Addis College

School Of Graduate Studies

Department of Construction Technology and Management

The Effect of BIM based Construction Digitalization Implementation on Productivity & Profitability of Construction Companies in Addis Ababa

By

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DECLARATION

I certify that this research work titled "**The Effect of BIM based Construction Digitalization Implementation on Productivity & Profitability of Construction Companies in Addis Ababa**" is my own work. The work has not been presented elsewhere for assessment. Where material has been used from other sources, it has been properly acknowledged/referred.

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Hanna Abayneh Alto | GSR/076/201

ENDORSEMENT

This is to certify that Hanna Abayneh Alto has conducted this thesis work entitled "**The Effect of BIM based Construction Digitalization Implementation on Productivity & Profitability of Construction Companies in Addis Ababa**" is under my supervision. This thesis work is original and suitable for the submission in partial fulfilment of the requirement for the award of Masters of Science Degree in Construction Technology and Management.

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ABSTRACT

In the construction sector, there are still significant challenges with a major negative impact on the project's productivity and profitability. Construction digitalization uses digital tools to manage, deliver, and operate projects, addressing challenges like unfulfilled client requirements, delays, cost overruns, quality issues, stakeholder conflicts, safety concerns, change order requests, material waste, and project complexity. Building Information Modeling (BIM) is a promising digitalization approach in the construction industry, used for planning, designing, constructing, and managing projects throughout their life cycle. This research was conducted on the effect of BIM based construction digitalization implementation on productivity & profitability of construction. ***.*** *The objective of the study was to explore the effect of construction digitalization on productivity & profitability. To achieve the above objectives the research design employed a questioner survey and Interview. Explanatory research and Purposive sampling method were used in this research to hit expected outcome. Various related literature was reviewed and several web sites were searched. The collected data was analysed by calculating frequency, relative importance index (RII) and by using SPSS software. The findings are analysed and presented by chart and table. The major finding of this research is that there is a low degree of BIM-based construction digitalization adoption. Despite the benefits, there are numerous high-level challenges that contribute to poor BIM readiness and implementation levels. Besides that, the research also indicated that BIM-based construction digitalization has a high effect on productivity and profitability. Therefore, all stakeholders in the construction industry are to take responsibility for adopting new innovations in order for the industry to remain competitive both internationally and nationally. The government have to develop and enact legislation and policy framework that clearly define the government's commitment to BIM implementation in construction projects.*

Key words: - Construction digitalization, BIM (Building information modelling), Building construction projects, Productivity, Profitability, Drivers, Benefits, Barriers

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LIST OF ABBREVIATION

BIM	Building Information Modeling
EC	European Commission
2D	Two dimension
3D	Three dimension
4D	Four dimension
5D	Five dimension
6D	Six dimension
7D	Seven dimension
ICT	Information communication technology
AI	Artificial intelligence
ICSIC	International Conference on Smart Infrastructure and Construction
PMBOK	Project management body of knowledge
IT	Information technology
DIHK	Deutscher Industrie- und Handelskammertag,
ROI	Return on investment
FM	Facility Management
LSE	London School of Economics
UK	United Kingdom
USD	United States dollar
CSCW	Computer Supported Collaborative Working
GIS	Geographic information systems
CAD	Computer-aided design
KPI	Key performance indicator
CDE	Common Data Environment
EIR	Employer’s Information Requirement
BEP	BIM Execution Plan
QTO	Quantity take-off
VR	Virtual reality
ECPMI	Ethiopian construction project management institute
SPSS	Statistical Package for the Social Sciences
RII	Relative Importance Index

CHAPTER 1

1. Introduction

This chapter provides background on the study in which previous studies state about construction digitalization and its gap, which explains the area of the research to set context for the problem at hand and how BIM-based construction digitalization affects that led to the research questions and aims of the study.

1.1 Background of the study

The construction industry is a significant contributor to the socio-economic development of any country. Nevertheless, owing to the complexity of the construction industry, it faces several challenges such as low productivity, poor quality, rising cost, construction waste, delays, and lack of information sharing among project stakeholders. (Eze et al., 2022)

In the construction sector, there are still significant challenges with a major negative impact on the project's productivity and performance. 69% of home owners report that contractor's performance is the main reason for poor project performance. Repetition is now a given. It is estimated that about 30% of the construction work is repetitive work. Labour shortages are a major issue for the industry. 80% of construction companies cannot find the people they need. 34% of industry professionals report that the main reason for poor data and information derives from incorrect project data. In terms of productivity, the industry has only seen a 1% increase in the last 20 years. Finally, 93% of industry professionals report only a basic level of confidence in construction as an industry, and only 37% report high levels of confidence (*How BIM & digitalization is transforming construction*. (2020, December 15)).

In the last few decades, digitalization has transformed many sectors of the economy, including construction. The adoption of new technologies and digital tools has revolutionized the way construction projects are planned, designed, built and managed. (Attencia & Mattos, 2022)

Construction is undoubtably a tough market in which it is particularly difficult to maintain competitiveness. In light of this, digital transformation is now top of the agenda for many construction firms. The benefits of digitization have been championed across industries to the extent that we now see most businesses implementing construction software at some level. (Larsson & Teigland, 2019)

The process of digital transformation involves the integration of digital tools to optimize processes and make them more efficient. It has been proven to create significant value for construction firms, with a swift ROI and increase in productivity. (Picazo Rodríguez et al., 2023)

Digital construction is using digital technology to improve how a construction project is operated on, managed, and delivered. In other words, this involves using digital tools across the management, delivery, and operation of construction projects to bring about more collaborative and efficient ways of working. (Attencia & Mattos, 2022)

Building Information Modelling (BIM) is today one of the most promising approaches to achieve digitalization in the construction industry over the complete building life cycle. Meanwhile most of the projects in research, industry or public authorities focus on the planning or construction phase, the practical usage of BIM in operational phase within Facility Management (FM) is still rare. BIM as the leading technology in modern construction works by means of software that represents a digital twin of a real building. (Williams et al., 2019)

BIM is utilized extensively in the construction industry as a collaborative digital tool for planning, designing, constructing, and managing building projects. Valuable information about various elements of a construction project is enabled through BIM and might include geometry, spatial relationships, material quantities, or schedules. Stakeholders such as architects, engineers, contractors, and owners use BIM to work together more efficiently, saving time, reducing errors, and optimizing project outputs. (Innovation, 2007)

BIM plays an important role in transforming the industry, but BIM alone is not enough to make a huge impact. BIM is linked to other examples in the industry, such as integrated project delivery, which is a process that optimizes the industry, strengthens the owner, and increases productivity. BIM is also linked to off-site construction, by reducing costs and increasing the quality of projects. Lean construction is a construction method that minimizes waste in the project life cycle. BIM is also associated with smart cities and sustainability. (Mordue et al., 2015)

This paper examines the effect of BIM-based construction digitalization implementation on productivity and profitability in construction, which includes the status of construction digitalization adoption, digitalization benefits, and the common barriers to the adoption of construction digitalization, specifically BIM, in the Ethiopian construction industry, focusing on grade one contractor and consultant companies, as a basis for developing a framework for effective implementation of construction digitalization in the Ethiopian construction industry.

1.2 Statement of the problem

The construction industry is among the least digitized industries, and the lack of innovation in construction project management practices has led to decreases in productivity. The slow adoption rate has been linked to the perceptions of the effectiveness of construction innovations. An implied link exists between digitalisation and productivity improvements. However, such a link is yet associated with ambiguities, suggesting that the influence is not linear. Despite the very low productivity rates achieved in the construction industry, studies on the association between technology adoption and productivity-related benefits and advantages are rare, and this may be a contributing factor to the indecision of construction firms to embrace digitalisation.

The construction industry, traditionally reliant on manual processes and fragmented workflows, is undergoing a transformation through digitalization. While digital technologies offer promising advancements, the effects of this shift on productivity and profitability within the construction sector remain multifaceted and complex. Projects vary significantly, and because of that, companies often struggle to implement new methods that can be used repeatedly. Limited budgets on digital technological implementation and the remote nature of some construction projects result in many E&C companies failing to invest in technologies.

The goal of this study is addressing these issues for the construction industry to leverage digitalization effectively and maximize its potential to significantly enhance productivity, streamline operations, improve project outcomes, and remain competitive in an evolving global landscape.

This research will try to explore the effect of BIM based construction digitalization implementation on productivity & profitability in Ethiopia's construction industry in Addis Ababa in the case of grade one contractors and consultants.

1.3 Research Question

1) How do construction stakeholders perceive the existing digitalization measures in terms of their adaptability to changing needs, capacity to handle project demands, and overall preparedness for digital transformation?
2) What factors influence the decision-making process for adopting digitalization in construction projects?
3) How does the integration of digital tools impact productivity and profitability in construction projects, and what are the quantifiable effects observed?
4) What are the primary barriers or challenges hindering the widespread adoption of digitalization in the construction industry?

1.4 Objective of the Study

In this section, the general objective as well as the specific objectives of the study will be clearly stated. The study objectives are presented as follows:

1.4.1 General Objective of the Study

To comprehensively investigate and explore the effect of Building Information Modeling (BIM) implementation in the construction industry, focusing on its influence on the productivity and profitability of construction companies in Addis Ababa (The case of Grade I contractors and consultants).

1.4.2 Specific Objectives of the Study

- To Assess the existing level of construction digitalization Implementation (Adaptability, Capacity & preparedness)
- To explore determinants for construction digitalization adoption on a construction project.
- To examine the role, benefits & effects of Construction digitalization on productivity & profitability.
- To find the barriers hindering the adoption of construction digitalization.

1.5 Significance of the Study

The introduction of construction digitalization technology to the construction industry would have positive impact on productivity, cost, time, and quality. Public projects would bring about environmental responsiveness, customer satisfaction and better city image. Design and construction professionals and companies in Ethiopia working in the traditional fragmented approach are also the benefit groups.

This study used to asses an alternative technique in design build and managing construction for stake holders. Construction digitalization mainly BIM will improve the quality and also improve construction industry by enhancing project management.

The construction industry in Ethiopia faces many challenges some of the problems Productivity, time and cost overrun. The study also tries to show how to minimize the common problems of our local contractor by assessing adoption of construction digitalization. This research could have policy impact on the way public projects are approached and designed. Academically this paper can be used as to professionals and other individuals whom in the future may establish too deeply conduct further researches related to the topic.

1.6 Scope of the Study

The main scope of the study is to assess the effect of BIM based construction digitalization implementation on Productivity & profitability of Ethiopian construction industry. The scope of the research involves in identifying the factors that leads to construction digitalization implementation, the expected barriers to implement construction digitalization in Ethiopian construction industry, the BIM maturity level of our construction industry and tries to identify the role of digitalization in the process of improving productivity and increase profitability. This study is limited to Addis Ababa where building contractor and consultants are resided. It is also limited to grade one building contractors and consultants; this is because of the financial capacity to implement construction digitalization and their organizational structure is full of professional.

CHAPTER 2

2. Literature review

This chapter provides a literature review which allow to gain familiarity with the current knowledge in BIM based construction digitalization, as well as the boundaries and limitations of the knowledge area. This chapter also helps to gain an understanding of the theories driving the construction digitalization, allowing to place the research question into context.

2.1 Introduction

Digitization in the construction industry is multi-faceted: it involves digital tools, process automation and digital project communication. Thanks to the wave of digitization, the immense volumes of data from construction processes are now also being efficiently organized and structured via cloud computing (*Digitization of the Construction Industry: Digital Transformation Takes Hold*, 2023b).

But these developments are not just about collecting, providing and processing digital data. Social networks, for example, play an equally central role, as all industrial sectors now communicate their activities transparently and digitally. Thus, the digitization of the construction industry defines universal processes on the Internet, ranging from planning and execution to documentation and communication. Today, time- and location-independent communication channels and digital infrastructures are therefore also indispensable in the construction industry (*Digitization of the Construction Industry: Digital Transformation Takes Hold*, 2023b).

Digital technologies and their integration in the construction sector are often viewed as a key element that can help tackle some of the aforementioned challenges. However, the construction sector is one of the least digitalised sectors in the economy. With the exception of Building Information Modelling (BIM), few digital technologies have been widely adopted. Yet, as recently highlighted in a European Commission (EC) report, the digitalisation of the construction sector goes beyond the sole use of BIM and includes data acquisition, automating processes and other digital information and analysis related technologies. (Chertkov, 2022)

2.2 How is digital construction changing the construction industry?

2.2.1 Safety

Tragedies like the Grenfell Tower have caused the whole industry to think more carefully about safety in construction. This combined with the rate of accidents that occur regularly on construction sites in the UK has created a place for digital construction.

This technology works to bring greater transparency and accountability on-site to help promote safer practices across the entire construction workflow (Stewart, 2023)

2.2.2 Productivity

Productivity in construction is lagging behind the total economy. In a survey, 70% of contractors agreed that utilising advanced technologies helped them enhance productivity, while a study by McKinsey revealed that adopting digital technology was one of the key drivers that would help construction significantly improve their overall productivity.

By improving the efficiency of on-site workflows digital technology is helping to bring the construction industry to speed (Stewart, 2023)

2.2.3 Profits

One of the underrated benefits of digital construction is that it helps to reduce costs on projects by capturing inefficiencies and streamlining processes. In fact, it's estimated that digital technology can help reduce project costs by up to 45% - something that's increasingly important in an industry where low margins have become the norm (Stewart, 2023)

2.3 Why haven't construction companies readily adopted new digital technologies?

Companies often fail to meet their expectations because of unclear definitions on the meaning of digital, poor integration of digital technologies and lack of sustainable improvements. (Zhang et al., 2023)

Digital transformation is especially hard in the construction industry for the following reasons:

2.3.1 Lack of replication

You've heard of the adage "No construction project is the same".

Even if two buildings were to be designed and constructed to be identical in every imaginable way, they'll be unique and one of kind in some way.

Consequently, it necessitates unique approaches that are rarely replicated. For that reason, it's more challenging to introduce unique changes through multiple projects.

Full digital transformation requires changes through multiples small scale projects. It's perhaps possible to introduce replicable changes across major projects. (Zhang et al., 2023)

2.3.2 Decentralisation

Because large engineering and construction projects are funded by federal agencies and smaller units within the project following their own processes, it means projects are largely decentralised.

Furthermore, most individual projects are situated quite far from the offices that use technologies. It's also a challenge to train workers on novel ways to use advanced digital technologies. (Zhang et al., 2023)

2.3.3 Constant change

The transient nature of construction projects means almost every project will involve a new projects teams or new organizations working together. The problem is even more pronounced among contractors who experience high workforce turnover. At both the construction and operational/ company level, contractors, subcontractors, consultant, and sub consultants face difficulties in creating alternate ways of working that will continuously build from one project and carry over to future projects. (Zhang et al., 2023)

2.3.4 Fragmentation

Construction projects have entities divided up between specialists from various disciplines. The challenge then is one of collaborating effectively with digital technologies among all or at least most project parties.

Coordination is not only required among subcontractors and subconsultants, but also among organisations.

One example is the ICE publication 'International Conference on Smart Infrastructure and Construction 2019 (ICSIC): Driving data-informed decision-making' by MJ DeJong.

This covers smart infrastructure, construction, information on cities, structures, geotechnical capabilities and digital solutions. With the rapidly changing civil engineering construction and design sector, we need to educate ourselves on the area of digitisation and implement technologies that will drive the industry further ahead.

Civil engineering and construction companies have lagged in successfully implementing digital technologies to multiple projects, due to the constantly changing nature of projects, the fragmentation of tasks into specialised disciplines and decentralisation.

By thoughtfully approaching the problem of digital transformation, companies will improve their chances of reaping the benefits of digital technologies. Our focus should be on improving software productivity and promoting digital platforms that promote collaboration between multiple disciplines working on a project. Also, companies can focus on training engineering teams to focus more on iterative design skills.

This can be aided by focusing on products that automate certain design stages and allowing engineers to focus on more challenging design tasks. However, digitization projects in the construction industry also harbour challenges as well as promising opportunities. (Zhang et al., 2023)

2.3.5 Strong digital leadership needed

This is evidence that engineering, and construction companies are successfully overcoming challenges digitally. To continue the successful trend, companies must continuously train engineering teams in applicable digital skills, use technology that promotes collaboration, connect projects that maximise impact, and focus digital technologies on fixing problems.

The success of the digital transformation warrants strong leadership from managers and executives. They must have a clear perspective on how to create value for not only their business, but also the construction projects.

Furthermore, they must have a clear understanding on how social value will be increased using digital technologies.

For example, in the case of a construction project, say a new highway, how will the use of digital technologies create designs that improve road safety for drivers?

It starts from the time spent on operational change. An operational change will ensure that work is done in a way that increases productivity. (Zhang et al., 2023)

2.4 How to use BIM to drive productivity and profitability in construction projects?

The rapid adoption of BIM in the construction industry comes as no surprise due to the precision it offers the stakeholders. Apart from precise information, technology also brings several other benefits to the table. It makes it easy to plan, design and construct buildings using 3D, 4D, and 5D technical drawings. There are also other benefits, including real-time updates, collaboration in the cloud, effective visualization, and so on. (LetsBuild (2023a)

But the main benefit lies in the fact that it saves time and money for construction projects. So, how is BIM used by construction firms to drive productivity and profitability in different construction projects? (LetsBuild (2023a)

2.4.1 Use of BIM to enhance productivity in construction.

Every successful project is based on two key pillars communication and collaboration. This is true for small-scale as well as large-scale projects. This is especially true of construction where so many different teams have different tasks to accomplish. (LetsBuild (2023a)

One of the main cause of delays in construction is a lack of communication between these teams. Given the dynamic environment, certain changes must be made on the spot. Situations such as a change in the materials or a specific part of the project may call for some quick decisions to be made. Those changes then need to be conveyed to everyone impacted by it. Unless done efficiently, this can lead to delays, wasted efforts, time loss, and rework. (LetsBuild (2023a)

BIM can be used to bring better coordination between teams and reduce errors that can occur due to miscommunication. Each of the professionals working on the construction project can get instant updates on their devices as BIM models can be updated regularly to reflect changes. This instant relay of information allows the on-site managers to execute the changes, plan for their responses, and drive modifications in the plans of individual teams faster and more efficiently. (LetsBuild (2023a)

BIM can also be used to increase the productivity of the construction projects by neatly organizing all the aspect of the project onto a single platform. This can be viewed by all construction personnel and project managers. This common platform makes it easy to spot possible areas of conflict. For instance, the power utilities and the plumbing may have been planned for the same place. If all the relevant teams have access to the plan beforehand it becomes easy to avoid clashes. Changes can be made to the plans before the work gets done. This helps prevent costly and time-consuming rework. (LetsBuild (2023a)

BIM also helps create a unified reference source of information. For instance, the Active Document part of the program can be used to store and update all the necessary documents related to the project. This can then become the single source of truth for the entire project. This single reference source helps project teams work faster since they spend less time looking for information and more time working on it. (LetsBuild (2023a)

It is often difficult to capture all the information on construction sites on an ongoing basis. From aerial images to laser scans of the infrastructure, many techniques are employed to capture the information accurately. But what next? How is this information to be presented to the stakeholders? This is where construction firms are using BIM to compile and present all the inputs accurately in a simple, intuitive, easily understandable model. The model offers the teams an updated version of the construction site in its “as-built” state. This offers a realistic basis for the teams to base their future plans on. (LetsBuild (2023a)

This one unique model also reduces duplication and rework of the drawings. Moreover, the drawing tools used in BIM are faster than the 2D drawing tools, with each object connected to a database. Also, the documents created are more accurate. It is this quick digitalization, which can save a significant amount of labor costs and overall time. (LetsBuild (2023a)

Another innovative application of BIM is in training project personnel and resources. For instance, BIM models can help new recruits get familiar with the ongoing construction quickly. They can see the overall plan, the constituent elements, the time-based schedules, and the immediate tasks. Therefore, this can act as a handy guide for rookies and bring them up-to-speed and make them productive faster. (LetsBuild (2023a)

2.4.2 Use of BIM to increase profitability

BIM can be used for accurate estimations of material requirements. Construction teams can order material quantities appropriately and can also time their orders much better by relying on the insights gained from the BIM models. This helps optimize the order values and reduce mistakes of over or under-ordering. It also helps reduce storage costs, losses due to improper storage facilities on-site, and damage due to poor on-site conditions. The significant cost-savings helps drive up project profitability. (LetsBuild (2023a)

Using BIM construction plans, teams can gain a tremendous amount of accuracy when it comes to scheduling and measurement among other aspects. This helps them plan for project completion and deliveries better. In many projects, this can help drive up profitability significantly. In multi-family homes, accurate time estimates, and a good track record of deliveries can help drive sales. In public infrastructure projects, meeting committed deadlines can help win project bonuses or at least avoid incurring penalty clauses. (LetsBuild (2023a)

BIM can be used to curb safety hazards to a large extent. With accurate plans, better collaboration, and more efficient execution, construction teams can focus on various safety aspects while on the job. Greater safety is, of course, a reward in itself but it also helps prevent losses due to fines and penalties. (LetsBuild (2023a)

BIM is gaining widespread acceptance by proving its worth in different projects. And it is safe to say that in the future, technology will become even more commonplace. It helps drive up productivity and improves profitability -that business case is compelling! (LetsBuild (2023a)

2.5 Digitalizing Construction Stakeholder Management Practices to Enhance Performance in Construction Projects

Large construction projects are mostly focused on overcoming current infrastructure capacity problems or opening new business opportunities, and they bear great importance for the promotion of the economic and social wellbeing of the wider stakeholder community. These projects include numerous contracting parties and a vast range of potentially conflicting interests, which requires highly complex problem-solving activities such as stakeholder management. Stakeholder management comprises two major processes (e.g., stakeholder analysis and engagement), and it is increasingly becoming a part of construction project practice. Inadequate stakeholder management has led to process disruptions and adverse outcomes in many large construction projects and it is considered as a fundamental instrument for setting the direction of projects. Additionally, there is a great need to manage stakeholders through various engagement strategies (i.e., communication, partnership, and capacity building strategy) to increase the sustainability of construction projects. Significant empirical research conducted in recent years further divides stakeholder analysis processes (i.e., stakeholder identification, classification, assessment of stakeholder influence, etc.) and stakeholder engagement processes (i.e., stakeholder communication, involvement, collaboration, etc.) which is consistent with stakeholder management becoming a formal project management knowledge area. The project management body of knowledge (PMBOK) standard for project management formalizes stakeholder management through four processes (identification of project stakeholders, planning of stakeholder engagement, management of stakeholder engagement and monitoring, and control of stakeholder engagement), which comprise several underlying practices (Prebanic (2021b)).

Through rapid advancements in ICT, opportunities arise in enhancing communication between participants of different organizations (i.e., internal stakeholders) in construction projects. Furthermore, obtaining external stakeholder support necessitates strategic engagement, often using information and communications technology (ICT). Building information modelling (BIM) promotes the collaborative working of different stakeholders, enabling them to support and reflect their respective responsibilities by inserting, extracting, updating, and sharing information through the BIM model. Computer-mediated collaboration has been the main focus of Computer Supported Collaborative Working (CSCW) studies, which deal with ICT-supported information sharing, information exchange, collaborative decision making, and control protocols. Web (cloud) applications exploit Internet and web technologies to enhance information sharing between various project stakeholders throughout the project lifecycle. In large construction projects, ICT supported visualization and simulation are considered very important for coordination of both internal and external stakeholders. Additionally, software packages supporting a social network analysis method (i.e., UCINET, NetMiner, etc.) can be used to analyze and visualize stakeholder relationship networks and their influence. Ninan et al. provides evidence that ICT was used strategically to hegemonize stakeholder support and persuade stakeholders to support project decisions. They emphasized social media as a key type of ICT system which can assist in conducting stakeholder engagement strategies (Prebanic (2021b)).

Using digital technology for communication and collaboration is often seen as an important managerial tool, and project managers are left with the increasingly important task of finding proper ways to harness ICT collaboration tools for the involvement of project stakeholders. The digitalization of various construction project management practices is relatively well researched, considering the number of various ICT tools and articles dealing directly or indirectly with this broad research field. Nevertheless, the adoption of the digital way of performing project and stakeholder management practices in construction projects is still very low compared to some other industries, and part of this problem lies in the weak systematization of ICT systems which support these practices. There is not enough information on what a particular ICT tool serves for, which stakeholder should use it, and for what purposes; in other words, research streams related to the digitalization of various management processes and activities (i.e., stakeholder engagement, collaboration, analysis, etc.) are vague.

There are numerous papers dealing with the collaboration and cooperation of specific internal construction project stakeholders through various ICT tools (i.e., contractor with subcontractors, project manager with other stakeholders), and on the other hand, ICT usage for external stakeholder involvement and analysis (i.e., project end users) is becoming an increasingly important topic (Prebanic (2021b)).

2.6 Opportunities and challenges of the digital transformation

2.6.1 Advantages of digitization in the construction industry:

2.6.1.1 More efficient, simpler processes in construction: With the help of new process structures, planning and construction projects can be made more transparent, more reliable and less prone to errors. Software that creates a digital twin of a real building is used for this purpose. Stakeholders use these models to record and manage data and see building changes in real time (Digitization of the Construction Industry: Digital Transformation Takes Hold, 2023c).

2.6.1.2 Increased efficiency in planning and design: Digitization has enabled construction professionals to use advanced 3D modeling and building simulation tools to plan and design projects more efficiently and accurately, recreating what the building process will look like before it starts and anticipating risks (Digitization of the Construction Industry: Digital Transformation Takes Hold, 2023c).

In addition, other technologies such as geographic information systems (GIS) are used to analyze field data and plan construction projects more effectively. Finally, computer-aided design (CAD) software allows architects and designers to create detailed and accurate designs that can be easily adjusted and modified to the needs of each project (Digitization of the Construction Industry: Digital Transformation Takes Hold, 2023c).

2.6.1.3 Improve environmental performance of buildings: Digital models help reduce environmental footprints. Designs are quickly calculated digitally and adjusted just as quickly depending on building requirements (Digitization of the Construction Industry: Digital Transformation Takes Hold, 2023c).

2.6.1.4 Safer construction site: Digitization has also improved construction site safety. Drones are used to perform inspections and risk assessments in hard-to-reach locations. Smart glasses and other wearable devices allow workers to receive real-time information about safety and precautions to take to avoid accidents (Digitization of the Construction Industry: Digital Transformation Takes Hold, 2023c).

At the same time, we have digital algorithms that can help us make decisions in the construction process, such as simulating the passage of time in one material or another. In a final note on safety, it is worth mentioning off-site construction. As we have already mentioned in another blog article, this is a great pending revolution in the sector that would reduce both cost overruns and the high accident rate. A model that is closely related to digitalization (Digitization of the Construction Industry: Digital Transformation Takes Hold, 2023c).

2.6.1.5 Faster workflows through automated processes: Cloud solutions not only save paper. They are suitable for agile, efficient collaboration in construction projects because they can take over small tasks such as reminders for maintenance processes (Digitization of the Construction Industry: Digital Transformation Takes Hold, 2023c).

2.6.1.6 Reduce costs and construction time: Digitization has also enabled a reduction in costs and construction time. Digital planning and design tools allow teams to identify and resolve problems before construction work begins, reducing costs and time. In turn, it has enabled the automation of many tasks, reducing errors and the time required to complete them (Digitization of the Construction Industry: Digital Transformation Takes Hold, 2023c).

In this aspect, the use of data is key. Big Data technology allows us that massive data management that brings value to the construction process. It is through data management and analysis that we can minimize risks and improve production and economic margins ((Digitization of the Construction Industry: Digital Transformation Takes Hold, 2023c).

2.6.1.7 More sustainable than traditional construction: As mentioned above, new technologies allow the construction sector to work with greater foresight and adjust needs. This makes it possible to accurately measure the materials needed for each project and to prevent 35% of the materials from being wasted, as happens in traditional construction (Digitization of the Construction Industry: Digital Transformation Takes Hold, 2023c).

All this allows it to become a circular process in which the environment is not damaged so much and the budget is better adjusted, thus generating a more sustainable system, also economically (Digitization of the Construction Industry: Digital Transformation Takes Hold, 2023c).

However, despite the many benefits of digitalization in construction, there are still challenges that need to be addressed. The lack of digital skills among workers, familiar with the traditional model, is a major obstacle to the implementation of new technologies (Digitization of the Construction Industry: Digital Transformation Takes Hold, 2023c).

2.6.2 Key challenges of digitization in the construction industry

2.6.2.1 Building specialist expertise among employees: In order to properly apply digital solutions, basic knowledge and sufficient in-house specialists are needed. According to the PwC study "Challenges facing the German construction industry in 2021", the construction industry is confronted with aspects such as internal acceptance and appropriate cyber security (Digitization of the Construction Industry: Digital Transformation Takes Hold, 2023c).

2.6.2.2 Connecting the analog and digital worlds: Industries have so far been characterized by analog. Today, this leads to networking and digitization strategies becoming complex tasks (Digitization of the Construction Industry: Digital Transformation Takes Hold, 2023c).

2.6.2.3 Invest in digitization: For digital implementations, the crisis-ridden construction industry needs financial resources to manage the transformation—and time for implementation (Digitization of the Construction Industry: Digital Transformation Takes Hold, 2023c).

2.7 Trends in the construction industry digitalization in construction

There is a **race to digitize in construction**. The industry is embracing new technologies at speed, from automation to BIM and analytics tools. However, with so many products on the market, it can be difficult for business leaders to know which to invest in (Stone, 2022).

Introducing the right tools, hardware, and software can be game-changing for a construction firm. The **industry faces many unique challenges**, such as:

- Project delays
- Labor shortages
- Compliance regulations
- Worker productivity
- Poor visibility and reporting
- Rising cost of materials

On top of this, digital transformation in the construction industry isn't as simple in as it is for other industries. Projects are complex, contractors and subcontractors are brought in on a short-term basis (and don't have time to learn new tools), and builds happen on problematic construction sites, where it is difficult to deploy technologies (Stone, 2022).

Despite these challenges, **digitization in the construction industry is moving forward**. Business leaders are adopting digital construction tools and seeing the benefits of their investment. But which technologies have been most effective and how are they changing projects for the better? Here we identify **five key trends** which are taking the industry by storm (Stone, 2022).

2.7.1 BIM Software

Building Information Modelling (BIM) software lies at the heart of digital transformation in construction. It helps an organization to manage information throughout the lifecycle of a construction project – connecting data across the value chain. During the lifecycle, a detailed description of every part of the build is developed, using a combination of 3D technology, structured data, and collaborative handover methods (Stone, 2022).

Why adopt BIM ??

BIM is rapidly becoming standard practice throughout the construction industry – for good reason. It is the first truly global digital construction technology and is rapidly being deployed in every country. In construction, an ROI grows alongside a commitment to BIM processes and standards (Stone, 2022).

For business leaders looking to adopt new technologies, BIM is a great place to start. A digital tool for the AEC industries (architecture, engineering, and construction) should be BIM compliant as a priority. There are levels of maturity for BIM compliance and choosing a digital tool that promotes a high level of compliance is an important first step (Stone, 2022).

2.7.2 Digital Documentation

In the age of digital transformation, businesses are looking to eliminate manual processes. For construction firms, many still exist, including:

- Contractor/ subcontractor onboarding
- Permit to dig
- Health & safety reports
- Material requisition
- Risk assessments
- Project approvals

These processes are typically carried out via manual methods, but construction firms are beginning to migrate toward digital documentation. Construction relies on cross-organizational content, with processes taking place across clients, architects, suppliers, contractors, subcontractors, engineers, operations, and stakeholders. Transferring documents to submit approvals or requests, complete a process, or achieve transparency between parts of the value chain is necessary for this industry (Stone, 2022).

Why use digital documentation?

Transferring documents via email chains, or other manual methods (pen/paper) is not sufficient in this industry. Content-based workflows touch all parts of the construction lifecycle and, to stay competitive, businesses must pivot toward digital documentation. Construction firms need to find a digital construction platform that supports the flow of large, complex documents, which is both user-friendly and productive (Stone, 2022).

FlowForma's construction software makes the move to digital documentation easy. The no code platform digitizes construction workflows, forms, and document generation for businesses to get up and running straight away. This helps construction firms avoid delays in construction projects (Stone, 2022).

2.7.3 Mobile First Tools

Construction projects by nature, happen remotely. The builds take place on remote sites, often outside of cities, and do not always have the infrastructure to support digital systems. The job sites can be exposed to brutal weather conditions and have minimal internet service options. Deploying stationary hardware on-site, such as desktop computers and servers, is usually not an option (Stone, 2022).

Why use mobile devices?

In this industry, workers require quick access to accurate information during the build stage. Decisions often need to be made "on the fly", and, without access to project data, problems can begin to stack up (Stone, 2022).

Because of this, construction workers are increasing their reliance on mobile-first tools. A digital construction tool that can be used on-site is valuable to employees working remotely. With a mobile-first tool, construction workers can communicate effectively and collect and access data in a more structured way, rather than via paper forms or email in which there is a high chance of human error. The devices allow employees to react promptly to unanticipated events on job sites and minimize the risk of project delays (Stone, 2022).

2.7.4. Process Automation

Productivity in construction has always been a problem. In the United States, between 1947 and 2010, productivity levels in construction barely changed at all – despite new technologies on offer. Digitization in the construction industry has been slow and even today – when businesses across the globe are using technology for greater productivity – construction workers swear by old-school methods (Stone, 2022).

Many construction firms still rely on manual methods (paper forms, email chains, content spreadsheets, and Word documents) to complete processes throughout the value chain. For example, site managers will request new materials on-site by sending an email to the requisition teams. This method might appear sufficient, but emails are misunderstood around 50% of the time we read them, according to Nick Morgan, author of Can You Hear Me? In construction projects, misunderstandings amount to wrong materials arriving to job sites and subsequent delays in projects. For other processes, such as those concerned with health & safety, the misinterpretation of data can have more serious implications (Stone, 2022).

Why use process automation?

There are so many processes by which a construction project operates. Automating just some of these creates a large uptick in productivity and helps construction firms to stay compliant. With FlowForma's process automation tool, site managers can use automated digital forms to request materials, using accurate data fields that cannot be misinterpreted. Or site risk assessments can be carried out safely and reliably, in a way that meets compliance regulations (Stone, 2022).

Process automation can mean the difference between a business that remains unproductive and one which regularly hits productivity, cost, and deadline KPIs. Time and time again, automation is hailed as the best way to boost productivity within a company. Construction firms, such as FlowForma customer Sullivan Engineering, have saved over 700 hours per year on repetitive tasks, using intelligent process and workflow automation. With FlowForma's process automation tool, construction workers are empowered to digitize processes in-house, unlock serious savings, and gain a competitive advantage within the market (Stone, 2022).

2.7.5. Data Software

Data has become a commodity for organizations worldwide. In construction, it's no different with business leaders approaching digitization in the construction industry as a way to access and harness project data. Over the lifecycle of a project, vast amounts of data is produced, from building models and cost estimates to scheduling and process insights. If a construction firm uses a connected data repository (or connected construction platform), business leaders can gain a holistic and detailed picture of their company's operations (Stone, 2022).

Why use data software?

Data software is vital for construction firms that want to take a long-term view. Many construction firms do use content repositories (e.g. OneDrive, Google Drive), but these are not sufficient for data analysis. Typically, a wealth of data will exist in these repositories, but employees do not have the technology or know-how to leverage it (Stone, 2022).

Connected construction platforms, like FlowForma's process automation tool, join up a construction firm's data in one central environment. This includes project data from every part of the value chain, giving business leaders a holistic picture of operations. With FlowForma's reporting function, analytics can be pulled easily from data repositories. Employees can create reports on their business processes that are visually appealing and simplify complex data profiles. FlowForma's customers use the reporting tool to make data-driven business decisions and improve processes in the long term (Stone, 2022).

The Bottom Line

Digitization in the construction industry is moving forward. Despite unique challenges, the construction industry is embracing five key digitization trends.

Adopting BIM standards connects construction projects across the value chain. A shift toward digital documentation ensures better document management and productivity. Mobile-first tools allow construction workers to complete processes on job sites and access project data. Process automation fast-tracks construction processes for a rapid ROI. And using data software gives business leaders a holistic picture of processes, enabling better business decisions (Stone, 2022).

2.8 Types of Digital Construction

2.8.1 Project management software

Project management software, otherwise known as progress monitoring software or on-site execution software is concerned with helping digitally manage the hundreds of thousands of activities that take place on a construction site. It helps to streamline construction execution - the construction phase that is notoriously difficult to manage and often results in costly mistakes and delays (Stewart, 2023)

Project management software can be used by both project managers and trades working on a project. Parties can connect through their mobile devices, send real-time updates from anywhere and track every detail of the project (Stewart, 2023)

This type of technology has seen a dramatic increase in investment activity due to its track record of having a significant impact on projects in both the short and long term (Stewart, 2023)

2.8.2 BIM or Building Information Modeling

BIM has taken the construction industry by storm and still remains one of the most talked about types of digital construction. It replaces traditional blueprints with 3D representations of buildings, using predictions and historical data to plan projects more efficiently. It can also be circulated to help visualise the project's progress (Stewart, 2023)

2.8.2.1 BIM as the leading technology in modern construction: Building Information Modeling (BIM) works by means of software that represents a digital twin of a real building. With BIM, virtual modeling and visualization are possible from construction and equipment to maintenance and repair. In short, BIM covers the entire life cycle of construction projects. This leads to a lower error rate, less material consumption and reduced time thanks to digital visualization.

2.8.2.2 How does BIM help construction firms?

BIM technology is **crucial for construction firms**. It joins up a previously fragmented value chain, ensuring that data is passed from the design stage, onto engineering, construction, and operations etc. A BIM platform will open information up to workers across a project lifecycle, meaning that important data gets handed over at each touchpoint (Stone, 2022).

BIM technology **improves productivity** throughout a project, making every build more collaborative. With a new **visibility over project data**, logistical problems are flagged earlier and decisions can be made at speed. BIM technology fast-tracks the construction lifecycle, without compromising the quality of a build. It **reduces the project delays** seen so frequently in construction and delivers **significant cost savings** across the lifecycle of a project (Stone, 2022).

2.8.2.3 Key Considerations When Moving to BIM

Some people mistakenly think of BIM as just a new variety of software. BIM is a process that relies on information rich models to help owners and AEC service providers to more efficiently plan, design, construct, and manage building and infrastructure projects. Implementing BIM will impact your business and your processes, as well as your technology toolset. As you move to BIM you should be aware of how your organization's Design Management Using BIM: Case of Pilot Projects in Addis Ababa 2020 26 business, processes, and technology might change, so you can better position your firm to reap the benefits of BIM (van Nederveen , et. Al. 1992).

2.8.2.4 Key drivers for adoption of building information modeling

The implementation of Building Information Modeling (BIM) can be driven by various factors. Here are some common drivers of BIM implementation:

1. Improved Collaboration and Communication: BIM promotes better collaboration and communication among project stakeholders, including architects, engineers, contractors, and owners. It allows for real-time sharing of information, coordination of designs, and seamless integration of project data. The desire to enhance collaboration and communication is a significant driver for BIM adoption.

2. Cost and Time Savings: BIM can help optimize project schedules, reduce rework, and improve efficiency in construction processes. By using BIM, project teams can identify and resolve clashes, conflicts, and design issues before construction begins, reducing costly changes during construction. BIM also enables better project planning and sequencing, leading to time and cost savings throughout the project lifecycle.

3. Enhanced Project Visualization: BIM offers 3D modeling capabilities, enabling stakeholders to visualize the project in a virtual environment. This visualization can help in better understanding the design intent, identifying potential issues, and making informed decisions. Improved project visualization is often a driving factor for implementing BIM.

4. Regulatory Compliance: Some regions and industries have mandated the use of BIM for certain types of projects. Governments and regulatory bodies recognize the benefits of BIM in terms of improved project outcomes, sustainability, and facility management. Compliance with regulations and requirements can drive the adoption of BIM in such cases.

5. Lifecycle Management and Facility Operations: BIM extends beyond the construction phase and can be used for managing the entire lifecycle of a building or infrastructure asset. It facilitates the integration of asset data, maintenance information, and facility management systems, allowing owners to effectively operate and maintain their assets. The desire for better lifecycle management and facility operations can be a driver for implementing BIM.

6. Improved Quality and Reduced Risk: BIM helps in identifying design clashes, constructability issues, and potential conflicts early in the project lifecycle. By resolving these issues proactively, BIM contributes to improved quality, reduced rework, and minimized risks during construction. The need for higher quality and risk mitigation can drive BIM adoption.

7. Sustainability and Energy Efficiency: BIM can facilitate energy analysis, simulation, and optimization during the design phase, leading to more sustainable and energy-efficient buildings. It enables better decision-making regarding material selection, energy systems, and construction methods. The focus on sustainability and energy efficiency can drive the implementation of BIM in the AEC (Architecture, Engineering, and Construction) industry.

These are some of the key drivers of BIM implementation, although the specific drivers may vary depending on the project, organization, and industry context.

2.8.2.5 What are the BlM Software in the Market?

As already stated, BIM is not a software tool but rather a process. It is however, greatly assisted by BIM-enabled software. So much so that in many instances, it would be justifiable to say that without BIM-enabled software and technology, BIM Levels 2 and 3 would be impossible to deliver, requiring as they do, digital communication of vast quantities of data. The software industry is very aware of this rapidly growing need for technological solutions to these process needs, and has responded with an ever-expanding number of tools and services, covering every aspect of the BIM workflow. It would be unrealistic and unproductive to sample all of these tools in this Virtual Project, but we have chosen a selection of applications from across the market, which will demonstrate each genre.

There are many BIM software in existence, including: Autodesk© Revit©, Archicad©, Vectorworks©, Allplan©, Digital Project© etc. However, the most popular is the Autodesk Revit- which is currently a merger of Architecture, Structure and MEP platforms, making it arguably the most complete BIM Design Software in the industry.

2.8.2.6 BIM Maturity levels/BIM Maturity stages

In the process of moving towards a fully collaborative and integrated working process in the construction industry, the UK set a milestone being defined within the process in the form of levels which is called BIM levels. The UK government recognized that the process of moving the construction industry to ‘full’ collaborative working will be progressive, with distinct and recognizable milestones being defined within that process, in the form of ‘levels. These have been defined within a range from 0 to 3, and, whilst there is some debate about the exact meaning of each level, the broad concept is as follows.

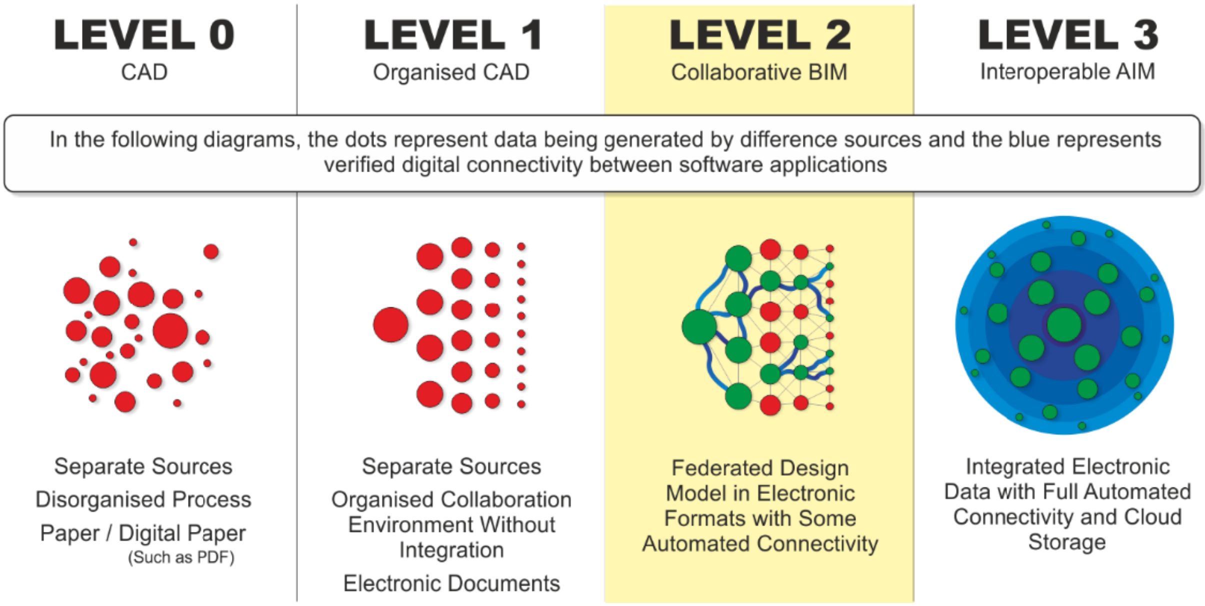


Figure 1-BIM maturity Levels

2.8.2.7 What is the process of BIM?

The process of BIM supports the creation of intelligent data that can be used throughout the lifecycle of a building or infrastructure project.

A. Plan

Inform project planning by combining reality capture and real-world data to generate context models of the existing built and natural environment.

B. Design

During this phase, conceptual design, analysis, detailing and documentation are performed. The preconstruction process begins using BIM data to inform scheduling and logistics.

C. Build

During this phase, fabrication begins using BIM specifications. Project construction logistics are shared with trades and contractors to ensure optimum timing and efficiency.

D. Operate

BIM data carries over to operations and maintenance of finished assets. BIM data can be used down the road for cost-effective renovation or efficient deconstruction too.

2.8.2.8 BIM-based design process

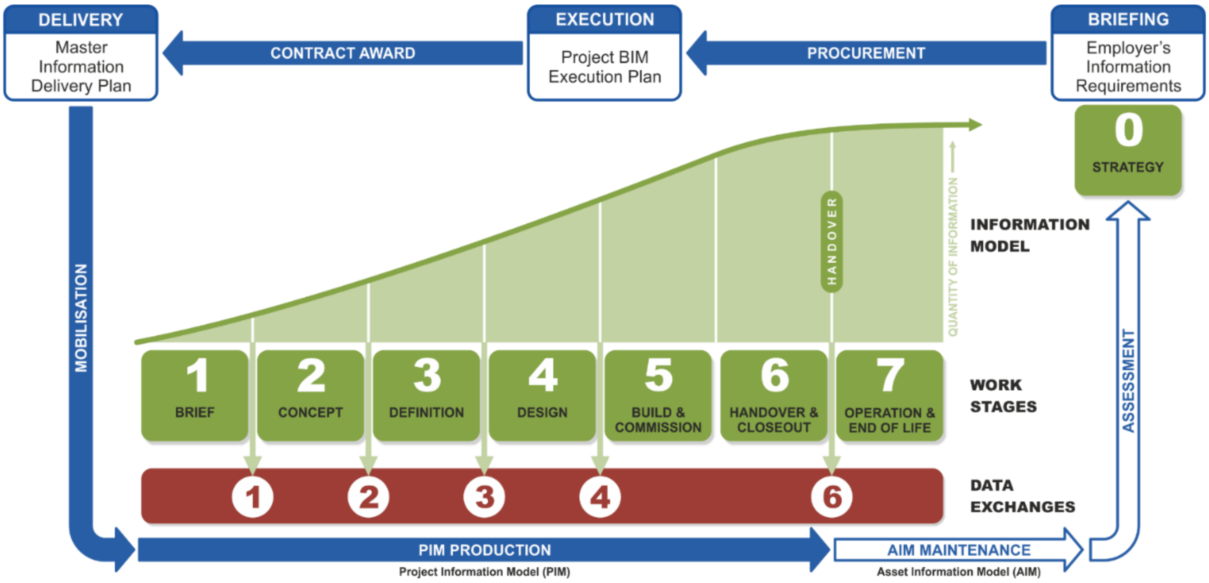


Figure 2-BIM based design process

A. Project design brief

At the project design brief start with client preparing EIR. The EIR is a key document for Level 2 BIM. The document is compiled by or on behalf of the client and is issued at tender stage, its intention is to define the client's requirements, and how the project model and information is to be delivered in relation to a number of standards, namely PAS1192. A set of Employer's Information Requirements is intended to be part of the wider tender document set for the procurement of the Design Team and the Constructor.

The main purpose of an EIR is to document the information requirements and also to establish the information management requirements. The type of information that is typically included in an EIR document.(BIM Academy 2017)

- Project brief
- BIM Execution Plan requirements
- Objectives
- Agreed Common Data Environment (CDE) and its management
- Client aspirations
- Information Manager and responsibilities
- Required data drops

B. Project execution plan

Then respond with their outline BIM Execution Plan (BEP). Essentially the BEP demonstrates how, if successful, the bidders will deliver and manage this digital information throughout the project. Typical issues that are covered in a BEP would include Project Information, as well as Project Objectives and Management which are really concerned with how and what you are going to provide the client and confirms that your sub-contractors can also perform regarding digital information. In the Technical & Procedural section you will explain technical details, for example the software expertise, and project specific BIM content.

C. Developing design

At this stage the designers are developing model information in accordance with the BEP requirements. For certain components the level of detail may be high whereas the level of information low and for other elements vice versa. It is important to remember when modelling objects that they should be modelled with enough detail and information to fit their purpose per the BEP.

It is easy to over model objects and saturate them with un-necessary high levels of detail and information which serves no purpose but to slow down model use. Any number of 3D modelling products could be used to produce the discipline specific models, here are just a few of them.

Designers will always prefer the product that suits their own work processes and internal requirements, this isn't a problem at all, the products ability to create a suitable exchange format as described in the project documents is what is important. The ability to communicate as defined in the EIR and BEP is vital, not what you use.

The architect develops the concept model for internal use and provides this information to the other discipline specific design team members. They each begin to develop their own internally hosted models based on the BEP requirements. The project BEP reflects the unique project stakeholders and their diverse software preferences, this will vary with each project. Design Management Using BIM: Case of Pilot Projects in Addis Ababa 2020 31

The structural engineer develops the model for design coordination and a number of other purposes, such as performing structural analysis and design options. This is sometimes referred to as value engineering, in essence trying to find the optimal design for the structure in terms of structural efficiency, cost, construction time and a host of other criteria.

At the same time the building services team are creating mechanical, electrical and plumping models. They too are performing analysis and design calculations on the systems to be installed.

D. Model Transmittal and Publish to Shared Folder

These models are shared at regular intervals by the team and it is important that prior to issuing them each model author performs a check on the model's content for validity and reliability. Prudent authors will always check their work prior to issuing to another party.

Whilst a number of file types exist, for practical purposes we will exchange and share models with the design team using our native 3D modelling software format. The files should be placed in the agreed location; mostly in Shared folder. This allows us to link these different models together for the purposes of undertaking a design review meeting.

E. Design Review

During this definition stage the design team will regularly undertake a design review to ensure design intent is being understood and wherever possible potential issues are reported for resolution amongst the team.

Here again the format these design review meetings takes may vary enormously depending upon the level of BIM sophistication amongst the stakeholders, they type of contract and the BEP requirements for data transfer.

It could be that model federation software is utilized, standard exchange formats such as IFC are adopted or native file formats are exchanged. File types could include RVT, NWD or IFC. Any design issues are allocated to the relevant designers for resolution and model revision (BIM Academy 2017).

F. Model Federation and Clash Detection

In this session we will consider model federation, the act of bringing together a number of discipline specific models often produced from different file formats. This is normally performed by the client's representative, the Information Manager or BIM Manager, and it is from this federated or aggregated model that tasks such as clash detection are performed.

Clash Detection refers to the automated or semi-automated procedures for identifying design errors in 3D models, where objects either occupy the same space (a hard clash) or are too close as to violate spatial constraints (a soft clash or clearance clash). Time-based clashes are either hard or soft clashes involving temporary objects competing for the same space at the same time. There are many BIM Software Tools that allow a combination of automated geometry-, semantic-, and rule-based clash analysis for identifying clashes.

Clash Detection consists of processing, coordination, and tracking activities leading to the resolution of detected conflicts, whether visually or automatically identified. When successfully conducted, Clash Detection offers the following main benefits:(BIM Dictionary 2019).

- Improved project coordination and quality;
- Reduction of workplace conflicts;
- Acceleration of the design and delivery processes; and
- Cost reduction through productivity increases

G. Model renderings

Model rendering are being created from concept modelling to handover, and they serve a broad range of requirements. In their earliest form as simple concept models they allow clients to identify with the project. As the scheme develops so too does the model and its usage, from urban planning to landscaping to the motion of people and traffic.

H. Time as 4D in Building Information Modelling

Time is a very unique non-material element in construction projects that can be represented in various perspectives, including time-space conflicts and construction schedule visualization. Attempts at incorporating time as additional information to evaluate and analyze different forms of project sequences comes in the form of 4D Computer Aided Design (CAD) (Algan.T, Zeeshan.A, Chuxiong.J, 2016).

Models and construction sequencing are not only used at the construction stage; stakeholders are increasingly preparing models for alternate initial engagements. For example, to meet planning requirements and engage with non-technical individuals during public consultations. At bid stage it is very powerful to be able to provide the client peace of mind that you have a clear understanding of what the design intention is, and more importantly that you can demonstrate how you are going to build the project.

4D is widely understood to represent the combination of 3D elements with time, in essence it could be considered to be the Model plus the Programme. Using the 3D models and Design Management Using BIM: Case of Pilot Projects in Addis Ababa 2020 34 allocating the construction programme to the objects creates 4D planning, where visually it is far easier to notice potential errors in the construction programme. This is far easier than reading through drawings and Gantt charts. In the image above model objects have been grouped into selection sets.

Model data can be imported into a quantity take-off (QTO) product such as Navisworks, to first derive material quantities, this detailed information may have a direct effect on the overall programme, for example a large volume of concrete may require additional time to pour, or additional joints which would result in additional tasks being created. The updated programme is then transferred back for visual scheduling of the new tasks (BIM Academy 2017).

Information on tasks and programmes can be used for a multitude of other planning requirements. For example, to show temporary works, transport access and egress, ancillary construction logistics such as scaffold and crane placement, delivery and storage of components and materials, temporary offices, and many more.

I. Cost as 5D in Building Information Modelling

Cost estimation is very significant for decision making as inaccurate estimation may lead to disastrous cost overrun and project delay. Early project estimation represents a major factor in business unit decisions and often becomes the basis for a project's ultimate funding. In spite of great importance given to cost estimation, it is neither simple nor straightforward due to deficiency of information in the early stages of the project(Sheng 2016).

The ability to derive material quantities at the earliest stages of a project is extremely beneficial for those tasked with producing cost estimation, or for comparison with the design brief.

The topic of quantity take-off often leads to some interesting conversations regarding model accuracy, level of information, and trust in the fidelity of the model contents. In this module we will consider this in more detail, and we'll use Navisworks to perform a material quantity take-off of the model objects.

A real strength of using the model to perform a material take-off is the ability to quickly perform this on the federated model, often comprising of a number of models originating from different authoring programs(BIM Academy 2017).

2.8.3 Virtual and augmented reality

On a construction project, anything and everything can go wrong. This is why strategic and in-depth planning of the project is so crucial. This is where virtual and augmented reality shines (Stewart, 2023)

Virtual reality or VR creates 3D simulations of buildings and augmented reality integrates digital information with the user's real environment in real-time. While VR works to help train workers on best-practice techniques to prevent errors, augmented reality or AR is useful to look forward to prevent hazards (Stewart, 2023)

2.8.4 Robots and drones

With labour shortages, a major challenge for construction, drones and robots are helping to provide a solution by reinforcing the construction workforce. They can be used in everything from site walk-throughs, safety inspections, site logistics and monitoring the progress of the project. While robots and drones won't replace people just yet, it is expected that they will increasingly be used in construction to provide a helping hand (Stewart, 2023)

2.8.5 Machine learning and artificial intelligence

Machine learning and AI on the construction site work by using data to understand patterns to predict what will happen in the future. This can be a game changer when it comes to understanding the root cause of delays, reducing costs and mitigating risks (Stewart, 2023)

2.9 Phases of digital technology construction

A. Digitisation

Digitisation is the process of moving from paper-based systems to digital, a process also known as digital enablement. Digitisation increases the availability of information so that it can be accessed from anywhere and at any time (Stewart, 2023)

B. Digitalisation

Digitalisation is when data *and* processes are moved from paper-based systems to digital ones. Digitising processes as well as data helps to drive efficiency gains across an organisation (Stewart, 2023)

C. Digital transformation

Digital transformation is when all elements of an organisation are enhanced through digital technology. This includes everything from strategies, employee enablement, jobsite workflows and applications. Digital transformation may encompass many digitalisation initiatives and it ultimately looks at harnessing digital tools to bring about business transformation (Stewart, 2023)

2.10 The place of BIM in the construction industry

The construction industry still plays some roles and develops activities like last century. Some construction sites look almost the same, with so much labor work on site and decisions made on the spot. The need for change and innovation is clear and better planning will lead to smoother executions on-site, less re-work, and higher coordination. With today's technical tools, information is easily accessible anywhere. It has enabled communication and collaboration in all areas of life and business, and building and construction should not be different. The current data quality and flow in this field are inadequate for today's needs. And here is precisely where BIM comes into play (Ag, 2023)

The state of the industry before BIM

The construction sector is clearly behind the industrial revolutions. BIM is the methodology that will help it reach and thrive in the industry 4.0 or 4th revolution, making the internet of things (IoT) and IT participative, available resources and solutions present in the building field.

The construction industry has almost made a tradition of lagging in productivity improvement. Several reports show that its yearly increase is way behind other sectors; globally, the industry has recorded average annual productivity growth of 1 percent since 1995. During the same period, the global economy grew on average by 2.8 percent (Ag, 2023)

The construction industry is notorious for its reluctance to embrace digitalization, lagging behind other sectors in terms of technology adoption. While other industries such as manufacturing, retail, and finance have already undergone significant digital transformation, the construction industry remains largely paper-based and manual. The lack of digitalization in construction has significant consequences for the industry, including decreased productivity, increased costs, and delays. Without digital tools, construction professionals struggle to collaborate effectively, manage projects efficiently, and monitor progress in real-time. This can lead to errors, rework, and cost overruns, resulting in delayed project completion and dissatisfied clients (Ag, 2023)

However, there is hope for change through the adoption of **Building Information Modelling (BIM)** and other new technologies. BIM is a digital model-based approach that enables collaboration, coordination, and communication across the entire project team. It allows for real-time data sharing, which facilitates better decision-making, reduces errors, and improves overall project efficiency. BIM can also help identify and resolve potential issues before they become costly problems, ensuring that projects are delivered on time and on budget (Ag, 2023)

In addition to BIM, other technologies such as drones, robots, and virtual reality can also help transform the construction industry into a 4.0 industry. These tools can improve safety, productivity, and accuracy, while reducing costs and the need for manual labor. For example, drones can be used for site inspection and monitoring, robots can be used for repetitive tasks, and virtual reality can be used for training and visualization (Ag, 2023).

In conclusion, the lack of digitalization in the construction industry has significant consequences, but the adoption of BIM and new technologies can help transform the industry into a 4.0 industry. By embracing digital tools, construction professionals can collaborate more effectively, manage projects more efficiently, and deliver better results for clients. The infrastructure sector now has a short time to make up for what it has neglected for years; smart buildings, climate change -the construction industry generates many emissions and consumes so many raw materials- and cost and time deadlines missed are the main challenges faced by the industry that a BIM adoption can help (Ag, 2023).

2.11 What is the current state of digitization in the construction industry?

Other sectors, such as the automotive industry or mechanical and plant engineering, are well ahead of digitization in the construction industry: The PwC study on the challenges facing the German construction industry showed that the hoped-for digitization boost from the pandemic failed to materialize (*Digitization of the Construction Industry: Digital Transformation Takes Hold*, 2023d).

The opportunities for digitization in the construction industry had been recognized, but the potential of new technologies had not been sufficiently exploited due to a lack of basic knowledge. There is a gap between existing technological potential and the actual skills of skilled workers. However, the construction industry is catching up step by step in all phases and together with the stakeholders, especially in terms of digital planning: 47 percent of all respondents stated that their own company had a high level of digitization. Although the study shows that technological potential is not yet being exploited, the construction industry is well on the way to transformation (*Digitization of the Construction Industry: Digital Transformation Takes Hold*, 2023d).

It won't work without digitization in the construction industry

The necessary foundations for digital transformation include cloud applications, for example: They enable large volumes of data to be stored in a central location. This data will later be a prerequisite for standardized and automated manufacturing processes on the factory floors. Without digitization of the construction sector, the industrial manufacturing industry will therefore face massive challenges (*Digitization of the Construction Industry: Digital Transformation Takes Hold*, 2023d).

In the wake of these developments, 82 percent of small & medium-sized enterprises are now planning to develop new services and business models, according to the DIHK Innovation Report 2020. For large companies, the figure is as high as 96 percent. What the construction industry urgently needs to meet the challenges is summed up in four words: infrastructure, corporate interest, skilled workers, builder competence (*Digitization of the Construction Industry: Digital Transformation Takes Hold*, 2023d).

2.12 Enhancing BIM implementation in the Ethiopian public construction sector: An empirical study

Infrastructure projects are generally considered as the fundamental structures, facilities, and systems that impact the public at large (Babatunde et al., 2012; Sinesilassie et al., 2017). This in turn makes these projects unique from their technical and financial point of view (Abd et al., 2017; Ozorhon & Karahan, 2017).

Infrastructure construction projects involve multiple stakeholders throughout the project life cycle. The coordination and communication between these stakeholders are essential to enhance project management and ensure success of infrastructure projects (Chileshe et al., 2020). In this context, the planning, design, construction and delivery of infrastructure projects become complex when it comes to low-income countries (Kekana et al., 2020; Porwal & Hewage, 2013).

According to the World Bank report, the delivery of infrastructure projects in several sub-Saharan African countries lacks efficiency; and are normally knotted with delay, cost overrun, low productivity, and dispute among stakeholders (Calderon et al., 2018). As a result, construction firms become less profitable and incompetent. In addition, literature highlighted that the application of change orders due to design errors, and use of old construction techniques in developing countries are thought as the major causes of poor performance in public infrastructure projects (Ismail et al., 2017; Koops et al., 2016). One of the ways to overcome the aforementioned problems is by introducing new technological innovations and processes such as Building Information Modeling (BIM) in the construction business operations (Ahn & Kim, 2016; Olanrewaju et al., 2020).

BIM is a technological advancement which revolutionizes the technical, managerial, as well as business aspects of the construction industry. Developed nations, in particular the European countries, USA, Australia and Hong Kong enjoyed the variety of BIM benefits over the past decade (Chan et al., 2019; Ullah et al., 2019). These countries formulated and endorsed national BIM policies and standards to enhance the adoption and diffusion of BIM across the construction sector (Kassem & Succar, 2017).

In recent years, BIM has also gained a widespread acceptance across developing countries, despite its low adoption rate in developmental infrastructure projects (Ismail et al., 2017; Olawumi & Chan, 2019). For instance, Ismail et al. (2017) reported an improvement in overall BIM uptake across the Asian developing countries although suggested for further extended studies. Similarly, Murphy and Nahod, (2017) call for an in-depth investigation of BIM adoption in public construction projects for a successful BIM adoption and diffusion. (Belay et al., 2021)

Moreover, recent studies revealed that there are only very few studies conducted in sub-Saharan African countries regarding BIM adoption in public infrastructure projects. Thus, to fill this gap, this study aims to explore the extent of BIM adoption readiness, including the benefits and barriers of adopting BIM in infrastructure projects. The study also examines the level of agreement between various respondent groups such as client, consultant, and contractor on each identified benefit and barrier. Further, the study provides key recommended actions to improve BIM diffusion across the construction market based on the findings from the factor analysis. (Belay et al., 2021)

This study contributes to the Ethiopian construction sector by (1) for the first time providing a set of potential benefits and critical hindrance of adopting BIM particularly in public construction projects, (2) highlighting thoughtful practical implications and recommendations to enhance the current BIM uptake in construction organizations. The findings of this study will help construction business CEOs and management team to concentrate on the key areas of improvement in the organizational structure. Moreover, government officials and policy makers will be beneficial in their quest to develop a national BIM adoption standard for the Ethiopian construction sector. (Belay et al., 2021)

BIM adoption in developing countries

Several construction organizations, professional associations, and government agencies have advocated the use of BIM in the AEC industry to improve project management and facilitate coordination among stakeholders in construction projects (Chan et al., 2019). Although the extent of BIM implementation varies around the world, developed nations such as the United States (Cheng & Lu, 2015), Australia (Kassem & Succar, 2017), and few European countries (Charef et al., 2019b) have led to the rapid diffusion of BIM across the AEC industry. These countries in particular utilized several in-depth research projects and strategies in certain knowledge areas to ensure effective adoption in both the public and private sectors (Chong et al., 2016).

In recent years, however, several developing countries have been trying to catch up and improve the current level of BIM uptake across the construction industry (Olawumi & Chan, 2019). Indeed, the potential benefits such as, improved architectural visualization (Chan et al., 2019), collaboration among parties (Husain et al., 2018), and effective asset management (Ahn et al., 2016) are some of the major driving factors that persuade BIM adoption in these construction markets. (Belay et al., 2021)

In contrast, prior studies also highlighted challenges and barriers of BIM adoption in low-income countries, despite the efforts by governments and respective stakeholders in the construction sector (Amuda-Yusuf, 2018; Olanrewaju et al., 2020). These hindrances are ranging from problems associated with low IT infrastructure, financial competency of construction firms, poor collaboration, lack of BIM courses in universities, and cultural barriers (Ghaffarianhoseini et al., 2017; Kekana et al., 2020).

Globally, most BIM related empirical studies in developing countries have been centered on three themes: (1) BIM benefits, (2) BIM barriers, and (3) BIM readiness (Abubakar et al., 2014; Chan et al., 2019; Olanrewaju et al., 2020). These studies examined the critical BIM attributes including at the pre and post adoption stages across the construction sectors.

Meanwhile, there is also a growing interest in BIM implementation to the public infrastructure construction sector either in the design, construction, and asset management of road and water works (Ahuja et al., 2020). In such a case, management and utilization of project data pertinent to project life cycle are a few of the center of focus in the public infrastructure sector (Chong et al., 2016).

More so, the gap in the economic development of countries and the differences in rate of BIM adoption across various disciplines have led to the notion that several researches are needed to contextualize the benefits and barriers of BIM in different geographical locations around the world. Thus, the current study aims to continue the rigorous efforts being taken towards the exploration of the key BIM attributes to enhance BIM implementation in the public sector. (Belay et al., 2021)

2.13 Getting started in your digital construction journey

2.13.1. Focus on fixing pain points rather than installing IT solutions

Construction companies around the world are investing in software to enhance field productivity. However, in many cases, this technology is being installed prematurely before companies understand how these tools will work in practice to solve their business challenges (Stewart, 2023)

Instead, you should first identify operations you'd like to improve and define digital use cases to bring these operational changes to pass. The key is to employ technology to fix pain points rather than simply jump a trend (Stewart, 2023)

2.13.2. Implementing digital use cases to promote collaboration

One obvious benefit of digital construction to the construction industry is the fact that it can help break down silos and foster collaboration on-site and beyond. Before implementing technology, you should think about how the technology can be used across different parties. How will the digital be used by those on-site and how will this information be fed back to those at head office? Thinking about these things in advance will ensure that the digital technology you employ will have a lasting impact (Stewart, 2023)

2.13.3. Share your vision

You've probably gathered by now that successfully deploying technology takes more than a great tool or device. People in your business will be the make or break of its deployment. You must understand the benefits of the technology for both those on-site and in the boardroom and communicate these unique benefits to each party. In the long term, cultural change is key to success, so don't underestimate the power of spreading your vision (Stewart, 2023)

2.13.4. Create a strategy

Clearly defining where you want to go as a company and taking a bottom-up approach to understand the exact steps you'll need to take to get there is essential. This will help you understand the type of technology that will work best for projects and will also help you to determine the type of technology provider you'll need to reach your goals. You should work with decision-makers to ensure that all stakeholders are on the same page (Stewart, 2023)

2.14 Summary of Literature Review and Gap Identified

The literature review for this thesis includes basic areas of knowledge whose understanding was deemed to be critical before proceeding further with the research. In the first section, after explaining about construction digitalization meaning, process, phases, effects on productivity and profitability, adoption at global level, in Africa & Ethiopia was discussed. Construction digitalization Implementation drivers, barriers and benefits were analysed. Part of the discussion was also dedicated to introducing the software.

Gap Identified

Through the literature review, the research has identified several gaps that the objectives of this research can address. Construction digitalization and BIM were introduced in Ethiopia relatively late, and this means there is limited research that takes into account the local context. Therefore, the technology hasn't had enough time to sufficiently mature, and research in general regarding BIM is limited.

This research will look into the current status of construction digitalization and BIM, specifically through the viewpoint of professionals that have implemented BIM in Ethiopia, in order to survey their viewpoints.

This research will contribute to the general body of knowledge and can be used by future researchers as a starting point and by policymakers when formulating future policy, especially with regards to the implementation of digitalization and BIM in Ethiopia as part of the National Development Plan.

CHAPTER 3

Research Methodology

This chapter deals with the research design and methodology that will be used to achieve the Objectives of the study, Research approach and design, population of the study, sampling design and sampling techniques, source and instruments of data collection, procedure of data collection and methods of data analysis are discussed. The validity and reliability test of the research and Ethical considerations are also addressed in this chapter.

3.1 Introduction

Research methodology refers to the systematic process researchers follow when conducting a study or investigation to answer specific research questions or achieve particular objectives. It involves the principles, procedures, and techniques used to collect, analyze, and interpret data in a reliable and valid manner. This research follows the explanatory type of research.

Explanatory research is a research method that explores why something occurs when limited information is available. It can help you increase your understanding of a given topic, ascertain how or why a particular phenomenon is occurring, and predict future occurrences. The Mixed types of quantitative and qualitative approaches were used under the two structures of inquiry modes.

3.2 Study Map

The study will be conducted in Addis Ababa which is the capital city of Ethiopia. The city is located at the geographical centre of the country and it lies between 800 55‘- 900 05‘north latitude and 380 40‘-380 50‘east longitude. Its average altitude is 2408 meters above the sea level. The city is endowed with numerous streams that start from northwest and northeast running towards the south and draining to the Awash River. The city administration extends over 540 square kilometres with 10 sub-cities and 116 Woredas for administrative purpose. Based on the census data in 2007 the population of the city is 2.7 million and the total administrative area is considered to be urban.

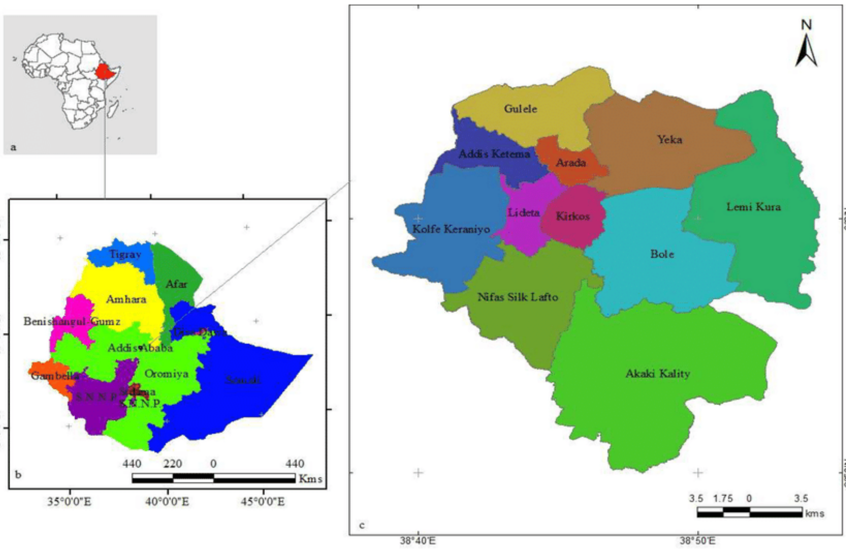


Figure 3- Map of Addis Ababa city

3.3 Research design

Research design is the arrangement considered for the collection and analysis of data to achieve the objectives of the research. This research follows the explanatory type of research. A qualitative and quantitative survey design were used in this research. The research is a qualitative type because it is concerned on describe the gaining information about the building information modelling based construction digitalization and it is a quantitative Assessment of adopting the Building Information Modelling type because it tried to specify the results of different stakeholders' points of view numerically. The first part of this work comprised a literature survey that was carried out to provide background information on effect of Building Information Modelling based construction digitalization on productivity & profitability and to identify the pushing factors and challenges or barriers to implementing BIM. Information is obtained through a literature search; this includes books and articles in online materials. The second part of the study entails a field survey and the main instrument employed is structured questionnaires.

3.4 Sources of Data

This study involved largely the use of primary data for the purpose of empirical analysis. The primary data were obtained with the use of structured questionnaires and selected interviews. Secondary data were used for preparation of the questioner and to discuss the findings of the research.

3.5 Data Collection tools

3.5.1 Questionnaire Survey

Before constructing the questionnaire, the potential ideas which can be developed into a questionnaire at a later stage are listed out. In order to have the ideas to develop into questionnaire, the research proposal and the literature review reviewed and all possible questions which are related to the research is written down to obtained the first thought questions. Those listed out question are all based on the aim and objectives of the research.

After the first thought questions have been identified, the final questionnaire constructed by introducing a number of section or categories for the questionnaire and the first thought questions are fitted into these sections. The research questionnaire is divided into two sections in which the first section is to obtain the back ground and information of the interviewees as well as their organization. This is to ensure that the contractor and the personnel is experienced enough and is highly knowledgeable to provide sufficient information required by the research. While for another section, the contractor will be asked to highlight the BIM practice in their company.

3.5.2 Basis of Interview Questions

The interview questions designed in wording that can be easily understood by interviewees. These questions were set to achieve the aim and objectives of dissertation. Information obtained should be able to support or make comparison with the theoretically as presented in the previous chapter. Through the interviews, the information regarding BIM practice will be obtained. Besides that, the importance of BIM will also be obtained. Each question will be designed to achieve certain aims and purposes.

3.6 Sampling

Sampling is an essential component of research, particularly in quantitative studies, as it involves selecting a subset of individuals or items from a larger population to draw conclusions about that population. There are several key components or considerations in the sampling process:

3.6.1 Population of the Study

The population of the study was building construction companies in Addis Ababa the capital city of Ethiopia, there are questions which are answered by the respondents, and the respondents in the research will be consultants and contractors with knowledge of construction according to their importance for successful accomplishments of the research study. For the purpose of this research category one contractors and consultant offices that are engaged in the building construction sector used in order to collect the relevant data through questionnaire.

3.6.2 Sampling Technique/s

Considering the homogeneity of the construction sector of grade one in terms of formulation and category, Purposive random sampling will be adopted for preliminary and final questionnaire distribution. Purposive random sampling, also known as selective sampling, is a non-probability sampling technique used in research where the researcher selects participants based on a specific purpose or criteria, but still employs some elements of randomness in the selection process. In purposive random sampling, the researcher identifies certain characteristics or criteria that are relevant to the research objectives which is construction companies those implement BIM in their construction process and then intentionally selects participants who possess those characteristics. The respondents are individuals who trained BIM.

However, within the pool of individuals meeting the criteria, the selection is done randomly to introduce an element of chance. This randomness helps to reduce bias and enhance the representativeness of the sample to some extent. Random sampling chosen to give equal chance to all contractors and consultants due to the fact that the sensitivity of the question types and needs some follow-up and further push to get reliable response and to have high number of returns of the questioners.

3.6.3 Sample Size Determination

Sampling is very important thing in research because the research work cannot be undertaken without sampling the study of total population. Determining the proper sample size for this research will be done through getting information from Ethiopian construction project management institute ECPMI and looking companies profile either adopt BIM or not.

Among the most important element of the research, the sample size is the one which addresses the characteristics of the whole file series with confidence. To stick with good statistical validity, the study made use of a representative sample size. For the study the numbers BIM trained personnel of grade one Contractors & Consultants are 119 and accordingly the sample size determined based on Yamane formula and found out the sample size of 55.

The Yamane sample calculation is a method of determining the appropriate sample size for a survey or research study. It was developed by the Japanese statistician Osamu Yamane. The formula is:

$n = N / (1 + N(e^2))$

where:

n = sample size

N = population size

e = margin of error (expressed as a decimal)

Taking the value of population N= 119, which is the total size of the population (Grade one) and a margin of error of 10 %, the Yamane formula would give you a sample size of:

$$n = 119 / (1 + 119(0.1^2)) = 54.333$$

Therefore, a sample size of 55 would be appropriate for this study.

3.7 Data Analysis

The data collected through pre-tested structured questionnaire then categorized and analyzed. Content analysis was further employed in the presentation of the results. The data tabulated, analysed and interpreted using SPSS (version 20), Relative Importance Index (RII) and Microsoft excel.

3.7.1 Statistical Package for the Social Sciences (SPSS)

SPSS, which stands for "Statistical Package for the Social Sciences," is a popular software program used for statistical analysis and data management. Descriptive Statistics SPSS provides tools to calculate and present descriptive statistics, such as means, medians, standard deviations, and frequencies, to summarize data. SPSS is widely used in academic research, market research, survey analysis, and various industries where data analysis plays a crucial role in decision-making. It has a large user base and a supportive community, which makes it a popular choice for statistical analysis and data exploration.

3.7.2 Relative Importance Index (RII)

Relative Importance Index (RII) is a non-parametric technique widely used by construction and facilities management researchers for analysing structured questionnaire responses for data involving ordinal measurement of attitudes.

3.7.3 Correlation Analysis

Correlation data analysis is a statistical technique used to determine the relationship between two or more variables. It measures the extent to which changes in one variable are associated with changes in another variable.

In correlation analysis, the strength and direction of the relationship between variables are expressed using a correlation coefficient. The correlation coefficient ranges from -1 to +1, where a value of -1 indicates a perfect negative relationship, +1 indicates a perfect positive relationship, and 0 indicates no relationship.

Correlation data analysis is widely used in various fields, including economics, social sciences, and finance, to explore and understand the connections between variables. It helps researchers and analysts identify patterns, make predictions, and assess the strength of relationships between variables.

To conduct a correlation data analysis, relevant data for the variables of interest need to be collected. Then, statistical methods such as Pearson's correlation coefficient or Spearman's rank correlation coefficient can be used to calculate the correlation between the variables. The results can be interpreted to understand the nature and strength of the relationship between the variables.

3.7.4 Regression Analysis

Regression analysis is a statistical technique used in data analysis to examine the relationship between one dependent variable and one or more independent variables. The goal of regression analysis is to understand the nature of the relationship, make predictions, and identify the strength and significance of the associations between variables.

In simple terms, regression analysis helps you to understand how changes in one variable are associated with changes in another. The variable you're trying to predict is called the dependent variable, while the variables you use to make the prediction are called independent variables.

3.7.5 Reliability and Validity

Validity and reliability are two important factors that determine the quality of research. Validity refers to the degree to which a study accurately measures what it is intended to measure, while reliability refers to the consistency of the results obtained in a study.

Here are some factors that affect the validity and reliability of research:

1. Sample Size: A small sample size can lead to unreliable results as it may not be representative of the larger population

2. Sampling Bias: Sampling bias occurs when the sample is not representative of the population being studied.

3.7.5.1 Reliability

Reliability is the overall internal consistency measure. The acceptance value for alpha if it equals to 0.70 or higher (Mirghani, 2016).

3.7.5.2 Validity

Validity is technical terms that refer to the objectivity and credibility of a research project. (Silverman, 2016). Validation of the data collected takes place throughout the process of data collection and analysis. since validity is one of the strengths of research as it defines the correctness of the information from the perspective of all the stakeholders of the research. In this research the logical process of constructing knowledge through brain storming is essential in providing concrete validity (Weston, et al., 2001). Furthermore, the questions in this research were developed from multiple literatures in the field of BIM

3.7.6 Qualitative Data Analysis

The research strategy that being use in this dissertation is qualitative research. Thematic analysis of qualitative data analysis is used for this research paper. Thematic analysis helps you identify, categorize, analyze, and interpret patterns in qualitative study data. Since it is qualitative research, it is necessary to analyse the content. It involves essentially analysing the interview contents to identify and isolate the main themes that permeate right through the responses from the interviewees Several steps are required to analyse the qualitative data:

Step 1: Set the objectives for the interview

Since the interview session is to obtain information to achieve the objectives of this research dissertation, the objectives of this research dissertation will as well be used as the objectives of the interview session.

Step 2: Identify and isolate main themes

Step 3: Classify responses under the main themes

A careful perusal of the descriptive responses from the interviewees for each question can uncover the meaning underlying the responses. Examine the responses in all the interviews and classify each response under the different themes which have developed. Use appropriate wording to accurately represent the meaning of the responses.

Step 4: Integrate themes and responses into the text of research write up.

While discussing the main themes that run through the research study, one can bring in verbatim responses to substantiate the discussion of the research.

3.8 Ethical Considerations

'Some important ethical concerns that should be taken into account while carrying out research are: anonymity, confidentiality and informed consent' (Sanjiri, et al., 2014, p. 1, my italics). Anonymity was achieved by not using any names of participants that contributed to this research; the participants were assigned codes in the transcription to maintain the anonymity (Saunders, etal., 2009) throughout the research. Additionally, no names or any other personal information will be used or distributed while making the presentation of the research. As part of keeping the of the participants, no personal information was taken Munhall (1988) argues that describing the experiences and information collected from participants in the most faithful manner is an ethical obligation to any researcher. This research has taken all the steps to keep the information true to its origin and has not been altered in terms of the meaning they carry.

CHAPTER FOUR

Result and discussion

4.1. Introduction

This chapter contains both analyses results and their interpretations. Under the explanatory type of research, the trends and overall performances of the variables are presented. The statistical tools such as tables, charts and graphs are used to describe the variables. The data tabulated, analyzed and interpreted using SPSS (version 20), Relative Importance Index (RII) and Microsoft excel.

As mentioned in section 3.6.3, the questionnaire form was distributed to 55 Grade I contractors and consultants implement in their companies out of which 49 Contractors & consultants have returned completed forms, representing an 89.09 % response rate.

4.2. Demographic Characteristics of Respondents

4.2.1 Gender

The gender distribution of respondents who filled up the questionnaires reveled that male respondents comprise the highest number of respondents which is 75.5% and female respondents take the share of 24.5%.

4.2.2 Age of Respondent

The second component of the figure shows below the age distribution of respondents. From the four age categories the dominant age group of the respondents is the one between the age of 20-29 (49 %) and 30-40(44.9%) followed by respondents between the age of 41-54 years (6.1%). No respondents between the age of over 55. This shows that the younger generation is mostly involved in this construction digitalization system.

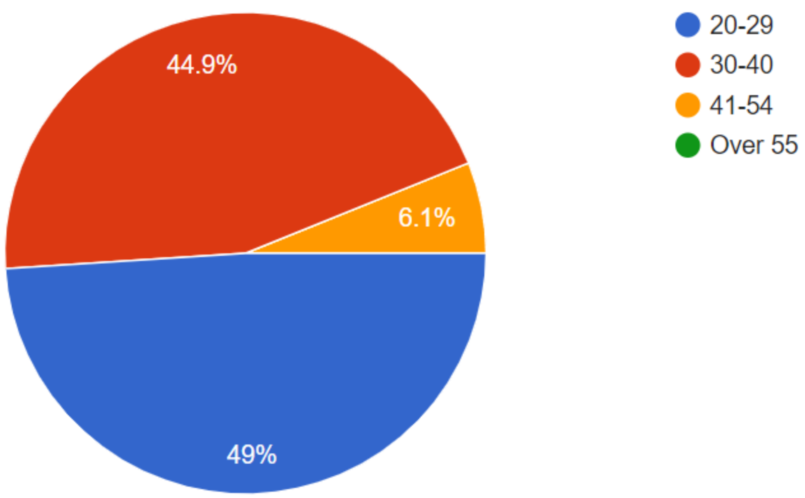


Figure 4-Age of Respondents

4.2.3 Educational level

The distribution of respondents' educational level has five layers of categories which represent certificate, Diploma, BSC Degree, MSC/MBA degree and PHD. According to the above Figure the majority of respondents have BSC Degree (73.5%) and MSC/MBA degree (26.5%). This shows almost all of the respondents are well educated and having enough knowledge.

4.2.4 Role in the Company

Role of respondent has been one of the variables considered with six different layers of Categories which represent Manager, Team leader, BIM Manager & project coordinator, Architect, Engineer and others, out of which the majority of them falls under Engineers category with 65.3%, Architect takes the second place with 20.4%, Team leader respondents Accounted for 4.1%, those working as Manager and BIM Manger(Project Coordinator) are 2% and finally respondents in the others Category score 6.1%. This indicates that Engineers and Architects are mostly participated in the BIM construction digitalization system.

4.2.5 Total year of experience in the construction sector

The figure below represents respondents' year of experience with in the construction center. Concerning year of experience with in the construction center respondents were given five choices to select among namely less than one year, 1-2 years, 3-5 years, 6-10 years and more than 10 years. Out of which 2 % of them have less than one year experience, 22.4% of the respondents have 1to 2 years of experience, 20.4% have 3 to 5 years of experience, 40.8% have 6 to 10 years of experience 14.3% have more than 10 years of experience. This Analysis indicates that the respondents are well experienced in the construction sector.

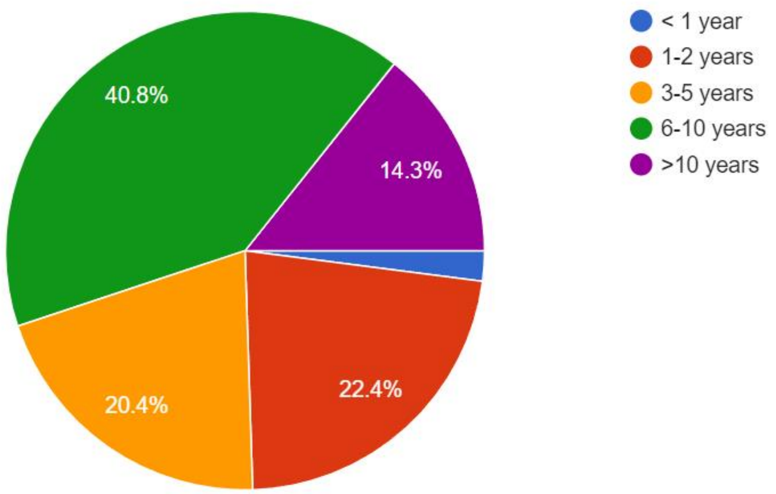


Figure 5-Year of Experience

4.3 Construction Digitalization and BIM Implementation

4.3.1 BIM Implementation & Digital Technologies used

BIM implementation refers to the preparedness, deployment, and improvement of BIM deliveries and workflows in a single organization, BIM diffusion demonstrates the rate that BIM tools and workflows are adopted across markets. BIM adoption regards to both BIM implementation and BIM diffusion. The BIM implementation proceeds through three phases. First, BIM readiness is the pre-implementation status regarding the planning and preparation for implementation, the potential to participate, or the capacity to innovate. Second, BIM capability refers to the determined implementation of BIM tools, workflows, and protocols. Third, BIM maturity presents the performance improvement milestones of BIM implementation.

In their construction process, almost all of the responding companies use construction digitalization. In terms of digital technologies for digitalizing construction 73.5 % of these organizations utilize Building Information Modelling (BIM), 16.3% use Construction management software, and the remaining 10.2% use mobile apps and others.

Regards to the organizational change for new technology adoption, Scott Morton (1991) developed the MIT90s Framework to help people understand the impact of adopting new technology in an organization. The model includes two groups of factors: internal components (structure, strategy, technology, management process, and individuals and roles) and external environment. Organizational culture as a part of an organization consists of organizational structure, management processes, and individuals and their roles. To develop the organizational readiness framework for BIM implementation in large design companies, five internal elements in the MIT90s framework are used as the baseline concept. However, the adoption of BIM is not only limited to the equipment of staff and technology infrastructure but also seen as a systematic approach to the lifecycle information related to a building. Information factors are also critical in BIM implementation (Chen et al., 2014). Therefore, six elements are studied to establish the organizational readiness framework for BIM implementation, including strategy, organizational structure, process, people, technology, and information

According to this research paper, In their projects and processes,47.6% of the responding organizations use Building Information Modelling (BIM), whereas just 52.4% do not use it in their projects just take the BIM training. Regarding the extensive use of BIM in organization projects that incorporate BIM, 37.5% of respondents from organizations concur, while 62.5% strongly disagree. This implies that the companies are not implementing BIM in their projects; those projects that incorporate BIM have a low extent of implementation and readiness level.

4.3.2 BIM maturity level

BIM maturity level can be described as ‘milestones’ for measuring the level of BIM adoption in a project, organization, or the construction industry within a specific region. The progressive and recognizable milestones are defined as different levels based on the level of collaboration promised by these milestones. We attempted to evaluate the company's BIM levels using these levels, which ranged from 0 to 3. Eight-point seven (8.7%) percent of the enterprises are at BIM level 0 (CAD), 49.4% are at BIM level 2 (collaborative BIM), and the remaining companies 41.9 % are at BIM level 1 (organized CAD).

The research indicates that the companies maturity level is BIM level 2 and level 1. This is distinguished by collaborative working all parties use their own 3D CAD models, but not necessarily working on a single, shared model. The collaboration comes in the form of how the information is exchanged between different parties and is the primary difference between Level 1 and 2. The design information is shared among varies parties with ease due to the use of a common file format which enables any organization to be able to combine that data with their own in order to make a federated BIM model, and to carry out interrogative checks on it.

4.3.3 Construction stage for BIM Implementation

Construction stage of implementation considered with five different layers of Categories which represent Planning stage, Design stage, Construction Stage, Operation stage and others. Out of which the majority of them falls under Design stage category with 67.3%, Planning stage takes the second place with 14.3%, Construction stage respondents Accounted for 12.2%, those on the operation phase are 2% and finally respondents in the others Category score 4.1%.

The majority of Building Information Modelling use occurs in the design phase exercised in our country. The digital model used at this critical stage allows for a complete visualization of the project and early detection of defects or gaps. Contrary to the design phase, the use of BIM in the operation phase is less widespread. However, the loss of data throughout the project, partially related to the multitude of stakeholders involved on-site, is a real problem that should not be overlooked. This research also ensures that we are using BIM mainly in design phase then planning phase but operation phase is not exercised yet.

Meanwhile most of the projects in the industry or public authorities focus on the planning or construction phase, the practical usage of BIM in operational phase within Facility Management (FM) is still rare.

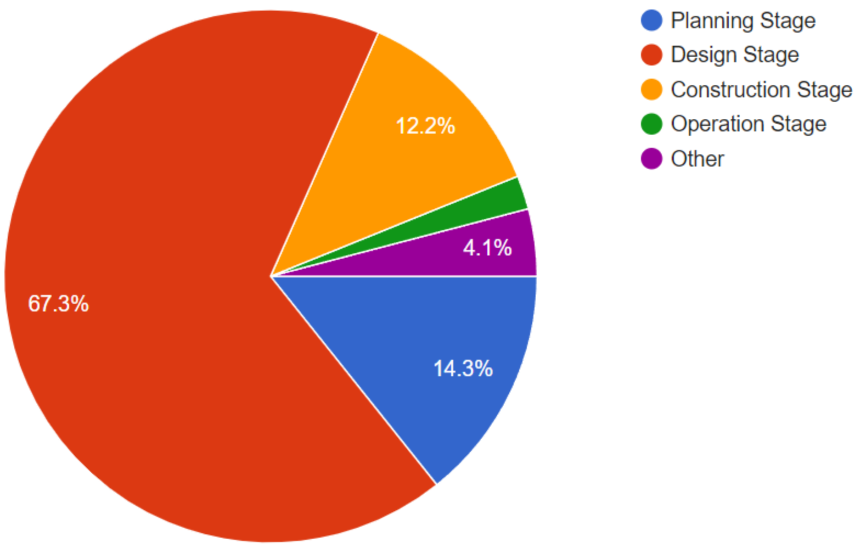


Figure 6-Construction stage of BIM Implmentation

4.3.4 BIM Utilization Extent

BIM utilization extent relates to dimensions; these refer to different aspects or levels of information that can be incorporated into the BIM models. Each dimension represents a specific type of data that enhances project management and decision-making throughout the project lifecycle. The types of BIM dimensions are 3D Modelling (3D Visualization and Clash Detection), 4D Modelling (Time estimation), 5D Modelling (Cost Estimation) and 6D & 7D Modelling (Sustainability factor and facility management). According to our assessment 79.6 % utilizes 3D Modelling (3D Visualization and Clash Detection), 12.2 % 4D Modelling (Time estimation), 6.1% 5D Modelling (Cost Estimation) and 2% 6D & 7D Modelling (Sustainability factor and facility management).

These dimensions enable the system to share an enhanced level of information, making the process much more efficient and transparent. Building Information Modelling technology has already evolved to 3D & 4D dimensions. Whereas the intervention of technology has led to the development of dimensions like 5D & 6D. Each BIM dimension has an attributed value of information that makes the system more efficient. While 4D BIM conveys timeline, scheduling, and duration information, 5D is more about cost estimation and budget analysis. Moreover, the 6D BIM dimension talks about building self-sustainable & energy-efficient values.

The research analysis summarized that the companies utilize 3D BIM dimensions in high level some of companies utilize the 4D BIM dimensions. In our country the construction industry is not utilizing 5D,6D & 7D dimensions. Each of these BIM dimensions is unique and has its purpose as well as contribution to the project. They help the stakeholders estimate project cost, gauge project timelines and calculate the building’s sustainability performance.

4.3.5 BIM tools (Software's)

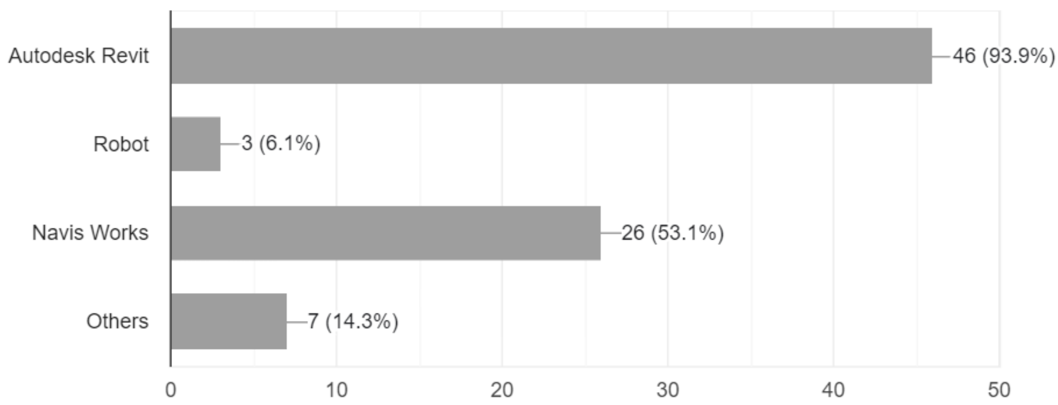


Figure 7-BIM tools

BIM is not a software tool but rather a process. It is however, greatly assisted by BIM-enabled software. So much so that in many instances, it would be justifiable to say that without BIM-enabled software and technology, BIM Levels 2 and 3 would be impossible to deliver, requiring as they do, digital communication of vast quantities of data. The respondent organization mostly uses Autodesk Revit and Navisworks as BIM-enabled software, while it also uses some other applications.

4.4 BIM based Construction Digitalization Benefit in terms of Productivity& Profitability

Building Information Modeling (BIM) offers several benefits in terms of productivity and profitability in the construction and architectural industries. There are perceived benefits of BIM use as a result of increased efficiency, collaboration, and communication to reduce project cost and time compared with the traditional approach. The effectiveness of Construction Digitalization/BIM for the successful delivery of construction is strongly agreed by all respondents of the construction companies.

4.4.1 Impacts of BIM based Construction Digitalization on productivity & profitability

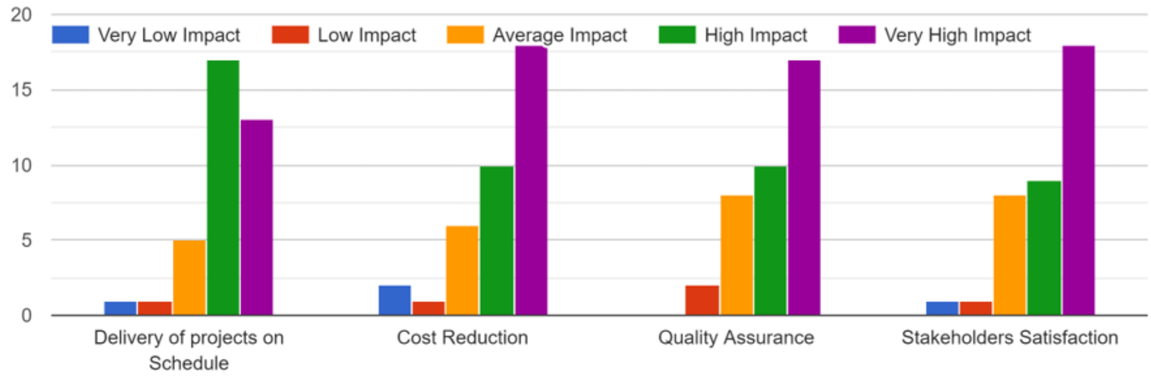


Figure 8-Impacts of BIM Based Construction Digitalization

From the above figure we can understand that BIM based construction have very high Impact for successful construction projects delivery in terms of delivery of projects on schedule, cost reduction, quality assurance and stakeholders' satisfaction.

Profitability Gains

BIM facilitates better collaboration among project stakeholders, including architects, engineers, contractors, and subcontractors. Improved coordination between disciplines helps prevent clashes and errors, reducing the need for rework and costly changes during construction. Improved coordination and clash detection reduce the likelihood of on-site issues, minimizing delays and rework. BIM helps in accurate quantity takeoffs and cost estimations, leading to better budget control.

Productivity Gains

BIM allows stakeholders to visualize the entire project in a 3D model, helping them understand the design intent and detect potential issues early in the process. Simulation tools enable analysis of various scenarios, optimizing designs for efficiency and performance.

Productivity gain is one of the major benefits of using BIM and is the top metric organisations expect to improve when they adopt the technology. Primarily, BIM realises this gain through

its ability to:

- Minimise project management
- Foster communication and co-ordination
- Identify errors early
- Reduce rework
- Reduce costs
- Improve quality.

We can conclude that from the research result and the literature reviewed before BIM has high Impact on all aspects of successful project delivery. It allows different teams to work together, no matter where they are. It's helping large-scale projects avoid delays and run more smoothly. There is an improvement in client and stakeholder relationships, plus cost and time estimates are much more reliable. Building Information Modeling (BIM) have high impact in terms of productivity and profitability in the construction.

4.4.2 Benefits of BIM-based Construction Digitalization

Building Information Modelling allows projects to be built virtually before they are constructed physically, eliminating many of the inefficiencies and problems that arise during the construction process. The benefits of BIM are through connecting teams, workflows, and data across the entire project lifecycle from design and engineering to construction and operations to realize better ways of working and better outcomes.

The Benefits were analysed using Regression analysis in SPSS software. The obtained results are shown below

Regression Analysis

Table 1- Building Information Modelling benefits

Descriptive Statistics

	Mean	Std. Deviation	N
For 3D Modelling and Visualization	4.3469	.85516	49
For clash detection	4.3673	.97241	49
For cost estimation	4.0204	.96803	49
For Quality Control	3.9388	.96627	49
For team collaboration and coordination	4.2653	.78463	49
For project scheduling	4.1224	.94940	49

Correlations

		For 3D Modelling and Visualization	For clash detection	For cost estimation	For Quality Control	For team collaboration and coordination	For project scheduling
Pearson Correlation	For 3D Modelling and Visualization	1.000	.846	.469	.556	.543	.306
	For clash detection	.846	1.000	.545	.490	.525	.379
	For cost estimation	.469	.545	1.000	.514	.459	.700
	For Quality Control	.556	.490	.514	1.000	.681	.553
	For team collaboration and coordination	.543	.525	.459	.681	1.000	.599
	For project scheduling	.306	.379	.700	.553	.599	1.000
Sig. (1-tailed)	For 3D Modelling and Visualization	.	<.001	<.001	<.001	<.001	.016
	For clash detection	.000	.	.000	.000	.000	.004
	For cost estimation	.000	.000	.	.000	.000	.000
	For Quality Control	.000	.000	.000	.	.000	.000
	For team collaboration and coordination	.000	.000	.000	.000	.	.000
	For project scheduling	.016	.004	.000	.000	.000	.
N	For 3D Modelling and Visualization	49	49	49	49	49	49
	For clash detection	49	49	49	49	49	49
	For cost estimation	49	49	49	49	49	49
	For Quality Control	49	49	49	49	49	49
	For team collaboration and coordination	49	49	49	49	49	49
	For project scheduling	49	49	49	49	49	49

Variables Entered/Removed[a]

Model	Variables Entered	Variables Removed	Method
1	For clash detection	.	Stepwise (Criteria: Probability-of-F-to-enter <= .050, Probability-of-F-to-remove >= .100).
2	For Quality Control	.	Stepwise (Criteria: Probability-of-F-to-enter <= .050, Probability-of-F-to-remove >= .100).

a. Dependent Variable: Productivity & Profitability

Model Summary[c]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	.846[a]	.715	.709	.46122	
2	.861[b]	.741	.730	.44419	1.844

a. Predictors: (Constant), For clash detaction

b. Predictors: (Constant), For clash detaction , For Quality Control

c. Dependent Variable: Productivity & Profitability

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	25.104	1	25.104	118.009	<.001[b]
	Residual	9.998	47	.213		
	Total	35.102	48			
2	Regression	26.026	2	13.013	65.952	<.001[c]
	Residual	9.076	46	.197		
	Total	35.102	48			

a. Dependent Variable: Productivity & Profitability

b. Predictors : (Constant): For clash detaction

c. Predictors: (Constant), For clash detaction, For quality control

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B		Correlations			Collinearity Statistics	
		B	Std. Error	Beta			Lower Bound	Upper Bound	Zero-order	Partial	Part	Tolerance	VIF
1	(Constant)	1.099	.306		3.589	<.001	.483	1.715					
	For Clash detaction	.744	.068	.846	10.863	<.001	.606	.881	.846	.846	.846	1.000	1.000
2	(Constant)	.801	.326		2.460	.018	.145	1.456					
	For Clash detaction	.664	.076	.755	8.773	<.001	.511	.816	.846	.791	.658	.760	1.316
	For quality control	.165	.076	.186	2.162	.036	.011	.318	.556	.304	.162	.760	1.316

a. Dependent Variable: Productivity & Profitability

Excluded Variables[a]

Model		Beta In	t	Sig.	Partial Correlation	Collinearity Statistics		
						Tolerance	VIF	Minimum Tolerance
1	For cost estimation	.012[b]	.127	.899	.019	.703	1.423	.703
	For Quality Control	.186[b]	2.162	.036	.304	.760	1.316	.760
	For team collaboration and coordination	.137[b]	1.517	.136	.218	.724	1.380	.724
	For project scheduling	-.017[b]	-.202	.841	-.030	.856	1.168	.856
2	For cost estimation	-.060[c]	-.628	.533	-.093	.623	1.606	.623
	For team collaboration and coordination	.042[c]	.383	.703	.057	.488	2.050	.488
	For project scheduling	-.122[c]	-1.357	.182	-.198	.678	1.474	.602

a. Dependent Variable: Productivity & profitability

b. Predictors in the Model: (Constant), For clash detaction

c. Predictors in the Model: (Constant), For clash detaction, For quality control

Collinearity Diagnostics[a]

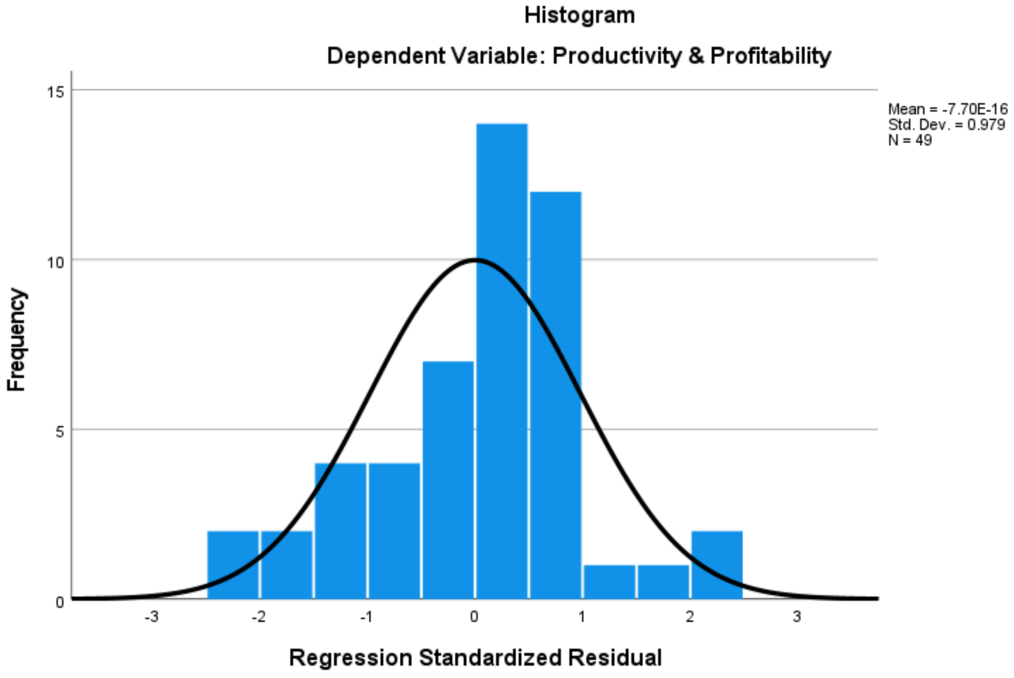
Model	Dimension	Eigenvalue	Condition Index	Variance Proportions (Constant)	BE2	BE4
1	1	1.977	1.000	.01	.01	
	2	.023	9.185	.99	.99	
2	1	2.948	1.000	.00	.00	.00
	2	.029	10.134	.41	.07	.93
	3	.023	11.285	.59	.93	.06

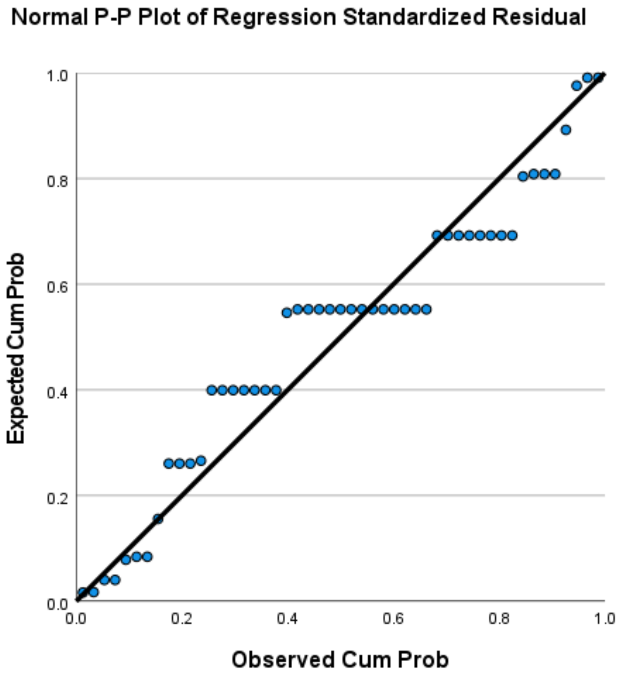
a. Dependent Variable: Productivity & Profitability

Residuals Statistics[a]

	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	1.6289	4.9414	4.3469	.73635	49
Residual	-.94870	1.05130	.00000	.43484	49
Std. Predicted Value	-3.691	.807	.000	1.000	49
Std. Residual	-2.136	2.367	.000	.979	49

a. Dependent Variable: Productivity & Profitability





The Analysis shows that BIM Benefits for clash detection and for quality control have significant benefits on productivity and profitability. The BIM approach allows enhancing the construction process with benefits such as a decrease in the project costs, a faster delivery of the result and an improved quality of the project.

BIM not only allows design and construction teams to work more efficiently, but it allows them to capture the data they create during the process to benefit operations and maintenance activities. This is why BIM mandates are increasing across the globe.

4.5 BIM based Construction Digitalization Barriers

4.5.1 Barriers for Effective use of BIM

The categorization of barriers to BIM adoption would be important to measure the maturity stage of BIM after it is adopted in a certain industry concerning the standard measurement tools of BIM implementation in every category. The categories listed below

- Process related barriers to BIM adoption
- Technology related barriers to BIM adoption
- Organization related barriers to BIM adoption
- Human/stakeholder related barriers
- Standards, policy, and guidelines related barriers

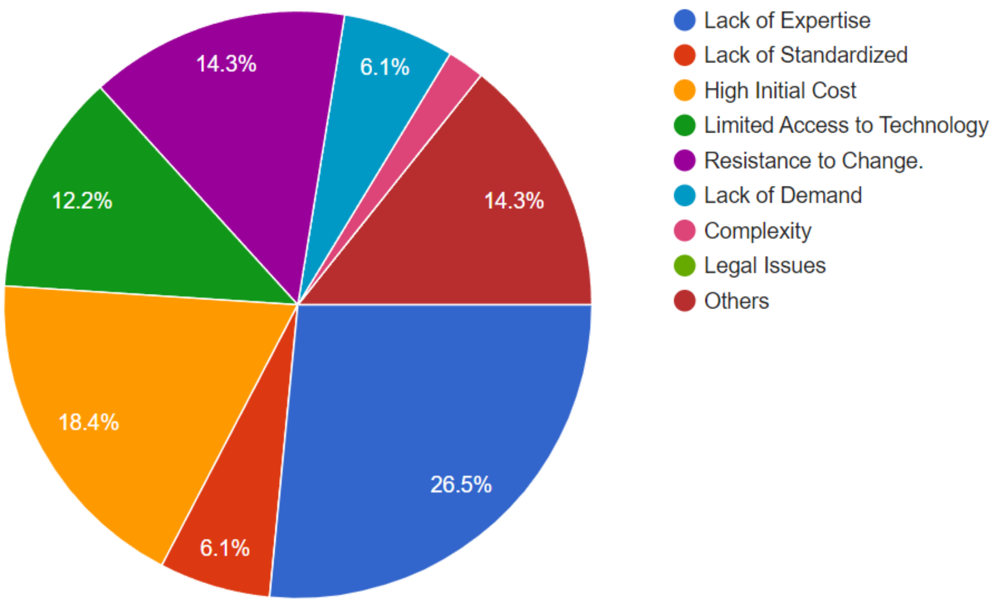


Figure 9-Barriers of BIM based construction digitalization

The effective use of BIM barriers is divided into seven layers of categories, as seen in the above diagram. The majority of the categories 26.5% come under the lack of expertise category, followed by high initial costs (18.4%), others and resistance to change (14.3%), limited access to technology (12.2%), lack of demand and lack of standardisation (6.1%), and complexity (25%). Every barrier found in the research analysis fits into one of the above categories and which negatively affects the construction industry to use BIM effectively.

4.5.2 Challenges of implementation of BIM-based Construction digitalization

Despite the demonstrated benefits from numerous case studies, there still remains a few BIM challenges that continue to hinder the wider adoption and implementation of BIM. A lot of smaller companies are apprehensive in shifting to the whole BIM process.

The challenges were analysed using Relative Importance Index (RII Table 2) and the frequency analysed from SPSS software. The obtained results are shown below

Table 2-Ranked Building Information Modelling challenges

No	BIM Challenges	Likert Scale	Wi	Frequency (fi)	fi*wi	∑ fi*wi	RII	Rank
	Organizational Culture	Very Low	6	5	30			
		Low	9	8	72			
		Average	5	4	20	560	2.285714	4
		High	22	18	396			
1		Very High	7	6	42			
	Stakeholder Engagement	Very Low	4	3	12			
		Low	5	4	20			
		Average	9	6	54	625	2.55102	2
		High	23	21	483			
2		Very High	8	7	56			
	Technology Infrastructure	Very Low	3	2	6			
		Low	10	9	90			
		Average	1	1	1	636	2.595918	1
		High	22	18	396			
3		Very High	13	11	143			
	Adequate BIM training and education for project team members	Very Low	4	3	12			
		Low	10	8	80			
		Average	2	2	4	576	2.35102	3
		High	21	16	336			
4		Very High	12	12	144			
	Project Size and Complexity	Very Low	4	2	8			
		Low	15	14	210			
		Average	10	9	90	492	2.008163	5
		High	14	11	154			
5		Very High	6	5	30			

The challenges of adopting BIM technology that ranked number one by the respondents was the lack of technology infrastructure on BIM software and hardware. The challenges of adopting BIM technology that ranked second according to the respondents was stakeholder engagement. Other challenges of adopting BIM ranked third is the lack of adequate BIM training and education for project team members. Then, the next challenges of adopting BIM involve organizational culture. lastly ranked challenge is project size and complexity.

Successful BIM adoption demands a level of expertise within the organization. It mandates a change in the organization's way of working. The cost and effort of leveraging BIM have restricted its impact to the larger, more visionary companies and projects. Construction companies in Ethiopia facing these challenges in BIM adaption.

4.7 Qualitative Data Analysis

4.7.1 Qualitative data Analysis

In addition to asking survey questions, the study tried to understand how BIM-based construction digitalization was being implemented and its effect on productivity & profitability by interviewing BIM experts. The interviewees were asked seven prepared questions. The responses from the interviewees are compiled here.

In Ethiopia's construction industry, the successful implementation of Building Information Modeling (BIM) can vary based on individual projects and companies. It's essential to conduct a comprehensive analysis of specific cases to determine the extent of BIM implementation in the country. The interviewees responses shows that there is extremely little implementation of BIM in their organization, even though the projects are just incorporating BIM into their projects. Currently, decision not to implement BIM stems from a comprehensive evaluation of the organizational needs, project requirements, and the existing technological infrastructure.

While recognize the numerous benefits that BIM can offer in terms of collaboration, efficiency, and project visualization, we have identified certain factors that led us to delay its implementation.

Firstly, current project portfolio may not fully leverage the advanced collaborative features of BIM. Primarily handle projects that are relatively straightforward in terms of design complexity and do not require the extensive coordination that BIM excels at. In such cases, the additional investment in BIM software and training might not yield a significant return on investment. The analysis reveals that most construction businesses do not completely utilise BIM due to the above-mentioned factors in addition to high initial investment cost. The implementation in interviewed companies is at initial stage of implementation.

Secondly, team has recently undergone changes, and we are in the process of assessing the skill sets and training needs of our staff. Implementing BIM would require a substantial investment in training programs, and want to ensure that our team is fully prepared to embrace and utilize the technology effectively. But the trained personals are also not implementing well.

While digitalization offers immense benefits, it also presents challenges. The industry needs to adapt to new technologies, and professionals must develop digital skills. Training and upskilling programs are crucial to ensuring that the workforce is equipped to leverage the full potential of digital tools like BIM.

Moreover, clients' preferences and requirements play a crucial role in shaping our technology adoption strategy. We consistently engage with our clients to understand their expectations, and currently, we haven't encountered a strong demand for BIM in our project delivery.

Building information modeling (BIM) has quickly attracted attention in the construction industry due to its promising benefits and has become the key technology affecting all phases of construction projects (i.e., design, construction, operation). BIM also offers a great potential to significantly enhance project performances through its integration with other emerging technologies, such as virtual reality (VR) for improved design inspection and laser scanning for capturing as-built conditions.

CHAPTER 5

Conclusion and Recommendation

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

5.1 Conclusion

The major current practices on BIM based construction digitalization implementation include

- According to the research, there is a low degree of BIM based construction digitalization adoption regards to both BIM implementation and BIM diffusion. BIM diffusion demonstrates the rate that BIM tools and workflows are adopted across markets. While working on projects, the majority of organisations do not use BIM. There is extremely little implementation (the initial implementation stage), even though the projects are just incorporating BIM into their projects. Implementation refers to the preparedness, deployment, and improvement of BIM deliveries and workflows in a single organization. Those organization in this research are partially integrated BIM into the companies' processes, as evidenced by their maturity level (BIM levels 1 and 2). Only 3D modelling is often used, indicating a low level of utilisation, and most organisations only use BIM during the design stage. We can conclude that Ethiopian construction companies implement BIM relatively little; this is seen from the companies' low levels of maturity, implementation stage, and utilisation extent.

- The research indicates that the effectiveness of construction digitalization and BIM on productivity and profitability for the successful delivery of construction is strongly agreed upon. However, there must be enough pushing factor to implement BIM. The potential impacts of BIM on successful project delivery on time, stakeholder satisfaction, cost reduction, and quality assurance are the key drivers for construction digitalization. We can conclude from the research results that BIM has a high impact on all aspects of successful project delivery, which drives the construction industry to implement digitalization and solve common construction industry problems.

- The research indicates that the BIM approach allows enhancing the construction process with benefits such as a decrease in the project costs, a faster delivery of the result and an improved quality of the project. We can conclude that from this research benefits of BIM for clash detection and for quality control have significant benefits on productivity and profitability.

- According to this research BIM uses many of the expensive software tools to process this leads to high Initial cost of software. Lack of trained personnel is also one of the main barriers in addition to incompatibility with other project stakeholders. Resistance to change and organizational culture are also barriers for BIM implementation.

5.2Recommendations

- Ethiopian construction companies implement BIM relatively little; this is seen from the companies' low levels of maturity, implementation stage, and utilisation extent. The government can play a massive role to present convenient practical strategic plans for BIM implementation by providing a timeframe to mandate BIM as an obligatory requirement in the construction industry projects. Develop and enact legislation or policies that clearly define the government's commitment to BIM implementation in construction projects. Clearly state the objectives, benefits, and expected outcomes of mandating BIM. Specify the minimum BIM requirements for construction projects, including the level of detail (LOD) and information (LOI) required at different project stages. Define standards and protocols for BIM data exchange, interoperability, and collaboration among project stakeholders.
- Invest in training and skill development. Establish training programs to equip professionals in the construction industry with the necessary BIM skills. Organizational decision makers have to ensure that their team is adequately trained in BIM software and methodologies. Provide ongoing training to keep them updated on the latest BIM advancements.
- Encourage educational institutions to incorporate BIM into relevant curricula. Creating awareness toward BIM by organizing events, seminars and discussion stages besides its important to include an introduction of BIM in the curriculums of undergraduate and graduate courses of engineering departments.
- For Individuals training and education: Invest time in learning BIM software such as Autodesk Revit, ArchiCAD, or Bentley MicroStation. Take advantage of online courses, tutorials, and certification programs to enhance your skills. BIM tools are constantly evolving, so stay updated with the latest software versions and features.

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APPENDIX

QUESTIONNAIRE

Questioner on Assessment of BIM-Based Construction Digitalization in Building Construction and Consulting Companies in Addis Ababa.

Dear respondents,

This questionnaire is prepared by Hanna Abayneh, Addis College Department of Construction Technology & Management second year master's Program student, who is currently working on the topic: Assessment of BIM-Based Construction Digitalization in Building Centre of Consulting and Construction Companies in Addis Ababa.

In order to achieve the goal of the study, I humbly request that you complete the questionnaire. Your information will be handled in the strictest of confidence and used only for academic purposes. Any form of support is greatly appreciated.

Thank you for your cooperation in advance!

Hanna Abayneh

abaynehhanna@gmail.com

Questioner on Assessment of BIM-Based Construction Digitalization in Building Construction and Consulting Companies in Addis Ababa

PART I. Background Information

Instruction

- Please read each question carefully.
- Kindly answer all the questions by ticking or filling in the spaces provided.

1. Gender
   - Male ☐
   - Female ☐
2. Age
   - 20-29 ☐
   - 30-40 ☐
   - 41-54 ☐
   - Over 55 ☐
3. What is your educational level?
   - Certificate ☐
   - Diploma ☐
   - BSC Degree ☐
   - MSC/MBA Degree ☐
   - PHD ☐

4. What is your role in the company?

- Manager
- Team Leader
- BIM Manager and Project Coordinator
- Architect
- Engineer (Civil, Structural, Electrical...)
- Other

5. Total year of experience in the construction sector?
   - < 1 year
   - 1-2 years
   - 3-5 years
   - 6-10 years
   - >10 years

PART II. Construction Digitalization and BIM Implementation

1. Do you use digitalizing in your construction process?
   - Yes
   - No

2. What digital technologies used in construction digitalization of your company?

   - Building Information Modeling (BIM)
   - Construction Management Software
   - Drones
   - IoT Sensors
   - Augmented reality (AR)
   - Virtual reality (VR)
   - Mobile Apps
   - Other

3. Does your company utilize Building Information Modeling (BIM) in its projects and processes?
   - Yes
   - No

4. If you have worked on projects that incorporated BIM, to what extent do you agree that BIM Is widely Implemented in your company?
   - Strongly Agree
   - Strongly Disagree

5. In your practice, in which BIM levels does the company Corporates?
   - BIM Level 0 (CAD)
   - BIM Level 1 (Organized CAD)
   - BIM Level 2 (Collaborative BIM)
   - BIM Level 3 (Interoperable Asset Information Modeling)

6. In which construction stage do you implement BIM?
    - Planning Stage
    - Design Stage
    - Construction Stage
    - Operation Stage
    - Other

7. In your practice, what are the extent of BIM utilization in projects ?
    - 3D Modeling (3D Visualization and Clash Detection)
    - 4D Modeling (Time estimation)
    - 5D Modeling (Cost Estimation)
    - 6D & 7D Modeling (Sustainability factor and facility managment)

8. Which of BIM tools (Software's) are used in your practice?
    - Autodesk Revit
    - Robot
    - Navis Works
    - Other

PART III . BIM based Construction Digitalization Benefit

1. To what extent do you agree that the effectiveness of Construction Digitalization/BIM for the successful delivery of construction projects?
    - Strongly Disagree
    - Strongly Agree
    - Neutral

2. How do you rate the impacts of BIM based Construction Digitalization for the success of building construction projects in terms of

	Very Low Impact	low Impact	Average Impact	High Impact	Very High Impact
Delivery of projects on Schedule					
Cost Reduction					
Quality Assurance					
Stakeholders Satisfaction					

3. What are the most valuable benefits of BIM based Construction Digitalization for the Company Productivity & Profitability?

	Very Low	low	Average	High	Very High
For 3D Modeling and Visualization					
For clash detection					
For cost estimation					
For Quality Control					
For team collaboration and coordination					
For project scheduling					

PART IV . BIM based Construction Digitalization Barriers

1. If you don't use BIM Effectively, please specify the reason.
   - Lack of Expertise ☐
   - Lack of Standardized ☐
   - High Initial Cost ☐
   - Limited Access to Technology ☐
   - Resistance to Change. ☐
   - Lack of Demand ☐
   - Complexity ☐
   - Others ☐
2. What are the challenges of implementation of BIM based Construction digitalization in projects under your construction company?

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Organizational Culture					
Stakeholder Engagement					
Technology Infrastructure					
Adequate BIM training and education for project team members					
Project Size and Complexity					

Interview Guide

This Interview questions are prepared for information gathering purpose and any form of support is greatly appreciated

1. Full name?
2. Position within the company and year of experience?
3. In Ethiopia's construction industry, do you believe BIM has been successfully implemented? and in your company, too?
4. What are the key benefits of implementing BIM in construction projects in terms of productivity & profitability?
5. What challenges or obstacles might be faced during the implementation of BIM in construction projects, and how can they be overcome?
6. What software tools or platforms are commonly used for BIM in the construction industry, and how do they differ?
7. In what ways can digital technologies, beyond or in collaboration with BIM, further enhance the efficiency and productivity of construction projects?