project Management Body of Knowledge (PMBOK); Project Integration Management, Project Scope Management, Project Time

Management, Project Cost Management, Project Quality Management, Project Human Resource Management, Project Communications Management, Project Risk Management, Project Procurement Management, and Project Stakeholder Management are collected. These data help to understand how the practice of BIM is different from traditional construction project management practice and in what ways it benefits project success.

3.2.1 Procedure for Case Study Method

An experienced BIM Manager actively engaged in the planning and implementation of the BIM execution plan of the Ethiopian National Theatre`s building under construction in the center of Addis Ababa is contacted to understand the convenience of the cases identified for the study. The Manager positively responded to the request to cooperate on the provision of relevant data on the intentions, practices, and gains of BIM practice and associated benefits. Moreover, the BIM Manager is requested to provide the contacts of relevant stakeholders believed to providing important data on the BIM application. Accordingly, stakeholders who took part in the planning and implementation of BIM practice are requested to share their experiences related to BIM implementation and benefits. After gaining their consent, interview sessions are arranged based on their convenience and data are collected from stakeholders through interviews.

3.2.2 Site Selection

The study is conducted in the Ethiopian capital, Addis Ababa with the participation of professionals and stakeholders who have active roles in implementing BIM in the Ethiopian national theatre building. Associated with the newness of the practice of BIM in Ethiopia, there are limited alternatives to choose from. However, the study identified the national theatre`s (2B+G+11) building with Stage installation under construction by Ovid Construction plc. The project is a theatre building constructed on 6200 square meters with a worth of about 2.7 billion Ethiopian Birr. The client of the project is the Federal Government Building Construction Project Office which is under the Ministry of Urban Development and Infrastructure of the Federal Democratic Republic of Ethiopia. The owner of this project is the Ministry of Culture and Tourism of Ethiopia. The consultant of the project is Addis Mebratu Consulting Architects and Engineers. The construction process is ongoing and expected to be completed in August 2025 (Ovid, n.d.).

According to Addis Fortune (2019), the building permit for the project was issued by the city's Integrated Infrastructure & Construction Permit & Control Authority on March 6, 2019. Upon completion, the cinema is expected to accommodate 1500 people and a museum. The Ethiopian National Theater is one of the 32 cinemas operating in Addis Ababa and is under the Ministry of Culture and Tourism. It was established in 1956, and it has more than 300 employees. In the 2017/18 fiscal year, the national theatre generated an estimated 3.8 million Ethiopian birr from 1.5 million audiences who visited the national theatre to attend music and theatre programs during the same year (Addis Fortune, n.d.).

Figure 7: Case study site (Source: Addis Fortune, 2024)

The earliest stages of the construction project followed traditional construction projects without a BIM execution plan. As the relevance of the BIM technology is understood, the practice shifted from traditional to the BIM process which is believed to yield multiple benefits for the project.

3.2.3 Selection of Participants

The Case study method is used; therefore, only professionals who are familiar with how the BIM execution plan for the project is prepared and being implemented are selected to be research participants. Accordingly, the construction supervision team delegated by the client, the BIM Manager from the contractor group overseeing the planning and implementation of the BIM process, and the BIM process consulting team are invited to participate in the research.

The purposive sampling technique is used to identify the right participants from project managers, BIM Managers, contractors, consultants, and clients who have experience in planning and implementing BIM. Moreover, it is a mode of non-probability sampling that can be used with both quantitative and qualitative research techniques. It is suitable to study a certain subject with experts in the domain (Tongco, 2007). A choice of sampling techniques, sampling strategy, and sampling size need to go with the purpose of the study.

This study used maximum variation sampling, heterogeneous sampling, and criterion sampling techniques. Maximum Variation sampling is a type of purposive sampling technique used to capture varying perspectives relating to the subject under the study (Mujere, 2016). All relevant stakeholders who have prime stakes in preparing the BIM execution plan and implementation, including the project owner, designers, contractors, engineers, major specialty contractors, and facility managers, are included in the study

In criterion sampling, criteria including the role in the BIM process are set to choose relevant participants, and participants who meet the criteria are selected. Accordingly, all participants of the study are partakers who contributed to the planning and implementation of the BIM execution plan of the Ethiopian National Theatre's new building under construction. Criterion sampling uses Clear inclusion/exclusion criteria which use specifications for methodological rigor. This technique is important to reflect on the subject critically from diverse perspectives (Suri, 2011).

One participant from each stakeholder group representing the unique interest of BIM partaker is recruited for the study. The participants come from the contractor, consultant, and owner groups. The inclusion of diverse participants ensures understanding of the subject from different angles, and this serves for data triangulation and quality.

3.2.4 Instrumentation

Open-ended questionnaires and semi-structured interviews are used in this study. The open-ended questionnaires are a means to collect data in written form. Participation in the study was voluntary, and primarily, a link to a Google Drive form was sent out to selected participants. Then, semi-structured interviews are conducted with participants to fill gaps perceived in the primary data collection through Google Drive form. The interview is also a means to provide participants with an opportunity to provide rich information and clarification on confusion. Different participants are asked different questions based on their role in the BIM practice, and the benefits they expect. The participants are asked about their practical BIM planning and implementation experiences in the National Theatre building. The data collected from different participants are grouped into different teams based on thematic similarity and coherence for analysis purposes. Interviews are commonly used to elicit data from respondents through question-and-answer sessions.

The first part of the questioning process was limited to open-ended questions about the indicators of BIM practice and benefits. The second part included open-ended, written response questions that focused on the merits of BIM practice as evidenced by the practical experience of BIM in the National theatre. The follow-up interviews and focus group discussions aim to continue the data collection on BIM practice and benefits.

Primarily, the open-ended, written response questions and interviews are designed to answer the research question, 1. How is Building Information Modeling (BIM) practiced? With a focus on how BIM is planned and implemented, stakeholders' identification and their roles, and challenges associated with planning and implementing BIM. Secondly, the data collection focuses on tracing the practical benefits of the BIM process mainly focusing on BIM process supports construction project management to meet the quality, time, and cost objectives of the project.

3.2.5 Data Collection

The mode of data collection is through interviews, and focus group discussions with key informants conducted as a follow-up to the primary data collection through questionnaire. Qualitative data are collected from 6 interview participants, 4 focus groups partakers, and 4 participants who filled out the questionnaire prepared to collect data. Qualitative Data collected or stored electronically in the form of a Google Drive format is exported to a Word format and the responses are rearranged based on thematic proximity and coherence. Qualitative data are powerful tools used to collect qualitative data in a word format to capture remarkable events and evoke clear memories of past events (Eisenhart, 2012). The Author meticulously approached participants to gain unbiased data the respondents provided without feeling influenced by the author. Moreover, the semi-structured nature of the interview enables flexibility for hosting content previously unexpected. The collection process involved recorded interviews, written notes, the participants' written responses to questions, and face-to-face conversations.

3.2.6 Data Analysis

The data collected through open-ended questions, and interviews are structured into two major parts; the first part focuses on the practice of BIM, and the second part mainly emphasizes the benefits of the BIM practice for analysis. The author used content analysis to analyze data gathered from participants in the study. Responses collected for the first main research question for this part, How is Building Information Modeling (BIM) practiced? are grouped into the four indicators: BIM planning and implementation, stakeholders involved, stakeholders` roles, and challenges in planning and implementing BIM. The questions that are asked about BIM planning and implementation are coded as Section l.a BIM planning composed of tasks, stakeholders, and their roles, and challenges in undertaking the BIM Planning, Section I.b. BIM Implementation: this is composed of tasks associated with the implementation of BIM Execution Plan, stakeholders, and their roles, and challenges associated with the process. Hence, data collected from different sources are categorized based on thematic proximity and coherence before conducting analysis. This helps to triangulate data and ensures the reliability and replicability of data analysis. The results of the analyses are presented in Chapter Five.

3.3 Reliability and Validity

The validity and reliability of research are critical in ensuring the quality of the study. Validity refers to the ability of the research to follow a rigorous research process and arrive at the right judgment, whereas, reliability is about consistency of the finding across various analysis methods. Hence, appropriate methods and techniques with data triangulation are used to ensure the validity and reliability of the study.

3.4 Ethical Considerations

The study adopted an ethical research practice by gaining research participants` consent on data usage and informing them how data collected from them is to be utilized and no personal data are used against agreed-upon ethical standards. Besides, the author utilized ethical standards that include confidentiality, security, and privacy. Moreover, participants have been confirmed confidentiality of the personal information they provided and the anonymity of their identity. In addition, they are assured that they could withdraw from data collection whenever they feel uncomfortable and feel at risk of being negatively affected because they participate in this study.

CHAPTER FOUR: FINDINGS AND DISCUSSIONS

4.1 Introduction

The main objective of this study is to shed light on tangible BIM practices and benefits in the Ethiopian construction industry by drawing lessons from experts and stakeholders involved in practicing BIM technology. Hence, qualitative data are collected from experts and stakeholders who have endeavors of BIM practice in the AEC industry. BIM project managers, Architects, structural engineers, and mechanical engineers are involved as participants in the study. Content analysis is used to analyze data collected from various sources including primary and secondary sources. The findings of data collection are presented in two parts; the first part focuses on the practice whereas, the second part emphasizes its benefits.

4.2 Building Information Modeling (BIM) Practice

BIM is a new technology in the Ethiopian construction industry. Ethiopia has less than a decade of history of BIM. Most of the efforts to practice BIM in the nation are efforts made out of the willingness of a few stakeholders in the construction industry. The government is a lion-share holder in the practice of BIM in the country. So far, various government institutions are trying to practice BIM and modernize the nation`s construction industry. In line with this the Federal Government Building Construction Project Office, an office operating under the Ministry of Urban and Infrastructure, the construction management institute, the Ethio-Engineering Group which was re-established in 2020 and highly hiring BIM experts and the Ethiopian Construction Works Corporation (ECC) are noteworthy in the country`s efforts to adopting BIM.

The primary effort to adopt BIM in the nation`s construction industry was started 8 years ago by training employees of the Construction Management Institute as Trainer of Trainees. Since then, several professionals in the construction industry have been trained. And, this training has played a significant role in educating stakeholders of the industry about the need to adopt this technology. Yet, since there are limited opportunities for exercising lessons gained from the training on real and on-ground projects, the outcomes of the training which limited in bringing real changes in the construction practice of the country.

Besides, the Construction Management Institute and other stakeholders including the Ethiopian BIM Society inspected global BIM standards including ISO 19650, BS1190, and CIC, and adopted the CIC standard with minor modifications. The standard inspection and adoption utilized volunteers who had other assignments and volunteers which made collaboration difficult. Yet, the adopted standard has limitations in terms of contextualizing the provisions of standards. Moreover, few stakeholders are aware of the requirements, and expectations associated with BIM practice. In line with this, some stakeholders questioned the relevance of the adopted BIM standards and guidelines to our local contexts.

4.2.1 BIM Planning and Implementation

BIM planning and implementation in the Ethiopian construction industry is at its early stage. Hence, expectations are not clear, roles are not known and practices are fragmented and voluntary which makes it difficult to understand the practice. The Federal Government Offices Building Project Office has tried to partially implement BIM in three government construction projects. The first one was the Ambassador's Residence project, followed by the Ministry of Justice`s building under construction. These two projects are projects that reveal the government`s determination to adopt the BIM technology. These projects are pilot projects undertaken in collaboration with the construction management institute. The practice is not participatory, integrated, and complete. Hence, They don`t show the whole picture of the practice and benefits of the technology. The third BIM practice effort by the Federal Government Offices Building Project Office is on a G+11 National Theatre Building whose construction was started in 2022. To ensure the successful implementation of the BIM technology, the planning phase involved acquiring resources such as high-performance computers, BIM software, and participant training. Moreover, the office issued tenders requesting suppliers to use BIM technology and working towards making BIM a mandatory requirement on Federal Government buildings starting in 2017 E.C.

The findings of the study revealed that internationally accepted BIM standards and best practices in similar projects are used to guide the BIM planning and implementation as the BIM standard wasn`t adopted at the start of the BIM practice effort. BIM planning and implementation in the National Theatre Building has two wings: one which is led by the local contractor who is in charge of constructing the building and another by the client. There is no collaboration effort between them. The consultant of this project is a consulting firm of Architects and Engineering and It is in charge of designing the 2B+G+11 building under construction. Yet, the consultant has no role in the BIM Planning and Implementation of this project. Co-production and collaboration among stakeholders of this project are weak.

4.2.1.1 BIM Planning Practice

The BIM planning endeavor, in an ideal situation, needs to be started with the development of Exchange Information Requirement(EIR) using Organizational Information Requirement, Asset Information Requirement, and Project Information Requirement at the project initiation stage. Moreover, the BIM planning process should be collaborative engaging all stakeholders including the client, consultant, contractors, suppliers, and more. However, the BIM practice just engages professionals of the contractor group and supplier in two separate teams.

The project information requirement is a prerequisite for the BIM execution plan and the client should be part of the team preparing the requirements. However, there was confusion on who was supposed to prepare the BIM Execution plan, and all other prerequisite documents, such as the AIR and PIR. Hence, the client requested the contractor to develop a BIM Execution Plan (BEP) with the 3D and 2D graphics gained from the consultant. In the process of developing BEP, the consultant was cooperative in providing requested data about the project. Yet, as the development of BEP continues, delay of response delayed the process and the development. The BEP developed had limitations of data which were filled by additional data gained from the consultant. The BIM planning practice utilized a local server as a host of a Common Data Environment and a purchased Revit software, Solibri Office, and BXEL for various functions of the BIM planning process. The model authoring task utilized Revit, whereas cost calculation utilized BXEL software. Moreover, the team utilized Solibri Office/Solibry for model-checking purposes.

4.2.1.2 BIM Implementation Practice

The BIM implementation practice experience of the national theatre projects demonstrates that associated with the lack of strict follow-up and BIM protocol guiding responsibilities, accountabilities, and expectations of various stakeholders, all these have limited the practice. Hence, the implementation practice linked with the project has become more of a suggestion than a recommendation or a formal agreement between stakeholders. For instance, the project documentation and reporting process follows conventional reporting since none of the stakeholders are within the Common Data Environment (CDE) used by the contractor who is the sole planner and implementer of the BIM process it leads. As BIM practice in Ethiopia is in a pilot project state, its application, so far, is limited to model authoring, visualization, and 3D coordination. Hence, the application contributes to the identification of errors that can be identified visually and through clash detection tools. Moreover, the application of other features of the technology would help to benefit from other advantages of the system. Even though BIM practice passes through the eight workflow stages stated in the ISO 19650 part 2, the practice in the project under the study is limited to information production and delivery of the information model.

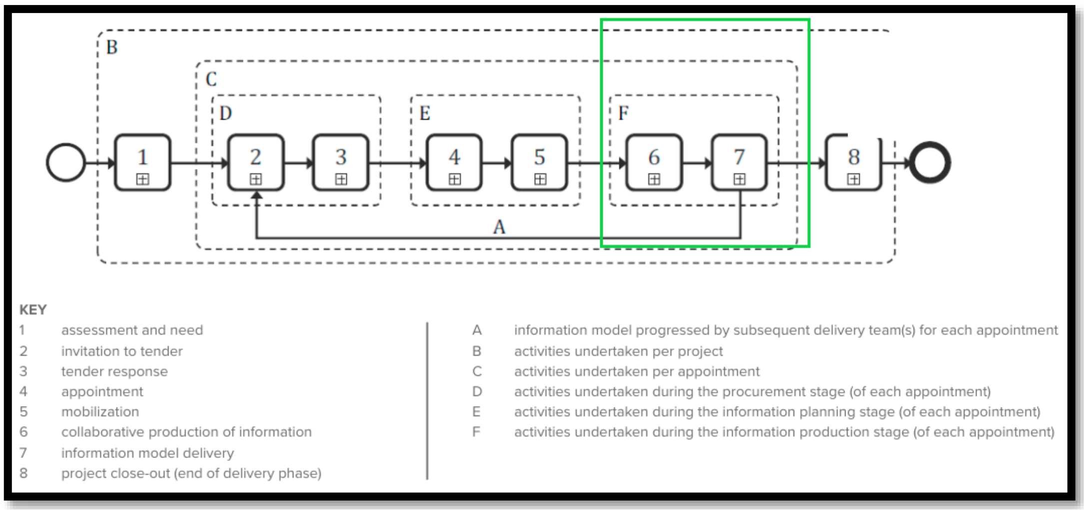

Figure 8: Major focus areas of BIM Practice in the project

4.2.2 BIM planning and Implementation Stakeholders and their Roles

BIM practice in Ethiopia involves various stakeholders including institutions (government, clients, contractors, consultants, and professionals in the AEC industry. The Government of Ethiopia through its many offices including the Construction Management Institute (CMI), the Federal Government Building Construction Project Office (FGBCPO), the Ethiopian Construction and Works Corporation (ECC), and the Ethiopian Standards Institute is playing the leading role in adopting and practicing BIM. CMI is a federal level institution under the Ministry of Urban and Infrastructure which is responsible for effective management of construction projects. The role of CMI in training human resources in the AEC industry has enabled stakeholders in the industry to be well aware of the need and importance of BIM technology. Moreover, the role of the Ethiopian BIM society in raising awareness among professionals and stakeholders in the industry and also contributing to the adoption of BIM standards and guidelines was important. Furthermore, the role of the Ethiopian Standards Institute in facilitating the adoption of BIM standard documents is worth mentioning.

In an ideal situation, BIM planning and implementation requires collaboration among various stakeholders gathered around the construction project including the client, contractors, consultant, and suppliers. However, the BIM planning and implementation have utilized the expertise of human resources within the contractor company. The project Manager of the Building was the only professional with experience in BIM. In an effort, the company hired Architects, Engineers, and Project managers and trained them to support the project with the new skills gained. Accordingly, the project involved 1 BIM manager who used to act as a Project Manager, 1 BIM Coordinator, 2 Architects, 1 Structural Engineer, 2 sanitary Engineers, 1 Mechanical Engineer, and 1 BIM Project Manager.

The BIM Manager was in charge of overseeing the overall project progress and making sure that the project was on track to achieving its objectives. Under the supervision of the BIM Manager, The BIM coordinator was responsible for overseeing the collaboration among Architects and Engineers. Besides, He was responsible for ensuring interoperability among the outcomes of various experts and identifying clashes by running a clash detection test. The BIM project Manager was responsible for developing schedule (4D) and cost estimation (5D).

4.2.3 BIM Planning and Implementation Challenges

The challenges of BIM practice in Ethiopia include a lack of strict follow-up and unified enforceable protocols facilitating the practice. Up until recently, the industry has no binding legal framework guiding the BIM practice. Recently, the Ethiopian Standards Institute adopted the CIC standard. The BIM practice in different units is based on different requirements. The lack of detailed protocols binding all stakeholders created unclear role division and expectations and a lack of evaluation criteria, the difficulty associated with no timely updating of the BIM Execution Plan creates a mismatch with reality on the ground, and inconsistency in design (between structural, stairs, opening & accessibility challenges).

In line with this, the majority of the firms which claim to practice BIM use ISO 19650, whereas, one of the stakeholders just developed their pragmatic information exchange protocol. Developing one's information exchange protocol requires understanding how the technology could be utilized for its optimized usage. Yet, the development of new protocols needs to depend on existing ones by understanding their drawbacks and potential. Yet, the BIM team within the client team confirmed that they have limited knowledge about the ISO-approved standards and the recently ratified national BIM standards. This revealed limitations in terms of practice.

Moreover, before having standards, having a comprehensive guideline on which the development of standards depends should have been a priority. In addition, the document isn`t fully compiled and it lacks detailed templates that closely guide the practice. Besides, limitations in terms of updating one`s professional competency and lack of collaboration among stakeholders (clients, contractors, consultants, and sponsors) were the significant drawbacks of BIM practice. Furthermore, lack of knowledge of BIM practice or different levels of knowledge among stakeholders has been a challenge to exercise a full-fledged BIM practice. The BIM practice effort in the Nationa Theatre`s building reveals that the contractor's Human Resources have a certain level of competency and preparedness by taking training, whereas, the client and consultants have no role in the preparation and implementation of the BEP which limited the outcome of the practice. Accordingly, though quantity takeoff was conducted, the cost estimation hasn`t been produced yet. BIM-based cost estimation involves developing a Bill of quantity and estimating costs directly from 3D models. Would cost estimation have been conducted early on the project undertaking, it would have guided financial resource mobilization requirements and budgeting. However, conducting cost estimation would still benefit the rest of the activities to be conducted.

Furthermore, the lack of IT infrastructure, and software, and the turnover of Human resources due to the attractiveness of the BIM market have challenged the BIM practice effort of the Ovid group. An Architect, Structural Engineer, Sanitary Engineer & BIM Project Manager left the office and were hired somewhere else. Hence, limitations in stakeholder engagement, technology acquisition, collaboration among various stakeholders, accessibility of BIM protocols, and unclear role division hampered the practice of BIM in Ethiopia.

4.2 Building Information Modeling (BIM) Benefits

The benefits of BIM practice lie in its ability to feed important information to the project to ease informed decision-making. In line with this, the clash detection report of the project revealed that the project benefited from BIM practice by enabling the project team to be able to identify errors that could negatively affect project progress. Moreover, the ability of BIM to ease collaboration among professionals from various backgrounds has enabled the project to easily detect inconsistencies among outcomes of various disciplines. BIM`s potential for early detection of errors lies in its features such as 3D visualization, clash detection, information exchange, and live collaboration.

Moreover, the collaboration among professionals has enabled professionals to develop team-playing skills which is critical in tasks that require team performance. Besides, the BIM Planning endeavor has enabled the project to properly quantify needed resources for the project. Hence, this avoids under-quantification and over-quantification of materials. To mention a few of the benefits of the BIM practice in the National Theatre`s Building, the BIM planning effort in the project enabled the project team to redress clashes between the position of stairs and walls, inconsistencies between the type of opening on various floors within the building and missed items. Furthermore, the 3D visualization of the project guided the project team`s decision to change the cladding material of the podium from concrete to composite structure.

4.2.1 Contributions of BIM in Enhancing Project Quality, and Timely and On-budget Completion of Projects

The richness of information associated with BIM practice plays a significant role in optimizing the quality of project deliverables, reducing project duration, and minimizing project costs. Yet, it is hard to put the benefits of BIM practice in quantitative terms of time, costs, and quality are expressed. Yet, the study tried to use globally accepted quantitative implications on benefits claimed out of BIM exercise.

BIM technology does more than identify potential errors delaying the project, incurring additional costs, and reducing project quality. An ideal BIM application benefits from features of BIM application that include existing conditions modeling, programming, design authoring, 3D coordination, design review, visualization, analysis, drawing production, scheduling, cost estimation, field information, and asset management. However, the benefits of the system in the Ethiopian construction industry are limited to design authoring, visualization, and 3d coordination which are important to see the 3D model of the building to be constructed and check the coordinated functioning of different elements of the building. Yet, advanced benefits of the system including the production of high-performance, energy-efficient, sustainable buildings are realized as the project practice matures.

The practice of BIM in Ethiopia is at its infant stage which revealed that the majority of the efforts among various stakeholders are in the form of pilot projects which is important to understand practical hurdles and areas of future interventions. This has limited the benefits the construction industry could claim from the adoption of the technology. However, the limited benefits of the system would still contribute to project success. Hence, that should not be undermined but exploited, and further capitalized on. The 3D visualization and clash detection conducted on the project models revealed critical errors including openings that dropped from their level and walls causing accessibility challenges. One can estimate the benefits of identifying such errors early on in project planning in terms of enhancing project quality saving cost and reducing time. Moreover, It is expected that as the nation continues to engage in the practice with more skilled human resources, advanced technologies, and context-sensitive protocols governing the practice, the country could claim more advantages of using the system.

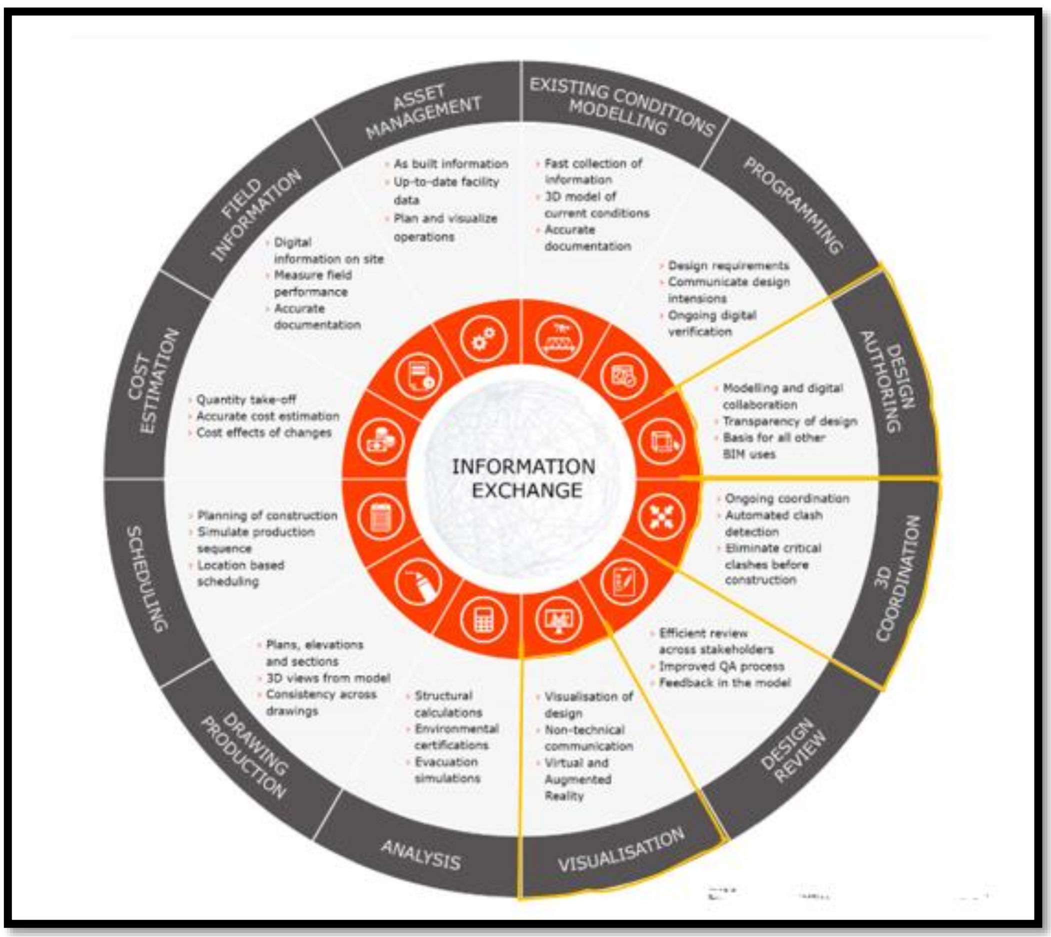

Figure 9: BIM practice and Benefits in the project

4.2.1.1 Contributions of BIM in Enhancing Project Quality

Project quality is the product of informed decision-making. The accuracy and richness of information provided by the BIM technology is the backbone of any construction project that practices BIM well. In line with this, the practice of BIM in the project under study benefited from outcomes of BIM to enhance quality project progress. Collaboration among coordinated efforts of various professionals within the contractor team contributed to the quality of the project by allowing early detection of errors, and inconsistencies, identification of missed items, and accurate quanitification. Thus, the practice of BIM has enabled the project team to request design modification for part of the projects not undertaken and could be fixed at this stage. Accordingly, though limited by its lower scale of application, the practice of BIM contributed to project quality enhancement by allowing coordinated planning, rich data access, quality design outcomes, and increasing transparency, and control efficiency. One can imagine the quality implication of errors fixed, inconsistencies addressed, and collaborations achieved in terms of aesthetic, social, and environmental values. Moreover, the significance of quality enhancement could be shown at a bigger scale would all stakeholders were engaged and collaborated in the practice of BIM early on at the start of the project.

4.2.1.2 Contributions of BIM in Timely Project Delivery

Inconsistencies and errors identified on-site require time to negotiate on how they should be fixed, who should fix them, and the like. By helping identification of such errors and taking additional time early on in the project planning stage, the BIM technology contributes to timely project delivery. Moreover, the live collaboration feature associated with the BIM technology allows prompt information exchange and decision-making. Moreover, the efficiency of the exchange of information, collaboration, and identification of errors through BIM practice contributed to cutting the time needed for project activities. The project under study is building the structural element when they identified errors and inconsistencies in the design of non-structural elements. These defects are addressed since the corrections are possible as the project progress allows the correction. Fixing errors and inconsistencies early before the project undertaking is conducted saves time to fix such errors on site. Thus, BIM practice on the project increased the accuracy of the construction process, helped to track project progress, and aided swifter decision-making which would help to complete the project on time.

4.2.1.3 Contributions of BIM in Cost-efficient Project Delivery

Construction projects are complex and they are prone to cost overrun (Love, et., 2009). One contributing factor to cost overrun is poor planning. Planning heavily depends on accuracy, timeliness, and richness of information. The more accurate and timely information the project team gets, the more effective decisions the project team makes in various areas including matters that are associated with finance.

BIM-based cost estimation involves developing a Bill of quantity and estimating costs directly from the 3D model. It provides more accurate, reliable, and detailed cost breakdowns. This helps in budgeting by allowing for better cost control and forecasting. The estimation aids visualization of cost implications and development scenario analysis. Besides, it improves transparency and accurate targeting of milestones and project delivery. Hence, the project didn`t benefit from the cost estimation feature of BIM technology.

However, even though it is difficult to put it in quantitative terms, the errors and inconsistencies fixed through BIM practice contributed heavily to reducing cost overrun which is common in most projects. Cloud-based live collaboration feature allows collaboration from wherever network access is available. Yet, since the BIM practice in the project is based on a local server, it requires physical proximity which is associated with cost for mobility, mill, and the like.

CHAPTER FIVE: CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

Understanding the practice and benefits of BIM technology in contexts where their usage and benefits are little known is critical in promoting its usage. The level of benefits gained from the adoption of new technology is dependent on how the technology is practiced. The study investigated the practice and benefits of BIM technology in Ethiopia by taking a case study of a public building in the center of Addis Ababa, Ethiopia.

The study revealed that there is a growing awareness, and ambition/interest to adopt and practice BIM technology. The government's determination to adopt BIM is promising and should be appreciated. The government's commitment towards BIM can be perceived through resources allocated for BIM Studio (FGBCPO, ECC), purchase of licenses software, hardware, and equipment (FGBCPO, ECC, CMI), extensive training delivered by CMI, and adoption of BIM standards and guidelines. Moreover, the issuance of tenders requesting suppliers to use BIM technology and working towards making BIM a mandatory requirement on Federal Government buildings starting in 2017 E.C would motivate private sectors to acquire the technology. The sector is demanding preparedness (technology, human resources, legal framework, culture/behavior). Limited preparedness in terms of technology, Human Resources, Policy, and culture/behavior is perceived which limits the practice. So far, preparedness, especially, from non-state actors including private consultants and contractors is limited.

Hence, the findings of the study revealed that the practice of BIM in Ethiopia is in its infant stage and is slowly growing. Project undertaking efforts with BIM technology are efforts to catch up with the project progress as BIM practice was started late after the structures were constructed. Nonetheless, the model authoring, 3D visualization, and collaborative work environment created by the BIM practice effort as revealed by clash detection reports, and progress reports have helped the progress of the project. Yet, compared with the potential of the technology, the benefits gained from the system are limited and associated with the infancy of the practice.

5.2 Recommendations

The main objective of the study is to learn from the practical experience of BIM practice and benefits in Ethiopia, identify pitfalls stakeholders in the construction industry need to work on, and potentials they can capitalize on. Accordingly, the findings of the study suggest that guiding BIM practice with proper protocols, adopting the technology, installing structures, and developing good behaviors are important if the sector has to claim the advantages of the system.

In line with this, developing agreed-upon protocols to guide roles, decisions, and expectations from different parties, facilitate collaboration, and dictate milestones and deliverables has paramount importance. In line with this, all stakeholders of the construction industry including consultants and suppliers need to be engaged in the process to collaborate and share responsibilities in practicing the technology well and claiming the potential benefits the system provides. Early engagement of stakeholders allows collaboration among stakeholders to ease Co-planning and co-implementation which are vital for project success. Stakeholder engagement may require motivating all stakeholders in the BIM planning and implementation process and providing incentives. Accordingly, supporting private contractors and consultants in enhancing their skills and acquiring the technology is critical to practice BIM.

The government's effort to guide BIM practice with a binding regulatory framework should be appreciated. However, developing standards alone wouldn`t guarantee the proper practice of BIM and its associated benefits. It requires developing consistent guidelines and templates dictating expectations and practices and adopting strict follow-up, accountability and transparency are important. At least, state-led contractors, consultants, and clients practicing BIM can collaborate on BIM practice if it is difficult to engage the private sector at this early stage. To facilitate this, clients need to hire experienced in-house BIM practitioners or external BIM managers who can represent the client or advise the client in its BIM-based project undertakings in conditions they don`t have skilled in-house staff. In such cases, the clients can delegate the responsibility of overseeing BIM planning and implementation to third-party consultants if are unable to assign HR that can act to the level expected as the ISO 19650 dictates. This is crucial in ensuring the benefits of the client in BIM practice and confirming full-fledged practice and benefits.

Besides, efforts need to be exerted to reduce turnover by providing incentives and motivation mechanisms. This would require assigning understanding and passionate leaders who are aware of the industry and technology well. Furthermore, seamless system adoption models, transition plans, and integrated BIM planning and implementation strategies need to be developed by learning from other countries' best experiences. Learning from other countries' experiences with similar contexts would aid the easy transition to BIM technology.

5.3 Future Research

The study revealed that the Ethiopian construction industry is at its early stage of BIM adoption. And, less is known about regulatory frameworks governing BIM practice, role divisions among stakeholders, and the benefits. Moreover, the practice isn`t been legally enforced so far. BIM adoption efforts in private companies are efforts made out of individual interests which creates granularity in BIM planning and implementation. The projects found to be studied are pilot projects whose BIM planning and implementation are started very late and struggling to catch up with the project progress. Moreover, documentation of lessons learned in BIM practice endeavors is minimal to contribute to organizational learning and improvement.

In light of this, It is difficult to capture the full practice and benefits of BIM technology. Hence, studying the practice and benefits of BIM technology in the context of developing countries like Ethiopia once the system engages at least a majority of stakeholders in the industry and more projects practice the system with more understanding, regulatory frameworks, and technology is worthwhile.

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Annexes: Research Instruments

Questionnaire for Data Collection

Questionnaire for Stakeholders with BIM Experience

I. **Project Profile**

1) What do the Project budget, schedule, and scope look like?

2) Which stakeholders are engaged in BIM planning and Implementation and what are their roles?

3) What BIM software, equipment, tools, and technologies did you use in your project?

II. **PRACTICES**

1) Can you discuss your experience with BIM-based cost estimating and budgeting, scheduling, and scoping?

2) How have you planned and implemented the BIM technology?

3) Describe the BIM process you followed from concept to construction.

4) How do you ensure the accuracy and consistency of BIM models?

5) How do you ensure the accuracy and integrity of BIM data when integrating data from external sources or systems?

6) How do you identify and resolve clashes in your BIM models?

7) How do you handle changes and revisions in BIM projects?

8) How do you use visualization to communicate design intent, and how does it help project delivery?

9) Can you discuss your experience with BIM-based energy analysis and simulation?

10) Do you have a BIM coordination meeting? How often?

11) How do you manage BIM coordination meetings, and what are the key outcomes?

12) How do you ensure BIM models comply with project requirements and client expectations?

13) How do you ensure the accuracy of quantity takeoffs and cost estimates derived from BIM models?

14) Can you discuss your experience with BIM-based documentation and reporting?

15) What strategies do you use to manage BIM model revisions and version control?

16) How do you ensure the interoperability of BIM models between different software platforms and disciplines?

17) How do you integrate sustainability principles into BIM projects?

18) How do you stay updated on the latest trends and advancements in BIM technology and practices?

19) Can you discuss your experience with BIM-based sustainability analysis and performance simulation in this project?

20) How do you approach model authoring and management in a multi-disciplinary BIM environment?

III. Project Information

4) How do you manage BIM data and information throughout the project lifecycle?

5) How is an Information container (named persistent set of information retrievable from within a file, system, or application storage hierarchy) used in the project?

6) What does the Information flow in the project look like?

a. 'workflow' – work in progress (WIP) or work approved regarding the status of information

b. 'lifecycle' – work in progress shared, published, or archived

c. a 'shared and single source' of information

7) How is the Common Data Environment (CDE) performance in the project?

a. availability, type, usage, and operation (who and how operated)

b. Cloud-based or server-based

c. Capacity

8) What does Information Management in the project look like?

a. Organizational information requirements (PIR)

b. Asset information requirements (PIR)

c. Project information requirements (PIR)

9) How do you ensure data security and confidentiality when sharing BIM models and project information with external stakeholders?

IV. BIM Execution Plan (BEP)

1) How did you prepare your BIM Execution plan?

a. defines how, why, when, and by whom the information modeling aspects of the contract

2) Which stakeholders are involved in the preparation of your BIM Execution Plan (BEP)?

3) How do you collaborate with other project stakeholders in a BIM environment?

4) What are the challenges and opportunities you have encountered when implementing BIM on projects, and how did you overcome the challenges and use the opportunities?

5) Can you explain the Level of Detail (LOD) used for the preparation of BEP and how it impacts project deliverables?

V. **BIM Standards and Regulations**

1) How do you ensure that BIM models comply with industry standards and regulations?

2) What role do BIM standards and protocols play in BIM implementation?

3) Which BIM standards and protocols did you use in BIM planning and implementation?

VI. Challenges and Opportunities

1) Have you faced an interoperability challenge? How do you address interoperability challenges when integrating BIM models from different disciplines?

2) What strategies do you use to ensure effective communication and collaboration between project stakeholders in a BIM environment?

3) What role does your 4D scheduling play in your BIM projects, and how do you use it to improve project planning and coordination?

4) What strategies do you use to promote BIM adoption and buy-in among project team members and stakeholders?

5) How do you leverage BIM for design coordination and constructability analysis?

VII. BENEFITS

1) What are the key benefits of implementing BIM in construction projects?

2) Can you explain how BIM helped to undertake tasks you can`t do using CAD (Computer-Aided Design) or other conventional approaches?

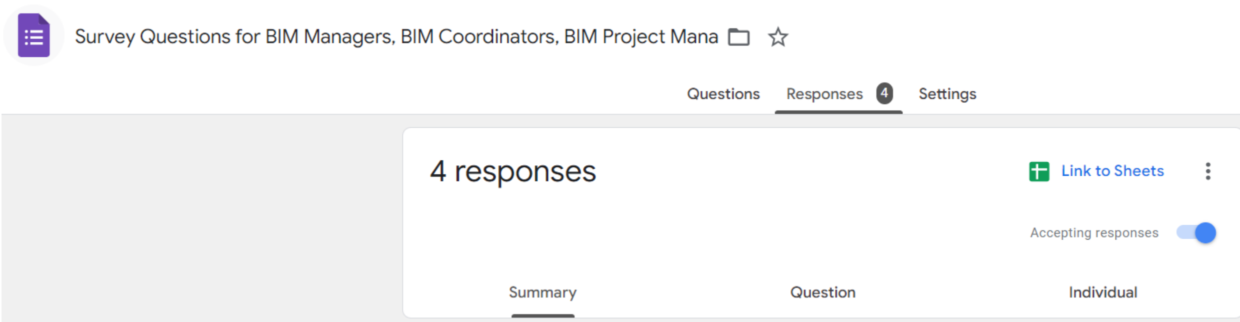
3) How does BIM practice help the project team to get ahead of cost, time, and quality constraints?

4) If any, did energy analysis help in planning energy supply?

5) What role does BIM play in post-construction activities such as facility management and maintenance?

6) What role does BIM play in construction safety planning and risk management?

Journal



1.1. What is your profession? 4 responses

Architect

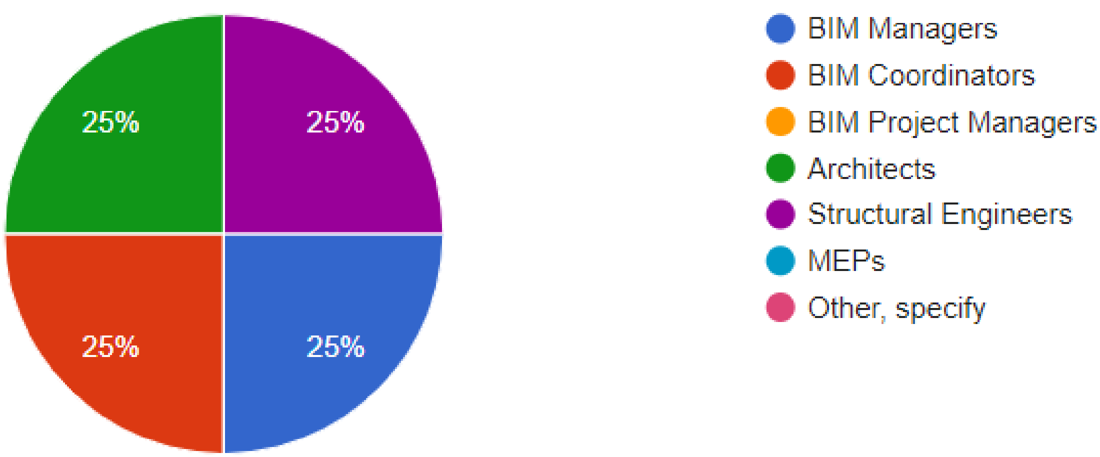
BIM for Structural and PM practitioners and professional instructors

Architect

Civil Engineer

1.2. What was your role in the project?

4 responses



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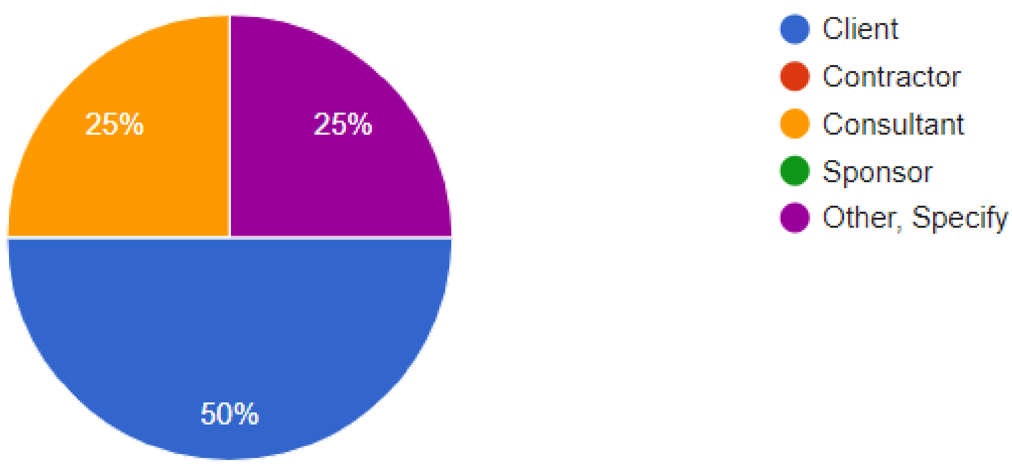
BIM Managers BIM Coordinators BIM Project Managers Architects Structural Engineers MEPs Other, specify25%25%25%25%

BIM Managers	1
BIM Coordinators	1
BIM Project Managers	0
Architects	1
Structural Engineers	1
MEPs	0
Other, specify	0

1.3. Which stakeholder did you represent? 4 responses



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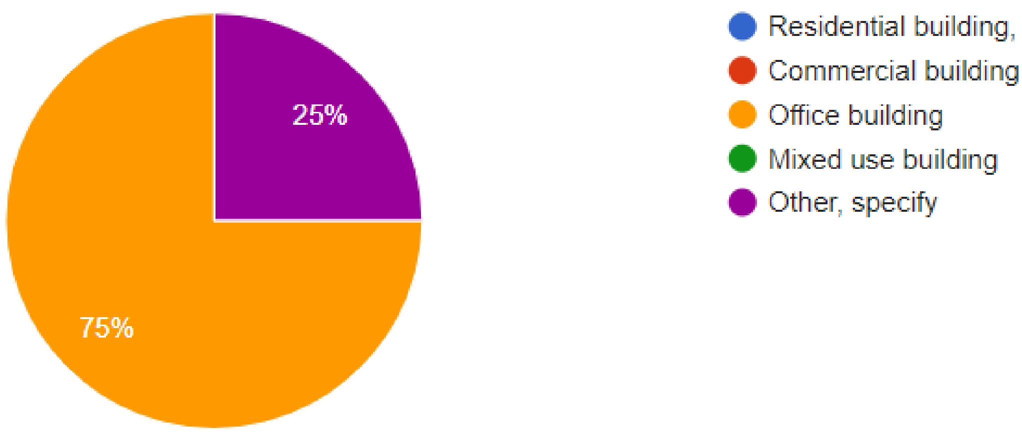
Client Contractor Consultant Sponsor Other, Specify25%25%50%

Client	2
Contractor	0
Consultant	1
Sponsor	0
Other, Specify	1

1.4. In what type of project did you **Practice BIM**?

4 responses



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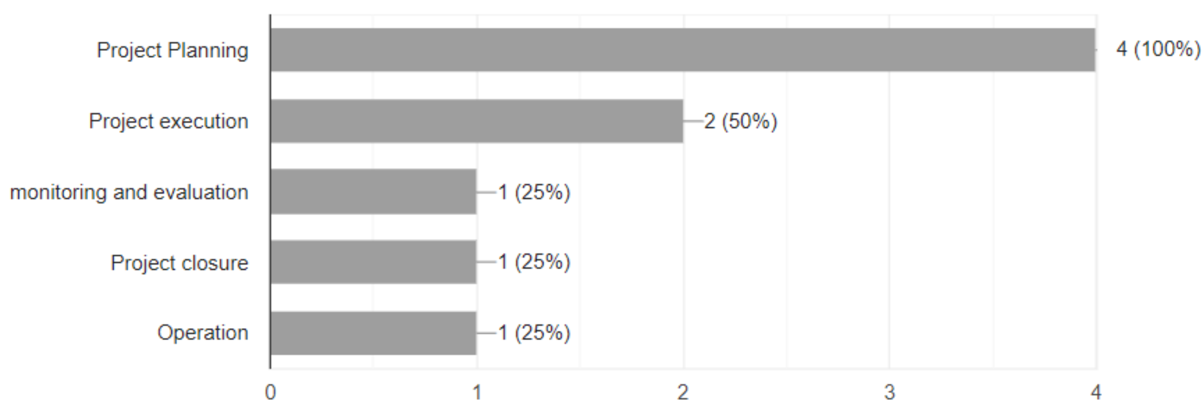
Residential building, Commercial building Office building mixed-use building Other, specify25%75%

Residential building,	0
Commercial building	0
Office building	3
Mixed-use building	0
Other, specify	1

1.5. At what stage did you use BIM?

4 responses



01234Project Planning Project execution monitoring and evaluation Project closure peration4 (100%)4 (100%)2 (50%)2 (50%)1 (25%)1 (25%)1 (25%)1 (25%)1 (25%)1 (25%)

Value	**Count**
Project Planning	4
Project execution	2
monitoring and evaluation	1
Project closure	1
Operation	1

2.1. How much is the project budget?3 responses

Not Real Remember

More than 2 billion birr

More than 1 billion ETB

2.2. How long it takes for the project to be completed since its initiation3 responses

3 month (design phase)

The project completion date on the contract is not now; it is ongoing.

Design and construction are estimated to take 28 months, the project is ongoing.

2.3. Which **stakeholders** are engaged in BIM planning and Implementation and what are **their roles**?

4 responses

All stakeholders

Consultant

Client, consultant, and BIM practitioner professionals

Owners/Clients: Define project goals and requirements.
Architects and Engineers: Design the project using BIM software.
General Contractors and Construction Managers: Plan and coordinate construction activities using BIM.
Subcontractors and Trades: Provide input on constructability and coordinate work.
Facility Managers: Ensure accurate information for facility operations.
BIM Managers and Coordinators: Oversee BIM process and provide support.
Regulatory Authorities and Code Officials: Ensure compliance with building codes.
Software Vendors and Technology Providers: Supply BIM software and support.
Consultants and Advisors: Provide specialized expertise and guidance.
Community and Public Stakeholders: Provide input for large-scale projects.

2.4. What BIM **software, equipment, tools, and technologies** did you use in your project?

4 responses

Autodesk Revit and Autodesk Navicework

ETABS, CAD, MS Project, Revit, Navisworks, etc.

Autodesk AEC suits of software

Revit, Navisworks, robot

3.1. Can you discuss your experience with **BIM-based cost estimating and budgeting, scheduling, and scoping**?

4 responses

I have the best worldwide experience to conduct accurate BIM-based quantification, budgeting, and scheduling.

BIM-based cost estimating involves extracting quantities and costs directly from the 3D model, providing more accurate and detailed cost breakdowns. This helps in budgeting by allowing for better cost control and forecasting. Scheduling in BIM involves creating 4D simulations that integrate time with the 3D model, aiding in project scheduling and sequencing. Scoping with BIM involves defining project scope more precisely based on the detailed model information, reducing scope gaps and change orders during construction.

BIM cost and scheduling estimation are more accurate and and realiable by its nature redundant are not happening

BIM-based Cost Estimating and Budgeting:

Accurate quantity takeoffs and cost analysis.
Visualization of cost implications and scenario analysis.
Improved accuracy and transparency.

BIM-based Scheduling:

4D BIM for time visualization and clash detection.
Resource allocation and integration with project management software.
Progress tracking and reporting.
BIM-based Scoping:

Early design analysis and collaborative scoping.
Scope verification and change management.
Comprehensive scope documentation.

3.2. How have you **planned and implemented** the BIM technology?

3 responses

Actual Pilate project based on international best practice

As per ISO 19650 BIM Standards and guidelines

To ensure the successful implementation of the new technology, the planning phase involved acquiring resources such as high-performance computers, BIM software, and participant training.

3.3. Describe the **BIM process** you followed from concept to construction.

3 responses

As per ISO 19650 BIM Standards and guidelines

It Called BIM Production Modeling start from project briefing - Concept - Defination - Design - Building and Commissioning - Handover and Closeout and finaly Operation and end of life

1, Conceptualization and Pre-Design:

Define Project Goals: Establish project objectives, requirements, and constraints.
Conceptual Design: Develop initial design concepts and feasibility studies.
BIM Setup: Create a BIM execution plan outlining project scope, deliverables, and responsibilities.
2, Design Development:
Architectural Design: Develop detailed architectural plans, elevations, and sections.
Engineering Design: Integrate structural, mechanical, electrical, and plumbing (MEP) systems into the BIM model.
Coordination and Clash Detection: Identify and resolve conflicts between disciplines using clash detection tools.

3, Construction Documentation:
Detailing and Documentation: Produce construction drawings, schedules, and specifications.
Quantity Takeoff: Generate accurate quantity takeoffs for material procurement and cost estimation.
Regulatory Compliance: Ensure designs comply with building codes, regulations, and standards.
4, Construction Planning and Coordination:
4D Scheduling: Integrate BIM with project scheduling software to visualize construction sequences.
Resource Allocation: Allocate resources, labor, and equipment efficiently based on BIM data.
Logistics Planning: Plan site logistics, material deliveries, and construction phasing.
5, Construction Execution:
On-Site Implementation: Execute construction activities according to the planned schedule and sequence.
As-Built Documentation: Update the BIM model with as-built information and deviations from the original design.
Quality Control and Assurance: Ensure construction quality through inspections and adherence to specifications.
6, Facility Management and Operations:
Handover and Commissioning: Transition the completed project to the owner and verify systems functionality.
Asset Management: Utilize BIM data for facility management, maintenance scheduling, and space utilization.
Lifecycle Analysis: Conduct lifecycle analysis to optimize operations, maintenance, and future renovations.

3.4. How did you ensure the **accuracy and consistency** of BIM models?

4 responses

Using visualization, model federation, etc

Due to a lack of time, proper planning, resources, and knowledge, the BIM design process had accuracy and consistency problems throughout the project. This led to delays and many errors.

all team work together as a single entity for a single project at a time through collaboration and interoperability

Standardization and Guidelines: Establishing and adhering to BIM standards and guidelines ensure consistency across models. This includes standardized naming conventions, layering systems, and modeling practices.
Collaborative Workflows: Encouraging collaboration and communication among project stakeholders fosters accuracy and consistency. Regular coordination meetings and interdisciplinary reviews help address conflicts and discrepancies early in the design process.

3.5. How did you ensure the **accuracy and integrity** of BIM data when integrating data from **external sources or systems**?

4 responses

Using collaboration BIM tools

There was no checking and quality assurance system when integrating and BIM elements or information from external sources. There should have been cross-referencing of information with multiple sources, for validation and a clear line of communication.

the BIM Operation system allows all stakeholders access the central data through collaboration and interoperability

Data Standardization: Ensure that data from external sources conform to standardized formats and protocols. Establish clear guidelines for data exchange, including file formats, naming conventions, and metadata requirements.
Interoperability Testing: Conduct interoperability testing to ensure that data exchange processes function correctly between different systems and platforms. Test data transfers under various scenarios to identify potential compatibility issues and resolve them before full-scale integration.

3.6. How do you ensure the interoperability of BIM models between different software platforms and disciplines?

4 responses

allow collaboration on a single project even with project coordinates

Using collaboration BIM tools

We all use the same software.

use Industry Foundation Classes (IFC) and Building SMART Data Models, which facilitate interoperability between different BIM software platforms

3.7. How did you identify and resolve **clashes** in your BIM models?

4 responses

Clash detection tools (software) and dropping one model to the next through the link (from the architectural model to the structural model)

By conducting clash detection analysis between discipline-specific.

We did not conduct cross-discipline clash detentions, but each team (AR, ST, and MEP) did a thorough check for their respective models.

Utilize specialized clash detection software integrated with BIM platforms. These tools automatically analyze BIM models for clashes and conflicts between different building elements, such as structural components, MEP systems, and architectural features.

3.8. How did you **handle changes and revisions** in BIM projects?

4 responses

We can handle such issues without extra time or effort.

With letters and verbal communications and by updating the central model and synchronising each model every time there is a design change or revision.

At the beginning of the project, develop a well-articulated BEP with PIR (BIM execution plan and project information requirements) so that project change will decrease.

Cloud Collaboration Platforms: Tools like Autodesk BIM 360, Revit Cloud Worksharing, or Bentley ProjectWise are used for real-time collaboration and version tracking.

3.9. What strategies did you use to manage BIM model revisions and version control?

2 responses

Centralized data control

In BIM, it is not required as such to have the strategy.

3.10. Can you discuss your experience with BIM-based **energy analysis and simulation**?

2 responses

It has a magnificent impact, but genuine software and cloud systems with localized standards are required.

Simulations based on BIM, like Insight and Autodesk Revit. To reduce the building's reliance on its mechanical system through retrofitting techniques, these instruments were utilized to assess the thermal comfort and energy efficiency of new construction as well as existing buildings.

3.11. How did you integrate sustainability principles into BIM projects?

2 responses

Sustainable principles are obtained to modernize the utilization of materials, power sanitary systems, etc.

Through the integration of data, processes, and stakeholders across the project lifecycle, building information modeling (BIM) has become an indispensable tool for accomplishing sustainable construction goals.

3.12. Can you discuss your experience with BIM-based sustainability analysis and performance simulation in this project?

3 responses

as my experience focused on the Pilate project, the findings were quite different than the traditional way

Please see 3.11

We did not do any kind of sustainability analysis and performance simulation in the BIM software, we used alternative systems for that.

3.13. Did you have a **BIM coordination meeting**? How often?

3 responses

Yes every morning and as required

Yes, daily and weekly.

No

3.14. How did you manage BIM coordination meetings, and what are the key outcomes?

3 responses

Defining project coordinate system, the definition of design project for each professional, collaboration method, central data environment, design approval system, process, etc.

Using the findings of the clash detection analysis

-

3.15. How did you ensure BIM models comply with project requirements and client expectations?

2 responses

Referring to BEP

Using EIR, please review all ISO 1950 BIM Standards and Guidelines.

3.16. How did you ensure the accuracy of quantity takeoffs and cost estimates derived from BIM models?

3 responses

BIM has the highest level of cost and quantity accuracy because dependent items and clashes are detected and managed beforehand.

Please review all ISO 1950 BIM Standards and Guidelines.

The design team leader and QA team do this check

3.17. Can you discuss your experience with BIM-based documentation and reporting?

3 responses

Documentation in the context of Building Information Modeling (BIM) is the production, administration, and distribution of digital data pertaining to the planning, execution, and maintenance of an infrastructure project or building.

This is mainly covered in the convesional design (consulnacy) contractual agreement; there is no specific IM-based documentation or reporting.

BIM delivery and documentation are the final steps after the team agreed to hand over the development to the project BIM manager (client representative) for final approval and utilization

3.18. How do you stay updated on the latest trends and advancements in BIM technology and practices?

3 responses

Globalization ----

By attending webinars and conferences regularly.

It may seem silly but YouTube.

4.1. How did you approach model authoring and management in a multi-disciplinary BIM environment?

3 responses

Collaboration and interoperable at the early project definition level

Please refer to ISO 19650 BIM standards and guidelines

BIM coordinators and managers assign each team member a specific task to do, so there won't be any task overlap if any team members communicate to resolve model ownership and authorization issues verbally.

4.2. How do you **manage BIM data and information** throughout the project lifecycle? 3 responses

Please refer ISO 19650 BIM standards and guidelines

According to the deliverables and agreement of the contract document

BIM is by its nature a data-centered working method; information is created with the physical model at an early stage, and then the data and information remain with the model throughout the project's life.

4.3. How is an **Information container** (named persistent set of information retrievable from within a file, system, or application storage hierarchy) used in the project?

3 responses

***

Please refer to ISO 19650 BIM standards and guidelines

We used a modified version of BS EN ISO 19650-1:2018

4.4. What does the **Information flow** in the project look like? (work in progress, shared, published, and archived)

2 responses

Please refer ISO 19650 BIM standards and guidelines

Project Folder: Under this folder, WIP (work in progress), Share, Publish, and Archive folders can be created, which means the WIP folder means the team-working active file, the Share folder means the project file shared within the BIM team, and the Published folder means the document shared with project BIM managers and files under implementation with approval. The final folder archive means the project design and as-built drawing files that serve throughout the project life cycles.

4.5. Can you explain the availability, type (Cloud-based or server-based), usage, capacity and operation (who and how operated) of your **Common Data Environment (CDE)** performance in the project?

3 responses

Please refer ISO 19650 BIM standards and guidelines

We used LAN based system, each team member has a specific read-only, read-write, and write-only parts of the CDE set for them by the IT department and BIM manager.

CDE is a normal file folder accessed by interested stakeholders. We can call CDE simply a published folder on our computer; however, the colud system allows us to access our data at any time, and currently, cloud systems supplied by many BIM tool suppliers and even in our own country, Ethiopian telecom, supply such facilities.

4.6. Explain your experience of **Information Management** in the project including Organizational information requirements (PIR), Asset information requirements (PIR), Project information requirements (PIR), and Exchange Information Requirements (EIR).

4 responses

These are all BIM standards.

no experience

OIR: information that states the organization requirement, the purpose and the process and the how,
AIR: is the process of stating the asset's under build infrastructure-requirement.
PIR: that is the inpute, the process, the out comes and the beneffite of the project
EIR: Level of detail, level of requirements, stage of data sharing, Project brief, Objectives, Client aspirations, Required data drops, Agreed Common Data Environment (CDE) and its management, Information Manager and responsibilities and BIM Execution Plan requirements and etc.

OIR refers to the information an organization needs to support its strategic objectives and business operations. These requirements guide the information management practices across all projects within the organization.
AIR details the information needed about the assets owned and operated by an organization. This includes data required to manage and maintain the asset throughout its lifecycle, from design and construction to operation and eventual decommissioning.
PIR encompasses the information needed to manage and deliver a specific project. This includes data required by the project team to ensure that the project meets its goals in terms of scope, time, cost, and quality.
EIR defines the information that needs to be exchanged between different parties at specific points in the project lifecycle. These requirements ensure that all stakeholders receive the necessary information in the appropriate format and at the right time.

4.7. How do you ensure data security and confidentiality when sharing BIM models and project information with external stakeholders?

3 responses

CDE method

Using ISO 19650 BIM standards

There is no robust security system, but we used access control for each user, and the BIM software had its backup system for WIP files. We did not do much.

5.1. How did you prepare your **BIM Execution plan**?

4 responses

As per EIR

Unfortunately, there was confusion on who was supposed to prepare the BIMExp, and all other prerequisite documents, such as the AIR and PIR, were not present.

BEP are prepared in various stage and detailed through the project (Pre-contract BEP, Post-contract BEP, BEP Checklist, BIM Kick-Off Meeting and BIM Execution Reviews)
The following are the minimum contents of the BEP: Overview, Project Information, Key contacts, Project scope and BIM-related Goals Organizational roles and staffing, BIM process design, BIM information exchanges, BIM and FM data requirements, Collaboration procedures, Model QA procedures, Technology infrastructure requirements, Model structure, Project deliverables, Delivery strategy and contracts and etc.

1, Identify Key Objectives
2, Identify Stakeholders
3, Assign Roles and Responsibilities
4, Define Key Processes

5.2. What are the motivations for preparing the **BIM Execution plan**? 3 responses

Ultimately, Leading the project within requirements and achieving those requirements without substituting.

In responding to the EIR

The project information requirement is a prerequisite for the BIM execution plan.

5.3. Which stakeholders are involved in the preparation of your **BIM Execution Plan (BEP)**? What were their roles? 2 responses

Client or Consultant (simply, we can call it ToR with traditional working methods)

The BEP is developed by the BIM manager in collaboration with all stakeholders involved in the project, including consultants, contractors, and building owners, and it must align with the project's objectives.

5.4. How did you **collaborate with other project stakeholders** in a BIM Execution Plan preparation? 2 responses

Using a cloud-based

None

5.5. Can you explain the **Level of Detail (LOD)** used for the preparation of BEP and how it impacts project deliverables? 3 responses

Please refer ISO 19650 BIM standards

BEP is used to specify

LOD is the process of creating a model with simple futures and developing and increasing the level of detail and complexity of the final delivery, e.g..
at Briefing level, there is no modeling or minimal physical modeling
at Concept-level physical modeling with a minimal level of detail
at Design level Pysical modeling with information having moderate level of detail and all team working together in a single model
at Design level, every physical model has considerable amount of information and detailing,
at Handover level, every physical model represent the actual real model and information has highly complex detail

6.1. How do you ensure that **BIM models comply with industry** standards and regulations? 2 responses

In our country, it is at its early stage and premature level.

Please refer to all BIM standards, which were developed by CMI in collaboration with an Ethiopian standard agency.

6.2. What role did BIM standards and protocols play in BIM implementation? 2 responses

Without BIM Standard and BIM Protocol, there will be no implementation of BIM working system

Please refer 6.1

6.3. Which BIM standards and protocols did you use in BIM planning and implementation? 2 responses

NBS, NATSPEC, EBIM Standard, BS etc.

Please refer 6.1

7.1. What are the **challenges and opportunities** you have encountered when implementing BIM on projects, and how did you overcome the challenges and use the opportunities? 2 responses

Challenges, Absence of localized and well-articulated Standards and protocols, New and change-oriented, Based On expert commitment level, Genuen computers and software Cloud documentation Opportunities Engage every stakeholder, Enhance early Contractor involvement, minimize human mistakes, Clash detects accurate quantity, scheduling, and changes.

Change resistance, initial investment, legal framework, lack of commitment, etc.

7.2. Have you faced an interoperability challenge? How have you addressed interoperability challenges when integrating BIM models from different disciplines? 2 responses

Yes, the interoperable process is the full implementation level of the BIM working process, which is the 3rd level, but currently, most of our country and most of the world-wide country are trying to implement the 2nd level of the BIM working process.

No

7.3. What strategies did you use to ensure effective communication and collaboration between project stakeholders in a BIM environment?

2 responses

Checklist, meeting, etc.

By setting BIM goals, selecting the appropriate software, creating standards and processes, training the team about BIM, and creating BIM project workflows are all essential components of the ideal BIM adoption plan for project team members and stakeholders.

7.4. What strategies do you use to promote BIM adoption and buy-in among project team members and stakeholders?

3 responses

Mobilization of genuine software, development of standards

Please see 7.3

Contractual Obligations

8.1. How did you use **visualization** to communicate design intent, and how does it help project delivery?

2 responses

Visualization n with 3D and walk-through animation

All other BIM elements were only used by each team member as a tool for design discussion; visualizations were only used for aesthetically pleasing building representations. Sadly, no BIM 3D model was used during meetings, presentations, or conversations with stakeholders, which made it more difficult to communicate effectively and comprehend the project.

8.2. What role did your BIM-based 4D scheduling play in your BIM projects, and how did you use it to improve project planning and coordination?

3 responses

Identifying problems that may not be visible via normal schedules, using Run scenarios, assessing the feasibility of execution, and finding the best solutions. Studying how the execution process will appear at different project stages, etc.

Our project did not reach this stage.

Enhancing project planning and coordination by integrating the three-dimensional model with the project schedule

8.3. How do you leverage BIM for design coordination and constructability analysis?

2 responses

Through the integration of information interchange, the primary function of BIM is to enhance collaboration and communication among diverse individuals and construction phases. When used effectively, the BIM process can enhance project information delivery and lower additional costs brought on by design modifications made during later stages of construction.

BIM leverages design coordination by integrating detailed 3D models from various disciplines, allowing for clash detection and resolution before construction begins. It enhances constructability analysis by simulating construction sequences, identifying potential issues, and optimizing workflows.

8.4. What are the key benefits of implementing BIM in construction projects?

3 responses

The implementation of BIM in construction projects has many advantages, including the capacity to expedite procedures, combine data for real-time collaboration, offer prompt updates, result in significant cost savings, increase productivity, and extend project success.

This is a very open ended question with lots of posiable answers but the key benefits of implementing BIM in construction projects include improved collaboration, enhanced visualization, clash detection, better project coordination, accurate cost estimation, efficient scheduling, and streamlined facility management.

Enhanced Design Quality
Accurate Cost Estimation
Increased Efficiency and Productivity
Improved Collaboration and Communication

8.5. Can you explain how BIM helped to undertake tasks you can`t do using CAD (Computer-Aided Design) or other conventional approaches?

3 responses

BIM is not designed to model a 2D model; it is a 3D parametric and digital model.
BIM software enables multiple team members to work on the same model simultaneously, enhancing collaboration and ensuring consistency. Unlike CAD, it integrates 3D models with detailed data, allowing for real-time updates, clash detection, and comprehensive project analysis.
Integrated Project Data and Management 3D Visualization and Model Coordination 4D Scheduling (Time) 5D Cost Estimation (Cost)

8.6. How does BIM practice help the project team to get ahead of cost, time, and quality constraints?

3 responses

There are three main objectives to complete a project successfully which are within time (schedule), within budget, and according to requirements. Every stakeholder such as engineers, architects, and construction professionals has found using BIM processes to be an effective strategy for minimizing risks that can impact the budget and completion timeline of building projects.
It helps the project team manage cost, time, and quality constraints by improving coordination, enabling precise planning, and reducing errors. It facilitates better resource management, and accurate scheduling, and enhances overall project efficiency.

-Detailed Quantity Takeoffs: BIM automatically generates detailed and accurate quantity takeoffs from the 3D model, reducing manual errors and ensuring precise cost estimates. -Real-Time Cost Updates: Any changes made to the design are immediately reflected in the cost estimates, allowing for real-time budget adjustments and better cost control. -3D Visualization: Provides a clear and detailed 3D representation of the project, making it easier to identify and address design issues early.

8.7. What role does BIM play in post-construction activities such as facility management and maintenance? 2 responses

BIM models play a crucial role in facilities management. They provide a clear understanding of the physical characteristics of a building, such as its size, shape, and spatial relationships, which are essential for facilities management activities such as maintenance, repair, and renovation. These models can streamline building management throughout its lifecycle and provide facility managers with real-time information about the building and its systems.

BIM supports post-construction activities by providing a comprehensive digital model of the building, which aids in facility management and maintenance. It offers accurate as-built information, streamlines maintenance tasks, and helps in tracking and simulating building performance over time.

8.8. What role does BIM play in construction safety planning and risk management? 2 responses

The capacity of BIM to recognize possible safety risks before the start of building is one of its main functions. Safety-specific data, such as details regarding building supplies, tools, and access points, can be added to BIM models.

BIM enhances construction safety by providing detailed 3D models for hazard identification, enabling clash detection, simulating safety scenarios, and improving communication. It also ensures compliance with safety standards and aids in worker training.