INVESTIGATING THE INFLUENCE OF BUILDING INFORMATION MODELLING (BIM) ON ENGINEERING CONTRACT MANAGEMENT IN KENYA: THE CASE OF NAIROBI COUNTY

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Investigating the Influence of Building Information Modelling (BIM) on Engineering Contract Management in Kenya: The Case of Nairobi County

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DECLARATION

This thesis is my original work and has not been presented for a degree in any other university.

Signature…………………………………. Date……………………….

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This thesis has been submitted for examination with our approval as the university supervisors.

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DEDICATION

To my Dad Zephaniah Mose and Mum Kemunto Mose you had the faith and the vision, now it is a reality. Smile with me from beyond for this success.

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I acknowledge the divine intervention throughout this process, to God be the glory.

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You have all left a beautiful mark in my life and may God bless you all.

I take full responsibility for this study. Any errors do not in any way reflect the contribution of the aforementioned.

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LIST OF ABBREVIATIONS AND ACRONYMS

2D-8D	Two-eight dimensions
AEC	Architecture, Engineering, Construction
AECO	Architecture, Engineering, Construction and Operation
BDS	Building Description Systems
BIM	Building Information Modelling
BPM	Building Product Model
CAD	Computer Aided Design
ECM	Engineering Contract Management
GBM	Generic Building Model
GLIDE	Graphical Language for Interactive Design
ICT	Information and Communication Technologies
IFC	Industry Foundation Classes
IPD	Integrated Project Delivery
NPB	Noteworthy BIM Publications
ROI	Return on Investment
TPS	Traditional Procurement System

ABSTRACT

Building Information Modelling (BIM) is a technology and a process that has brought changes in the construction procurement system. Kenya lacks contractual guidelines on implementation of BIM, and this makes the adoption of BIM slow and difficult. Previous research on BIM has left a gap in contractual relationships, roles and resulting risks. The purpose of this study was to investigate how contractual roles and responsibilities are affected by BIM in relation to systems and structures. The objectives were to assess BIM adoption, determine underlying components in its adoption, investigate influence of BIM on Engineering Contract Management (ECM) in Nairobi, Kenya and to formulate a BIM adoption and implementation framework. The research was designed as a survey. It targeted an individual within eight strata that comprised of Civil Engineers, Construction Project Managers, Architects, Quantity Surveyors, Mechanical Engineers, Electrical Engineers, Contractors and Facility Managers. Data were collected through self-administered questionnaires with a sample size of 371 and in-depth interviews comprising of 10 knowledgeable persons. Descriptive analysis, correlation analysis, regression analysis and Exploratory Factor Analysis techniques were used to analyse quantitative data. Qualitative data were analyzed thematically. It emerged that BIM adoption level was at 56.6% and shallow understanding of BIM capabilities and the Traditional Procurement System (TPS) remain a barrier to its adoption and implementation. It was also established that BIM improves ECM; that is when time, cost, quality, collaboration and return on investment improve, ECM becomes effective and efficient. The underlying factors found in BIM and ECM relationship were legal implications, awareness and knowledge, efficiency, versatility, mandate and leadership, and competitiveness. Further, the study found out that BIM influence on ECM demands for establishment of standards, guidelines and legal framework which can be achieved by amending the Public Procurement Act. BIM needs a new system to perform in because it conflicts with the traditional system of procurement. The knowledge gained will be important to the construction industry professionals, clients, students, and the government towards the efforts of BIM adoption and implementation in Kenya. The study formulated a BIM adoption and implementation framework.

CHAPTER ONE

INTRODUCTION

1.1 Background to the study

Building Information Modelling (BIM) adoption befits the dynamic nature of the construction industry that is characterized by unique projects with limited time and money. BIM presents a chance for continuity and consistency of information to enable collaboration in the lifecycle of a project (Nicał & Wodyński, 2016). Currently, the Kenyan industry is fragmented and adversarial in nature and is managed through the Traditional Procurement System (TPS), which allows BIM to utilize the three dimensional (3D) visualization only (Kumar & Hayne, 2016; Musyimi, 2016), whereas BIM demands for lifecycle utilization, thus creating conflict between BIM system and TPS (Bosch-sijtsema & Gluch, 2019). BIM is a system and not a software; it is about process, policy, and technology. One of the definitions of BIM states that: “BIM is a set of technologies, processes and policies enabling multiple stakeholders to collaboratively design, construct and operate a facility, further it is a methodology that generates, exchanges and manages construction facility’s data throughout its lifecycle” (Succar, 2013, p. iii). Computer Aided Design (CAD) is being phased out and the world is moving to BIM platform, countries must either implement it or lag behind leading countries (Khodeir & Nessim, 2017; Musyimi, 2016; Nicał & Wodyński, 2016).

BIM is a system with numerous benefits that the construction industry can use to make Engineering Contract Management (ECM) effective and efficient. Even though it is clear that BIM is the future option, there is absence of clear consensus on how to implement BIM, how to use BIM, how to handle contractual relationships and how to distribute the cost incurred during implementation (S. Azhar, Khalfan, & Maqsood, 2012). The industry generally lacks three ingredients which are key to BIM implementation: government regulatory effort to mandate BIM, a key champion to promote BIM and Noteworthy BIM Publications (NBP) (McAuley, Hore, & West, 2017). Major impediments to BIM implementation include, unclear legal status in relation to the collaborative nature of BIM (Manderson, Jefferies, & Brewer, 2015), how BIM should be defined by the scope of contracts (Olsen & Taylor, 2017), lack of universal contractual guidelines for BIM system (Arshad, Thaheem, Nasir, & Malik, 2019), lack of BIM standards (Bui, Merschbrock, & Munkvold, 2016) and legal, contractual and organizational risks (S. Azhar et al., 2012). Furthermore, there have emerged new skills that lack training or experience, hence, creating a gap towards roles and responsibilities (Arshad et al., 2019; Nicał & Wodyński, 2016). This in turn puts pressure on policy, decision making and procurement systems (Kumar & Hayne, 2016).

Globally, United States, United Kingdom and Scandinavian countries are leading in adoption due to government mandates (P. Smith, 2014b). Africa and other developing countries are facing various barriers to adoption (Bui et al., 2016). Whereas in Kenya, the TPS, lack of standards, guidelines and lack government efforts derails BIM adoption (Kimani, Jallow, Njuguna, & Alkizim, 2019; Manza, 2016; Musyimi, 2016). Studies on performance of the TPS in construction show that there needs to be a change of culture and attitude in the construction industry, to steer the move from traditional adversarial relationship into BIM cooperative and collaborative relationship. Accordingly, complexity, uncertainty and time pressure that characterize construction projects are increasing the need for this change (Hasanzadeh, Hosseinalipour, & Hafezi, 2014).

Research on BIM adoption, BIM's legal implications and contractual context for BIM has been carried out in developed countries, and the findings can be applied to most country scenarios (Arshad et al., 2019; S. Azhar et al., 2012; Borjeghaleh & Sardroud, 2016; Eadie, McLernon, & Patton, 2015; Kassem, Succar, & Dawood, 2014; Kekana, Aigbavboa, & Thwala, 2014; Khodeir & Nessim, 2017; Kumar & Hayne, 2016; Manderson et al., 2015; McAuley et al., 2017; Nicał & Wodyński, 2016; Olatunji, 2011; P. Smith, 2014b; Succar & Kassem, 2017). However, Bui et al. (2016) recommend comprehensive and customized research in developing countries to address localized perspectives, while also noting that there is limited attention given to BIM implementation in infrastructure and facilities management projects in developing countries.

Studies on BIM adoption in Kenya have been carried out and barriers to adoption identified (Kimani, Njuguna, Alkizim, & Jallow, 2018; Manza, 2016; Mutonyi & Cloete, 2018), however, there is a research gap that needs to address the legal and institutional framework that will enable the industry to adopt and implement BIM within the confines of a legal contractual framework. Musyimi (2016), opines that there is need to address the changing contractual relationships and responsibilities of stakeholders on the adoption of BIM. Further, The construction industry is unable to cooperate not because of lack of technological solutions (Nicał & Wodyński, 2016) but because there is no clear consensus on how to implement or use BIM or how to handle legal contractual relationships and risks (S. Azhar et al., 2012).

The present study therefore investigates BIM adoption and its influence on ECM in Nairobi Kenya. BIM being a relatively new technology, the study further investigates how BIM affects contractual roles, responsibilities, relationships and risks and whether the optimal performance of such new technologies rely on systems and structures support to achieve project success. It also sought to analyse the underlying factors both in BIM adoption and in BIM's influence of ECM.

1.2 Problem statement

The construction industry is dynamic in nature and is characterized by unique projects with limited time and money. Currently, inefficient collaboration and information management discontinuity has contributed to poor quality delivery, time and cost overruns in the lifecycle of a project. Advancement in modern technology has resulted into trends that contribute to construction projects becoming green, large scale and more complex. Without the necessary technology it is possible to duplicate efforts. While most BIM studies in Kenya, have focused on adoption of BIM in specific disciplines of construction or dimensions of BIM, the studies on influence of BIM adoption on the Engineering Contract Management (ECM) has not been undertaken.

In the Traditional Procurement System (TPS) design, construction, operation and maintenance stages are separate and independent, this has contributed to adversarial relationships in the industry. Additionally, TPS mainly utilizes 2 dimensional (2D) drawings either in softcopy or hardcopy; information is lost, misplaced or scattered, and there is a danger of using superseded versions. The foregoing has affected communication, collaboration, decision making and buildability; often varying opinions and interpretations are expected because components of design are understood differently and especially at preconstruction. Where components clash, it gets detected at construction when it is too late to avoid extra costs. The TPS has no reliable way of checking for duplication of efforts but BIM system uses computer simulation to deliver a solution before actual construction. The lack of consistency and continuity leads to avoidable reworks and conflicts hence negatively affecting the performance of ECM.

The BIM system fills this gap left by TPS, however, there are impediments to its adoption: Kenya lacks a legal framework for BIM implementation, more so due to its collaborative nature that is changing relationships, roles, responsibilities and risks. The Kenyan industry lacks consensus and a formula on how to handle BIM implementation, changes, legal implications and contract management. The consensus is made harder by the fragmented nature of the construction industry, absence of the Government's efforts to mandate BIM, lack of universal contractual standards and guidelines, absence of a key champion and Noteworthy BIM Publications (NBPs). The present study sought to investigate the industry players opinions and find out how the industry is interacting with BIM in presence of these impediments. It further sought to find out the changes brought by BIM in relation to ECM in Nairobi Kenya.

1.3 Study Objectives

1.3.1 General objective

To investigate the influence of Building Information Modelling (BIM) on Engineering Contract Management (ECM) in Nairobi Kenya with the aim of formulating a BIM adoption and implementation framework.

1.3.2 Specific objectives

The specific objectives of the study are: -

1. To assess Building Information Modelling (BIM) adoption in Nairobi, Kenya.
2. To determine the underlying components in Building Information Modelling (BIM) adoption in Nairobi, Kenya
3. To investigate the influence of Building Information Modelling (BIM) on Engineering Contract Management (ECM) in Nairobi, Kenya
4. To formulate a Building Information Modelling (BIM) adoption and implementation framework.

1.4 Hypothesis

Hypothesis 1 was based on objective 2 and hypotheses 2 and 3 were based on objective 3.

Hypothesis 1:

Null Hypothesis (H_0): There are no underlying factors associated with BIM adoption.

Scientific Hypothesis (H_a): There are underlying factors associated with BIM adoption.

Hypothesis 2:

Null Hypothesis (H_0): There is no relationship between BIM and Engineering Contract Management (ECM).

Scientific Hypothesis (H_a): There is a relationship between BIM and Engineering Contract Management (ECM.

Hypothesis 3:

Null Hypothesis (H_0): There are no underlying factors of BIM's influence on Engineering Contract Management (ECM).

Scientific Hypothesis (H_a): There are underlying factors of BIM's influence on Engineering Contract Management (ECM).

1.5 Significance of the study

The research probes acceptance of new technologies and how these technologies affect existing systems and structures. As these new technologies are being adopted, stakeholders would want to achieve optimal performance, consequently, demands arise for the principal agent or governments to establish contractual backing crucial in adoption and implementation. The study is therefore a timely contribution to knowledge on how new technologies demand for new structures and systems to enable efficiency and effectiveness in management. Therefore, the study fills the gap left by the influence of BIM on ECM upon its adoption and the resulting legal implications. It by extension stimulates the technological and legal fraternities to deliberate on the resulting contractual uncertainties to facilitate the uptake of BIM in the industry. The study highlights the gap that exists in the much-needed policy to guide BIM implementation, whose responsibility is the Government and its agents. Thus, the study seeks to formulate a BIM adoption and implementation framework to address the gap within the confines of this research.

1.6 Study Justification

The study is important to the Architecture, Engineering, Construction and Operation (AECO) industries by forming a basis for standardized guidelines which will make collaborating easier besides making BIM adoption process gradual rather than abrupt. The study identifies various legal implications that BIM triggers in contractual relationships of the clients, professionals and contractors towards their roles and responsibilities. It is also important to the government and its construction regulatory bodies in laying the foundation for formulation of the much-needed BIM policy framework. The BIM system has no legal precedence in Nairobi, there is need to establish a legal framework to respond to the legal issues that will arise.

Construction cannot continue to use outdated methods, because modern trends require equally modern techniques to solve problems. It is paramount to carry out economic activities efficiently and effectively without wasting resources, BIM is about saving resources through cooperation and collaboration. Green construction is relevant globally, knowledge of BIM enables energy and sustainability analysis through computer simulation prior to construction to enable responsible use of available resources for current and future generations. The new roles that the study identified provide job opportunities that will need trainers and training institutions. The new roles include BIM manager, BIM coordinator and BIM modeler. The study also identified areas for further research on BIM related topics.

1.7 Study Scope and Limitations

1.7.1 Scope

Geographically, the study is focused on Nairobi County. This is because Nairobi has the highest percentage of construction activities in Kenya (Republic of Kenya, 2014). For instance, 40% of construction companies are based in Nairobi (National Construction Authority, 2019), 87% of Consulting Engineers registered by Engineers Board of Kenya practice in Nairobi (Engineers Board of Kenya, 2019), 92% Architectural firms and 98% of Quantity Surveyor's firms registered by Board of Registration of Architects and Quantity Surveyors are in Nairobi. Further, Nairobi is the centre of businesses, technology and education in Kenya. Majority of the construction professionals practice in Nairobi. The high population in Nairobi makes it economically vibrant; it has a population of 4,397, 073, which is higher than any other counties (Kenya National Bureau of Statistics, 2019a).

Theoretically, the study uses Contract Theory, Diffusion of Innovation theory (DOI), theory of Technology Acceptance Model (TAM) and System Theory of Management (STM). The contract theory entails how parties to a contract organize their activities within a legal framework. DOI and TAM detail how BIM as a new technology spreads:

at varying rate of acceptance and it goes through levels of social systems and structures and judged on job relevance and output quality (Dwivedi, Rana, Jeyaraj, Clement, & Williams, 2017; Succar, 2013). In STM and contract theory, this new technology affects the existing systems and structures and automatically demands for new laws and policy from the principal party (Mouzas & Blois, 2008). The Management concerned will need to set up alternative systems and structures to consolidate interrelationships.

Methodologically, this is survey research, whose focus was on consultants aware of BIM regardless of their adoption status. The eight strata consultants included Civil Engineers, Construction Project Managers, Architects, Quantity Surveyors, Mechanical Engineers, Electrical Engineers, Contractors, and Facility Managers. Self-administered questionnaires and in-depth interview were used to collect data from the construction consultants. Data was analyzed using descriptive analysis, correlation analysis, regression analysis, exploratory factor analysis (EFA), and thematically resulting to both quantitative and qualitative data. This led to formulation of BIM adoption and implementation framework.

1.7.2 Limitations

The study was limited to a sample in Nairobi at the period of data collection due to cost and time restrictions. However, the study may apply to other counties within Kenya because the laws are uniform across the country, majority of professionals are based in Nairobi and they carry out projects all over the country further, the construction contracts are the same in all counties.

1.8 Study Organization

This thesis is delivered in five chapters. Chapter one is an introductory chapter, it presents the background to the study problem statement, purpose of the study, objectives, hypothesis, study assumptions, study scope, study significance and study justification and limitation.

Chapter two presents literature review starting with understanding BIM and its adoption, BIM and contract management, theoretical framework and conceptual framework.

Chapter three analyses the research methodology under titles the research design, data collection methods, pilot survey, data analysis, data presentation, and ethical consideration.

Chapter four presents the results and discussion per objectives. It begins with adoption of BIM in Nairobi is presented followed by underlying factors of BIM adoption and finally influence of BIM on ECM.

Chapter five presents conclusions and recommendations which are organized per objective. It also outlines BIM adoption and implementation framework. The chapter concludes with area for further research.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This chapter presents literature that leads up to identification of the research gap. Building Information Modelling (BIM) and adoption have its subtopics, namely the definition of BIM; history of BIM; difference between BIM and CAD; BIM knowledge; BIM adoption globally, in Africa and in Kenya; factors guiding BIM adoption; benefits of BIM; challenges of BIM and Barriers to adoption. Contract management, effects of BIM on contracts and legal and institution framework for BIM adoption are topics also reviewed. The chapter ends with the theoretical framework, conceptual framework and discussion of the literature review.

2.2 BIM and its Adoption.

2.2.1 Approaches to BIM Definition

Succar (2013) defines BIM as: “a set of technologies, processes and policies enabling multiple stakeholders to collaboratively design, construct and operate a facility” (p. iii). Autodesk (2019) defines BIM as an intelligent 3D model-based process that gives architecture, engineering, construction and operation (AECO) professionals the insight and tools to more efficiently plan, design, construct and manages buildings and infrastructure. According to The National Institute of Building Science, United States, (2019):

> “BIM is a digital representation of the physical and functional characteristics of a facility, BIM is a shared knowledge resource for information about a facility, forming a reliable basis for decisions during its (facility) life-cycle; defined as existing from earliest conception to demolition” (https://www.nationalbimstandard.org/faqs#faq1).

BIM is more than just a 3D digital model; it is also an intelligent database from where all the information of the building can be obtained in a collaborative environment. The model comprises the virtual equivalents of intelligent building elements allowing simulation of the facility so as to understand its behaviour in a computer environment before actual construction (Graphisoft, 2019).

Several terms have been used worldwide to refer to BIM. Succar, Sher, Aranda-mena, & Williams (2007) states that although the term BIM has been used and is accepted extensively, other terms that have been used include: Asset Lifecycle Information System by Fully Integrated & Automated Technology; Building Information Modelling (BIM) by Autodesk and Bentley Systems; Building Products Models by Charles Eastman a BIM researcher; BuildingSMART™ by International Alliance for Interoperability; nD Modelling by School of the Built Environment the University of Salford; Virtual Building™ by Graphisoft; Virtual Design and Construction & 4D Product Models by Centre for Integrated Facility Engineering Stanford University.

While all these terms are valid, the present study chose to use the term Building Information Modelling (BIM) as it is the term used in Kenya and in research papers that were reviewed. This study, therefore, defines BIM as a digital innovation that consists of a set of technologies, processes and policies based on an intelligent 3D model enabling AECO stakeholders to effectively collaborate throughout the lifecycle of the facility.

2.2.2 History of BIM

The years starting from 1980's to 2000's have seen a major shift in Information and Communication Technologies (ICT) for the construction industry by the implementation of BIM which is considered by the majority of industrial professionals and academic researches as the biggest paradigm shift after Computer Aided Design (CAD) (Kalinichuk, 2015). The History of BIM as illustrated by Goubau (2012) dates back from 1957 when Pronto was developed by Dr. Patrick Hanratty. It was originally a numeric control machining technology that later developed to Computer Aided Manufacturing (CAM). CAD and CAM were developed in the 1960's separately but were later intertwined. Dr. Hanratty, later developed computer-generated graphics and then developed Design Automated by Computer (DAC) in 1961 which was the first

CAD/CAM system that had interactive graphics and was used for General Motors complex die molds. In 1962 Douglas C. Englebart wrote a paper titled ‘Augmenting Human Intellect’ in which he made the first suggestion of object-based design, parametric manipulation and relational database (Bergin, 2012; Goubau, 2012). BIM as it is known today was first described by Charles Eastman in 1975, who published a paper of a prototype called Building Description Systems (BDS), that experimented on design applications. Graphical Language for Interactive Design (GLIDE) was created in 1977 by Charles Eastman. It exhibited most of the modern BIM characteristics but mainly on design and cost estimation (Goubau, 2012; Latiffi, Brahim, & Fathi, 2014).

Years later, in 1986 RUCAPS CAD program was developed and used in terminal 3 Heathrow Airport prefabricated construction system and the program is regarded as the forerunner of today’s many BIM software (Eastman, Teicholz, Sacks, & Liston, 2008). GLIDE was in use up to 1989, when Building Product Model (BPM) was developed. BPM was an application for design, estimation and construction process; then, in 1995 it was followed by Generic Building Model (GBM) with an aim of integrating information in the lifecycle of a project. However, due to the complexity of modern day construction environment and need for better performance, BIM was finally fully developed (Latiffi et al., 2014).

Several software supporting BIM were created as from 1980’s to 1990’s. Graphisoft ArchiCAD was created in1982 by Gabor Bojar in Hungary which marked the beginning of BIM, it was launched in 1987 making it the first BIM software available on a personal computer (P. Smith, 2014b). In 1988 Pro/Engineer was developed by Parametric Technology Corporation (PTC) which was, in BIM history, considered to be the first parametric modelling design software. International Foundation Class (IFC) file format was developed with the purpose of sharing files from different software platforms that support BIM (Goubau, 2012). Finally, in 2000 there was a global rush towards BIM implementation, one of the software being Autodesk’s Revit which was developed in 2000 and facilitated effective BIM implementation (P. Smith, 2014b). Presently BIM has been developed to allow all data access from mobile devices by client, contractor and the professionals from wherever they are (Graphisoft, 2019). Figure 2.1 shows the evolution of BIM.

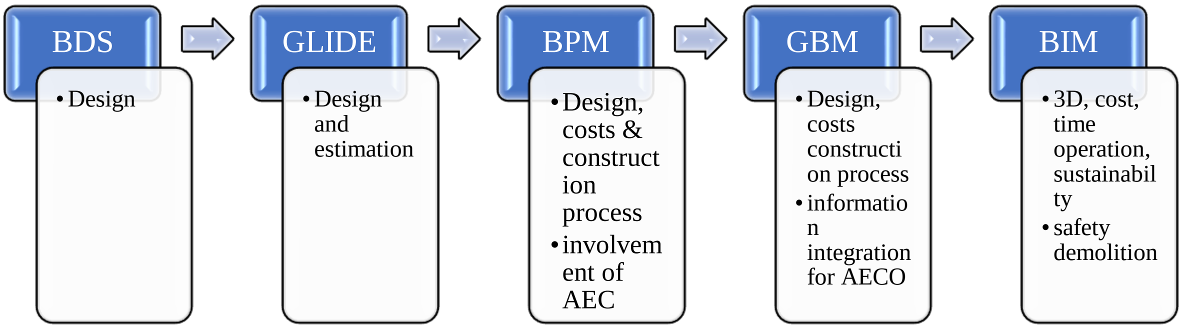


Figure 2.1: Evolution of object-based design from 1970's to present.

(Source: Goubau, 2012; Latiffi et al., 2014; P. Smith, 2014a)**.**

This history has shown that BIM has a dynamic evolution pattern, therefore its studies need to always be up to date. While the Kenyan construction industry missed participating in its innovation processes, it can still fill the gap left by the dynamics of BIM as a technology.

2.2.3 Difference between BIM and CAD

Autodesk (2019) defines CAD as technology for design and technical documentation, which replaces manual drafting with an automated process, either in 2D or 3D. Whereas BIM is a platform with technology, process, and policy. CAD drawings are created independently and modifications done on one of them has to be manually updated on each of the other drawings, whereas BIM is based on 3D parametric model and allows designers to come up with drawings similarly as the actual construction with all data stored within the model (Graphisoft, 2019). BIM includes Geometry (location of points in space), topology (connectivity between the points) and semantics (the meaning, the model has information useful in the lifecycle of the project) whereas CAD includes geometry and topology but lacks semantics (Kumar & Hayne, 2016).

The literature review shows that CAD and BIM are not software. A software supporting BIM should provide: openness, interoperability, simplicity, functionality, accuracy of Data, expandability (3rd party plug-in), time management, clash detection, cost estimation and facility management (Bouška, 2016). CAD is a system that replaced manual drafting and BIM is replacing CAD. Figure 2.2 shows evolution of design processes; from hand drafting to 2D CAD drafting to 3D CAD to BIM which is where the construction industry is currently at or migrating to. While the present research has tried to explain what BIM is through the literature review, the construction industry has a task of training the players thoroughly to eliminate confusion.

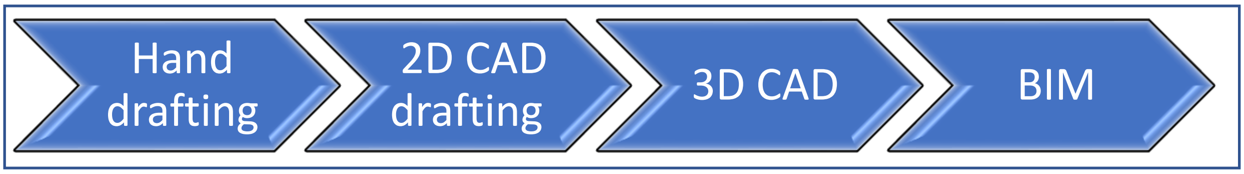


Figure 2.2: Evolution of design process.

(Source: Thomas, 2015)**.**

2.2.4 BIM Framework, Knowledge and Concepts

This section covers the BIM framework, dimensions and Noteworthy BIM Publication (NBPs). The BIM framework can be divided into three; BIM field - identifying domain players their requirements and deliverables; BIM stages - depicting minimum capability benchmarks; BIM lenses - represents layers of analysis to field and stage fields to generate necessary knowledge to topic (Succar, 2013). This framework is shown on Figure 2.3.

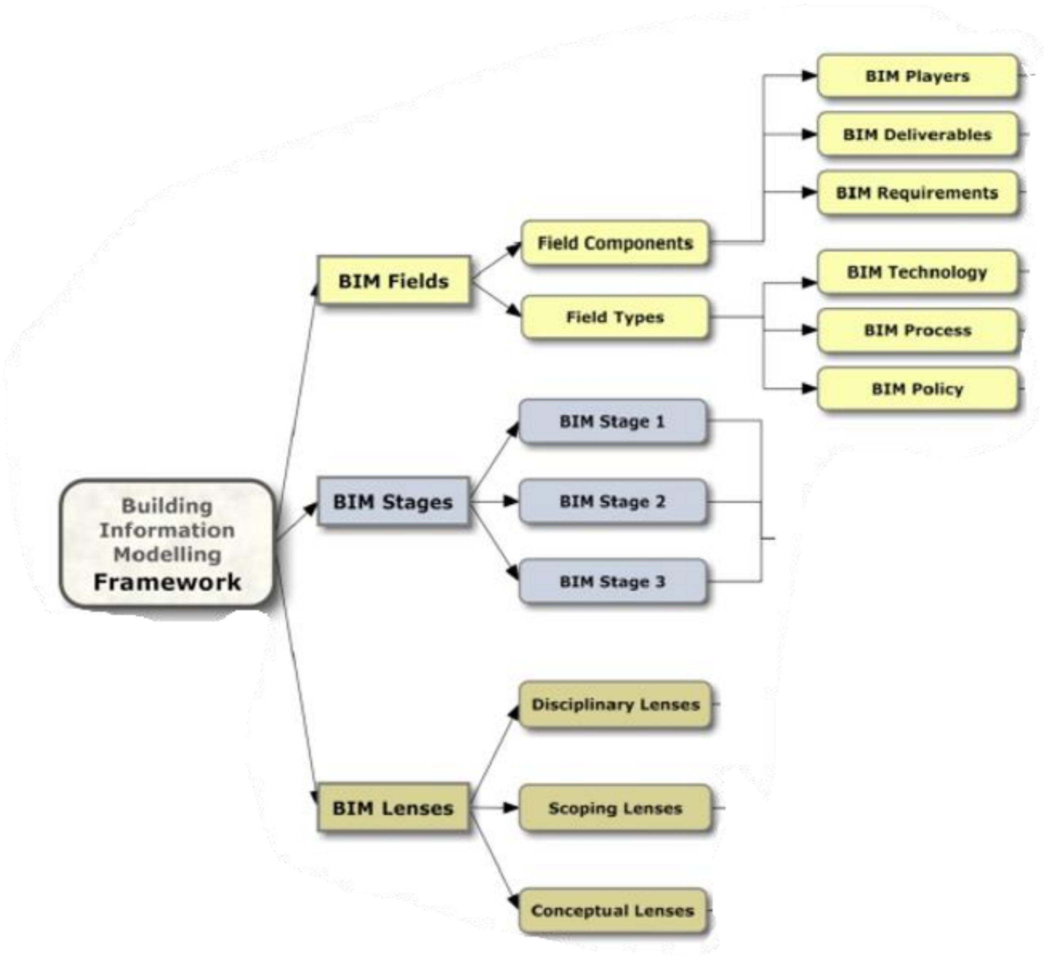


Figure 2.3 BIM Framework.

(Source: Succar, 2010b).

2.2.4.1 BIM Fields

BIM field can be divided into three fields: policy field, process field and technology field (Succar, 2009). Kalinichuk (2015) and Azhar et al. (2012) describe the three fields as follows: Technology covers software, hardware, and networks, it ensures project simulation that comprises the 3D parametric model. Process is about leadership, infrastructure, human resources, and services/product. It encompasses disciplines and systems of a facility within a single virtual model allowing team members to collaborate accurately and efficiently. Whereas policy presents contracts, regulations, research, and education. The three fields are put in two sub-fields each, namely players and deliverable (Kalinichuk, 2015). Figure 2.4 illustrates these fields. This study notes that policy, process and technology fields must work together for optimal benefits of the BIM system.

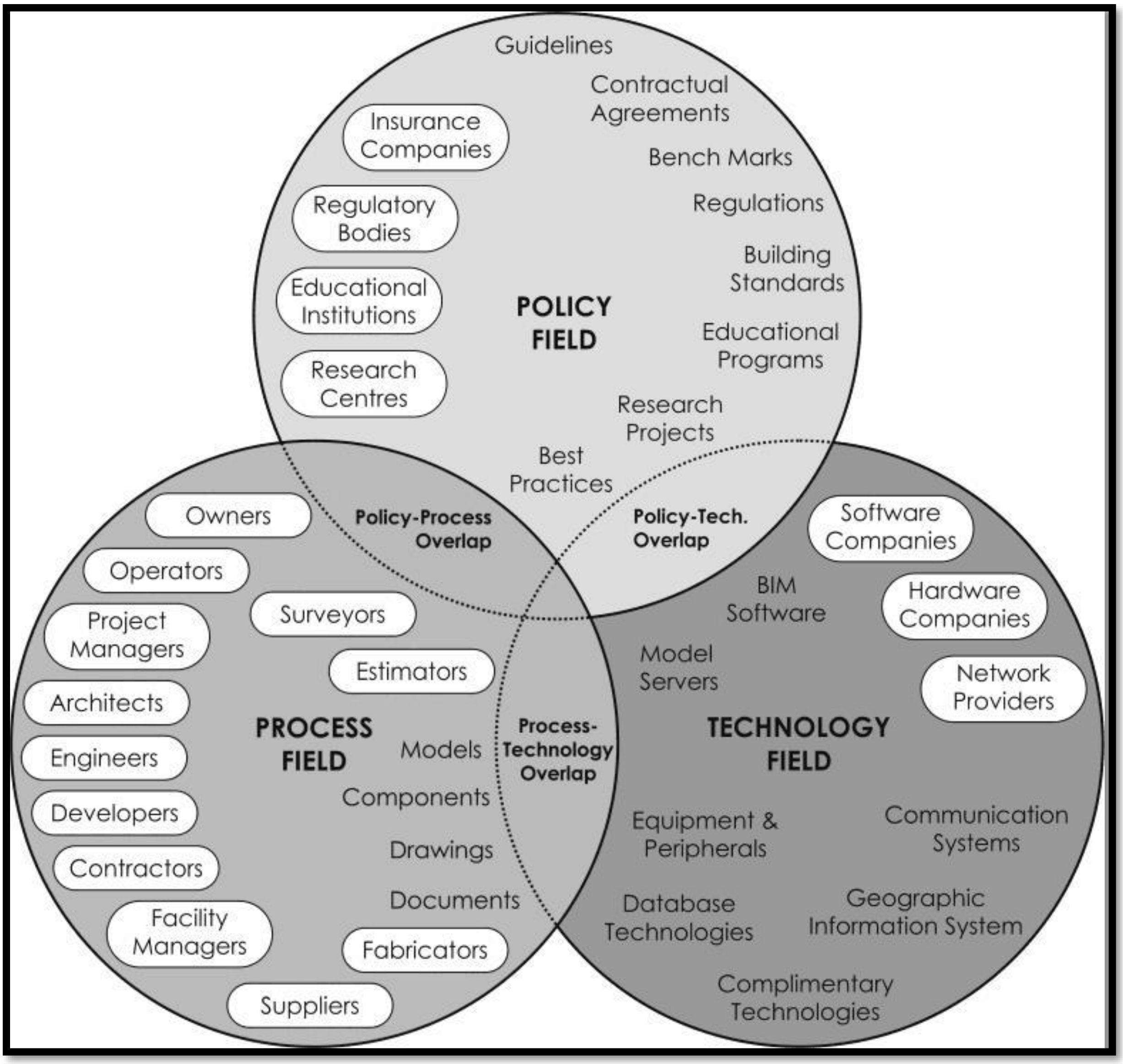


Figure 2.4: Technology, Process and Policy fields with players and deliverables.

(Source: Kalinichuk, 2015; Succar, 2010a)**.**

2.2.4.2 BIM Capability Stages

BIM stages are the minimum BIM requirements that need to be achieved by teams when implementing BIM, whereas maturity level measures ability steps within stages

(Succar, 2009). These steps are based on technology, process and policy (Succar, 2010b). Stages are radical while steps are incremental (Succar, 2010b). Figure 2.5 depicts these stages. The BIM stages are from pre-BIM to BIM stage 1, BIM stage 2, BIM stage 3 and the stages lead to Integrated Project Delivery (IPD).

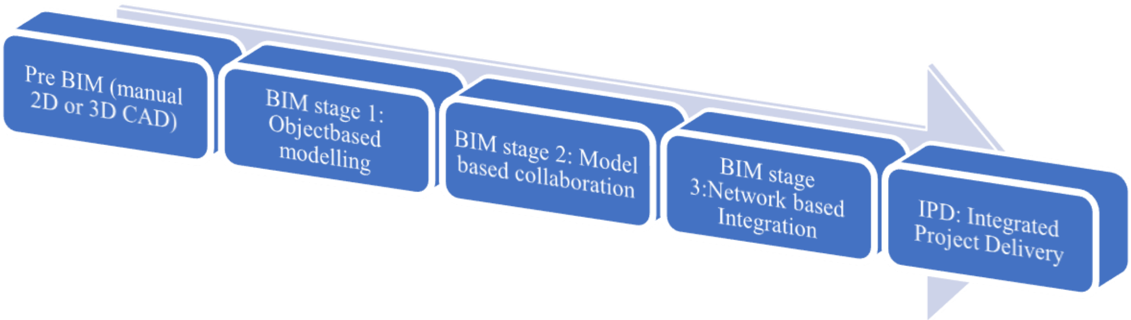


Figure 2.5: BIM Stages.

(Source: Bouška, 2016; Kim, Ji, & Jun, 2018; Succar, 2009; The American Institute of Architects, 2007)**.**

BIM stage 0 is the pre-BIM stage, where BIM is not in use (Succar, 2010b). The other stages are:

i. BIM Stage 1: This is Object based modelling, where parties work on their own model or data in isolation (Bouška, 2016).
ii. BIM Stage 2: This is Model based collaboration, where data collaboration and interoperability are practiced (Bouška, 2016; Succar, 2009).
iii. BIM Stage 3: This is Network based Integration; it is fully integrated and collaborative real-time project model and the process is likely to be facilitated by web services (Bouška, 2016; Succar, 2009).

Network based integration will ultimately lead to Integrated Project Delivery (IPD). The American Institute of Architects (2007) defines IPD as: “IPD is a project delivery approach that integrates people, systems, business structures and practices into a process that collaboratively harnesses the talents and insights of all participants to optimize project results, increase value to the owner, reduce waste, and maximize efficiently through all phases of design, fabrication and construction” This study notes that while assessing BIM adoption the stages and the steps within the stages are important in gauging a country's maturity level.

2.2.4.3 The Dimension of BIM

The model created by BIM is a live model with live feeds that all stakeholders can access in Real-time, and it can be generated on various subsets depending on information required (Grzyl, Miszewska-Urbańska, & Apollo, 2017). The various subsets of BIM are described in terms of dimensions (D): 3D (object model), 4D (time), 5D (cost), 6D (operations and maintenance), 7D (sustainability during maintenance) and safety for 8D (Bouška, 2016; Grzyl et al., 2017; P. Smith, 2014a).

2.2.4.4 Noteworthy BIM Publications (NBPs)

NBPs are documents that reflect BIM knowledge and are deliverables of BIM players, covering relevant BIM topics. They are selected and organized by country of origin. NBPs are classified into guides, protocols and mandates. Guides are descriptive and optional they include guidelines, best practices; protocols are prescriptive and optional they include standards, benchmark and mandates are prescriptive and dictated by an authority they include contract, policy (Kassem et al., 2014).

2.2.5 Global perspective of BIM adoption

Globally, the construction industry is increasingly using BIM at design, construction, and maintenance stages. Organizations involved in public procurement have very high BIM framework requirements for consultants (Grzyl et al., 2017). Most firms are progressing towards a BIM competitive edge, the private firms are more inclined towards BIM adoption and demand for implementation as compared to the public sector (Arshad et al., 2019; Grzyl et al., 2017; Hasanzadeh et al., 2014).

North America and Scandinavian regions are regarded as global leaders in BIM (Smith, 2014b). Governments mandates to use BIM on public sector projects, such as has occurred in the United Kingdom (UK) and the United States (USA), has accelerated BIM implementation (Hasanzadeh et al., 2014; P. Smith, 2014b). In

Europe, Scandinavia and UK are leading in BIM implementation, whereas, Germany, France and Austria are following closely; their success in BIM implementation is guided by the Government and its agencies (Grzyl et al., 2017; Kekana et al., 2014). According to Smith (2014b), Denmark, Norway and Finland in the Scandinavian region were among the first countries to adopt model-based collaboration, open BIM, interoperability and they have been part of developing of Industry Foundation Classes (IFC). The UK has the most ambitious BIM implementation strategy and the government has a Taskforce helping both the private and public sector to reassess their work practices (Smith, 2014a). The UK government had mandated BIM on all centrally funded public projects by year 2016 (McAuley et al., 2017). In China, the BIM policy development is not complete due to the government passive involvement, challenges being faced include unclear knowledge on ROI, immature BIM standards, unclear legal responsibility boundary, lack of BIM professionals and cost of adoption (Liu, Wang, Zhang, Liu, & Wang, 2017). Adoption of BIM in Iran lacks supportive regulatory environment and financial assistance by policy makers, the major drivers for BIM in Iran were found to be associated with profit and enhancement of competitiveness in the market (Hosseini, Azari, Tivendale, Banihashemi, & Chileshe, 2016).

The three key ingredients of BIM adoption are BIM Mandates by government, existence of key champions that promote BIM publicly and Noteworthy BIM Publications (McAuley et al., 2017). These key ingredients have shown a quicker adoption trend in countries that are leading in BIM adoption, this is shown in Table 2.1.

Table 2.1: Three key ingredients to BIM adoption around the world.

Country	Noteworthy BIM publications (NBP)	Government BIM Mandate	Key champion
Australia	Available	Plans are underway	Present
Austria	Available	Plans are underway	Present
Italy	Available	No Mandate	Present
Belgium	Available	No Mandate	Present
Netherlands	Available	No Mandate	Present
Switzerland	Available	No Mandate	Present
Portugal	Available	No Mandate	Present
New Zealand	Available	No Mandate	Present
Canada	Available	No Mandate	Present
China	Available	Under review	Present
Brazil	Available	Under review	Present
Germany	Available	Under review	Present
Spain	Available	Under review	Present
Chile	Available	Under review	Present
Denmark	Available	In place since 2011	Present
UAE – Dubai	Available	In place since 2013	Present
Finland	Available	In place since 2014	Present
Hongkong	Available	In place since 2014	Present
Norway	Available	In place since 2016	Present
France	Available	In place since 2017	Present
Singapore	Available	In place since 2015	Present
United Kingdom	Available	In place since 2016	Present
USA	Available	Multiple mandates	Present

(Source: McAuley et al., 2017)

Bui et al. (2016) who conducted a 6-step literature review study on adoption of BIM in developing countries, the findings showed that lack of BIM awareness, lack of BIM standards, little or no government support, lack of direction on the legal status of BIM, inexperienced modelers, unclear benefits of BIM, lack of financial resources and low data quality design are factors that are affecting BIM implementation in developing countries. Piracy of BIM software cause a security threat through unintentional exposure to viruses and hackers; BIM being about digital collaboration of several organizations through shared information space, this then becomes a major hindrance to BIM implementation. Even though the findings are valid, the methodology used was out of touch with the consultants practicing at that time, therefore the gap left by this methodology necessitated survey research in Nairobi, Kenya.

2.2.6 African perspective of BIM adoption

In countries such as Nigeria and Cameroon, BIM implementation has experienced barriers like lack of knowledge, lack of awareness and experience; resistance to change, costs associated with establishing BIM, speed of the internet and infrastructure required for adopting BIM and collaboration (Hosseini et al., 2016). In South Africa barriers to the adoption and implementation of BIM can be attributed to professional responsibility, contractual issues such as licensing, insurance, model ownership, implementation costs and personnel inadequacies in terms of education, training, and skills development and lack of strong willingness towards BIM adoption (Kekana et al., 2014). Study by Khodeir & Nessim (2017) showed that very few firms were using the BIM technology in Egypt, with challenges including client unawareness, high cost of implementation, unwillingness, lack of training programs, lack of BIM education curriculum, lack of studies on BIM implementation processes and its ROI.

2.2.7 Kenyan perspective of BIM adoption

Information and Communication Technology (ICT) in Kenya has advanced over the years and it has been successfully used in various sectors both in government and private institutions and benefits reaped have been greatly appreciated (Ndemo, 2015). So, their implementation is normally dragged. The Nairobi City County (NCC) is one of the government’s institutions where they have upgraded from manual system to ICT. 2D drawings are submitted online reviewed and approved, in addition inspection data is captured using smart phones and data is also archived (Nairobi City County, 2020). NCC has however not implemented BIM model approval into its system.

Research done by Kimani et al. (2019) on comparison of BIM awareness between Kenya and UK found that research, training and implementation of BIM in Kenya is undocumented unlike in UK where the government is proactive. The research further found that adoption and implementation of BIM in Kenya is still not as advanced as the developed countries and that there is limited BIM knowledge, the leaders in construction industry do not have BIM implementation formula because of lack of standards. The results of the research were based on a sample size of 12, there is need to use a bigger sample size for comparison.

There lacks a government agency to guide the process, leaving software sellers and specifically Graphisoft and Autodesk to push for its adoption (Musyimi, 2016). The professionals lack cooperation, hence lowering their capacity to push for its implementation. Studies done in Kenya have shown that the Traditional Procurement System (TPS), high cost of implementation, contractual and legal issues, lack of BIM standards and policy, lack of government involvement, clients not requiring BIM, lack of support in the current standard forms of contract and resistance to change are the challenges hindering BIM adoption in Kenya (Kimani et al., 2018; Manza, 2016; Musyimi, 2016). Studies also show that BIM in Kenya is still associated with software (Waigwa, 2016) and not a system.

Professionals in Kenya are flexible to new technologies. However, the TPS hinders technology adoption and digital workflows and there is no government mandate for the public sector to use BIM; the government has yet to realize the full benefits of BIM (Pring, 2019). It is unlikely that the government will set the BIM agenda, but the private developers especially the international ones, will push for it, this demands for BIM consultants to offer training (Waigwa, 2016). It has been reported that some professionals are adopting BIM to increase chances of getting international jobs and top management support is credited for influence on the decision to adopt (Kimani et al., 2019).

Research by Wambui (2018) found that majority of professionals in Kenya were in BIM stage 1, followed by BIM stage 2 and the minority are in stage 3. Musyimi (2016) established that majority of professionals were in stage 1 whereas stage 2 and 3 recorded zero. Further BIM was reported to be mainly in use during design stage, and it was minimally used in preconstruction, construction, and post construction. BIM has also been used to reduce design errors through clash detection, accurate cost estimation, project scheduling and resource allocation resulting in resource waste reduction (Gitee & Yusuf, 2018). Another research showed that BIM design and visualization reduces the risk of making changes later in the project (Mwangi Thiong'o

& Muchelule, 2019). Musyimi (2016) research on BIM adoption in Construction Project Management highlighted areas for further studies to include whether BIM affected contractual relationships and responsibilities.

This research addresses this gap left by the need for the industry to create systems and structures that support the BIM system. Further, this study utilizes stratified sampling, which allows inclusion of most of the professionals in the construction industry, hence filling the gap left by previous research on using either one or fewer professionals. Additionally, this study sought the underlying factors of BIM adoption, hence filling the gap left by previous research on various latent factors affecting BIM adoption.

2.2.8 Factors Guiding Adoption of BIM

The factors guiding companies to adopt BIM are based on its numerous benefits, cooperation in the industry, client's willingness, government mandates and Return on Investment (ROI). When firms in Iran conducted a ROI study, it helped the firms on moving to a BIM platform (Khodeir & Nessim, 2017). BIM enables optimized collaboration through stakeholders' cooperation in updating information important to each stakeholder, hence easier decision making (Grzyl et al., 2017; Khodeir & Nessim, 2017). Award of construction jobs to both local and international firms is based on competitiveness on BIM capabilities; the older professionals are hesitant, but the younger ones are quicker to adopt BIM and claim the newer opportunities (P. Smith, 2014b).

The adoption process relies on the power matrix whereby the client is the most powerful and will attain more benefits as compared to project manager followed by the Architect and the Engineer (Asad, 2016). The government being one of the biggest clients, could provide leadership and mandates to achieve mutual standards and protocols and avoid duplication of efforts, which has proven to be a critical factor for successful BIM implementation in leading countries such as USA, UK and Singapore (Smith, 2014a). Therefore, presence of a regulatory body to mandate the use of BIM in public sector, existence of key champions that promote BIM publicly, and NBPs are the three key ingredients for implementation and adoption of BIM (McAuley et al., 2017).

2.2.9 Benefits of BIM in the construction industry

BIM is described as a catalyst for change, an agent to reduce construction industry fragmentation, it improves on efficiency and effectiveness and it lowers the high cost of interoperability (Succar, 2013). The intelligent 3D semantically rich model is the center for visualization, collaboration, automation, integration, improved communication, improved decision management between the different stakeholders in the lifecycle of a project (Bosch-sijtsema & Gluch, 2019; Nowak, Książek, Draps, & Zawistowski, 2016; Succar, 2013; Xu, Ma, & Ding, 2014; Yalcinkaya & Arditi, 2013). BIM is a lifecycle information management tool handling collaboration, risk management to include safety and sustainability analysis (Xu et al., 2014; Yalcinkaya & Arditi, 2013), it further allows gathering of information on buildings for further studies such as energy analysis (Nowak et al., 2016), understanding of lifecycle costing and prediction of environmental performance, (Chandra, Nugraha, & Putra, 2017). Hence giving interactive feedback on design decision consequences (Nowak et al., 2016; Succar, 2013; Xu et al., 2014). These characteristics ensure that all players are interpreting the information from a central transparent source of information.

BIM is Information Technology (IT) and network driven, it presents a chance for seamless sustainable logistic flow of digital information whereby a lot of data is generated, needing cloud storage system that offers the required space and easier security management (Ding & Xu, 2014; Nicał & Wodyński, 2016; Nowak et al., 2016). This results in better coordination, detecting clashes, saving time and resources, improved speed and accuracy, during a projects' various phases hence promoting positive ROI (N. Azhar, Kang, & Ahmad, 2014; Aziz, Nawawi, & Ariff, 2016; Khodeir & Nessim, 2017; Olsen & Taylor, 2017; Succar, 2013).

Preconstruction visualization of spaces is a BIM benefit that enables consensus of the design before construction (Kalinichuk, 2015). Further, its real-time characteristics make changing of drawing information easier at any stage of construction (Asad, 2016). BIM allows the contractor's early entrance into the project, enabling suggestion of modelling techniques to the designer that will mutually benefit both parties and allow for the inclusion of BIM based quality take-off (Olsen & Taylor, 2017).

Other benefits of BIM include construction conflict management, structural analysis, shop drawing process, cost estimation and facility management. (Charehzehi, Chai, Yusof, Chong, & Loo, 2017). Facility management becomes efficient in terms of cost, time and quality, since the information is available for use for the entire Lifecyle hence translating to positive ROI (S. Azhar et al., 2012; Charehzehi et al., 2017; Nicał & Wodyński, 2016). BIM also enables improved profitability and improved customer-client relationships (S. Azhar et al., 2012). Other benefits noted by Borjeghaleh & Sardroud (2016) include generative designs; large scale and complex projects; optimized project management; informed design process; construction phasing; component interference elimination and reduced duplication and costs.

2.2.10 Challenges of BIM in the Construction industry

Lack of government's efforts to mandate BIM is one of the major barrier of BIM implementation (McAuley et al., 2017). Legal implications brought by the collaborative nature of BIM concerning ownership of the model, responsibilities and liabilities for errors, insurer's uncertainties over legal liability, contractual and organizational risks (S. Azhar et al., 2012; Kekana et al., 2014; Manderson et al., 2015; P. Smith, 2014a), as to how BIM defines or is defined by the scope of the contract (Olsen & Taylor, 2017), lack of contractual guidelines and standards are all challenges of BIM (Arshad et al., 2019; Bui et al., 2016). There is no clear consensus on how to implement BIM, how to use BIM, how to handle contractual relationships, who should develop and operate the model and how the developmental and operational costs should be distributed (S. Azhar et al., 2012). The consensus is made harder by the fragmented nature of the construction industry (Kumar & Hayne, 2016). This leaves a gap on legal implications of BIM adoption in Kenya. It is no longer lack of technological solutions that prevents the construction sector from implementing BIM-based revolution, but it is the construction industry inability to cooperate (Khodeir & Nessim, 2017; Nicał & Wodyński, 2016).

There is a conflict between BIM system and TPS (Bosch-sijtsema & Gluch, 2019; Kalinichuk, 2015). The TPS allows use of BIM for visualization only (Musyimi, 2016) whereas BIM's collaborative nature demands lifecycle utilization. Underestimation of Facility Management role, inhibits 6D and 7D implementation, though also lack of BIM knowledge and experience among the facility management practitioners is a barrier in itself (Nicał & Wodyński, 2016). This study finds a gap left by BIM's influence on the TPS, whereby, new skills that lack training or experience have emerged, creating a gap towards roles and responsibilities with regard to BIM with the new roles requiring titles and proper training (Nicał & Wodyński, 2016). These in turn are putting pressure on policy and decision on the procurement system (Kumar & Hayne, 2016).

Other challenges are change resistant attitude, rigid business culture and stakeholders hesitance in pioneering adoption (Nicał & Wodyński, 2016; P. Smith, 2014b). Further challenges are lack of finances for the initial large investment required in BIM implementation, these costs cover software, hardware, training and facilitator's fee (Bui et al., 2016; Ding & Xu, 2014; Hasanzadeh et al., 2014). How the compensation of the initial cost should be done, unclear benefits of BIM due to lack of sufficient studies on ROI and lack of case studies to prove the positive business value are challenges (Arshad et al., 2019; Bui et al., 2016; Khodeir & Nessim, 2017; Nicał & Wodyński, 2016). Further, complexity of preferred BIM software (Olsen & Taylor, 2017), interoperability (Nicał & Wodyński, 2016), big storage space required to store the large amount of information generated by the big number of collaborators (Ding & Xu, 2014), security of data due to pirated software pausing danger to the digital and collaborative BIM, hence exposing data to hackers and viruses (Bui et al., 2016). The present study however argues that data insecurity is not due to BIM, but it has been there even in pre-BIM.

2.2.11 Stakeholders' interaction with BIM

BIM encourages integration of the roles of all stakeholders, this ensures efficiency and harmony among players and eliminates adversarial relationships (S. Azhar et al., 2012). Drawings in BIM are informed, the model is information rich (Borjeghaleh &

Sardroud, 2016), the client is able to understand the expected product through generative designs that are helpful in decision making and controlling budgets, since the client is interested in maximum profits (Grzyl et al., 2017).

There is limited attention given to BIM implementation in infrastructure projects in developing countries (Bui et al., 2016). Civil Engineers are more comfortable with the traditional methods; they can however use BIM in design, construction, cost and contract management of civil and infrastructure projects, even though Architects are taking the lead in BIM (Asad, 2016; Eadie, 2014). The project and construction manager use BIM in management of: the contract, decision, information, quality, resource, safety, risk, value, time scheduling and cost using the 3D model to plan collaboratively with other professionals hence lowering risks and improving the ROI of the project (Yalcinkaya & Arditi, 2013).

The Contactor uses BIM to price the bills of quantities, schedule work, work on variation and plan a site layout (Grzyl et al., 2017). Occupation health and safety issues are important in construction industry. Since now design and construction planning can be done in one model, safety can be factored in and adequately be planned for (Musyimi, 2016). BIM can also be used to determine and predict the indoor air quality at the construction site before the actual construction work (Altaf, Hashisho, & Al-Hussein, 2014).

Facility management constitutes over 80% of the total life project cost, hence its imperativeness ought to be acknowledged (Costin, Pradhanananga, & Teizer, 2012). BIM 6D and 7D enables operation & maintenance stage to be treated as equally as the design and construction stages without breaking the flow of information (Nicał & Wodyński, 2016). BIM model provides information about a building and its spaces, systems and components; these data are transferred into facility management operations and can be accessed by clicking on an object of interest (S. Azhar et al., 2012). BIM 6D and 7D application include: Mobile localization of building resources, digital asset with real-time data access, space management, renovation planning, automated maintainability studies, energy analysis control and emergency safety management (Nicał & Wodyński, 2016).

2.2.12 BIM Education for Architectural, Engineering, Construction & Operation

Universities and colleges should be mandated to teach BIM through established course outline as this will help bring down the cost of BIM implementation to some extent (Asad, 2016; Liu et al., 2017). Currently, the challenge is that most of the universities lack understandings of what skills are needed in the industry and being that BIM is relatively new, there is no substantial research on the BIM course content (Abbas, Din, & Farooqui, 2016). BIM education should not focus on BIM software but, on BIM management, BIM and collaboration, BIM technical skills and knowledge, open BIM, benefits of BIM and ROI (Smith, 2014a). Most developed countries are including BIM as part of the university curriculum for construction related courses (McAuley et al., 2017). The education institutions are well placed to champion for BIM (Musyimi, 2016). This ensures that BIM skills are nurtured early; however Kenya does not have a BIM curriculum (Mutonyi & Cloete, 2018). The consequences of this gap are transferred to the job market where the employer is forced to train their employees.

2.3 BIM and Engineering Contract Management (ECM)

BIM is a new system whose adoption finds the existing TPS structure. The TPS performance in contract management has been tested for a long period, unlike the BIM system. This research sought to find out how BIM is affecting ECM, being that it is a technological advancement. BIM's three fields: technology, policy and processes work together to enhance collaboration and management of construction contracts.

2.3.1 Contract Management

Contracts provide a reference point for transactions between two parties and represents what those parties are entitled to receive. Contracts can be described as a manifestation of legally enforceable agreements in various business relationships (Murray, 2002).

Contract management is the process that ensures that both parties of a contractual agreement adhere to their roles and obligations as per objectives of that contract (Kiiru, 2015; Procurement Management & Procurement Strategies, 2017; Rotich, 2014). The construction industry processes are conducted within contract documents which are expertly managed to ensure that projects are done within budget, time and quality and that various parties adhere to their roles and responsibilities.

Management actualizes purposes or goals by organizing activities and resources through the processes which include planning, organizing, influencing and controlling (Certo & Certo, 2012). Top management deal with conceptual and design skills, middle management who deal with human skills, and supervisors who deal with technical skills; it also has global, innovative and entrepreneurial perspectives as the three-management perspective (Weihrich, 2013). Therefore, ECM in Kenya should adopt the three perspectives, where in the global perspective it should require an understanding of social, political, legal, and environmental forces across the nation. Whereas in innovation perspective, ECM should be flexible for enhancement and adaptation of new trends, and lastly the entrepreneurial perspective, ECM should enable opportunities to solve problems which result in sustainable surplus cash flow.

2.3.2 Effects of BIM on contracts

Design-Bid-Build (DBB) and Design-Build (DB) could be said to be the two dominant contract procurement methods in construction industry (Eastman et al., 2008). In the current times, these traditional methods of procurement have failed the expectation of the society because of increased construction period, loss of materials, low-quality performance and increased construction fees (Borjeghaleh & Sardroud, 2016). Therefore, governments around the world are actively adopting their procurement processes to suit collaborative BIM (Kumar & Hayne, 2016). Figure 2.6 shows comparison of traditional and BIM processes; whereas BIM is collaborative, the traditional process has separated processes.

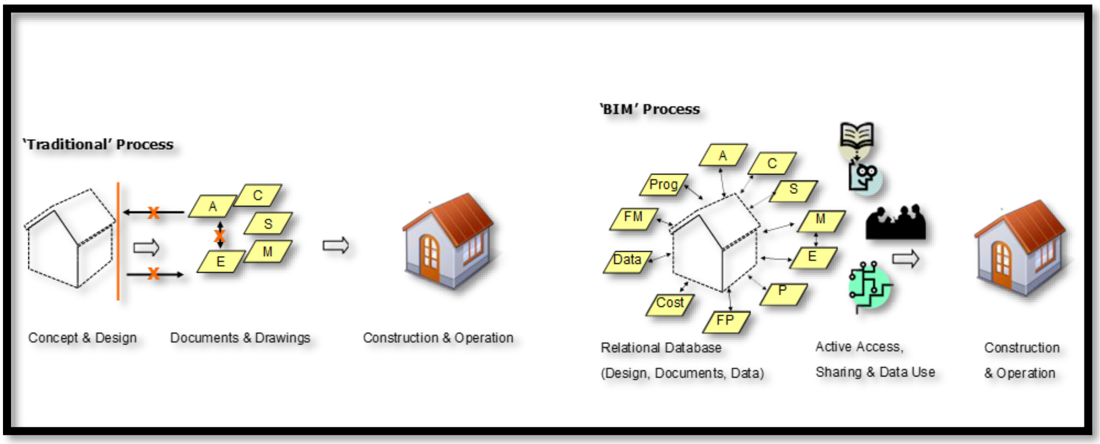


Figure 2.6: A Comparison between traditional and BIM process.

(Source: S. Azhar et al., 2012).

Though BIM has continued to be used in isolation with a few professionals on board, integrated BIM demands for the stakeholders to collaborate in the lifecycle of a project (Kuiper & Dominik, 2013). This BIM implementation should involve industry, government and research institutions (Olatunji, 2011). Legal foundation needed will help avoid risks and handle disputes. The risks include: intellectual property (IP) rights; sharing of copyright data; professional liability; conditions of contract; lack of standardization; data interoperability; protocols, processes new roles and responsibilities; collaborative working; claims and disputes; data security; cost compensation; BIM standards; standard of care and professional negligence; admissibility of electronic-based documents; model management and ownership; legal validation of design; legislation and judicial precedence; lack of software compatibility; additional project insurance; public sector and agency risk allocation (Arshad et al., 2019; Eadie et al., 2015; Manderson et al., 2015).

These legal risks should be addressed contractually; liabilities such as protocols, warranties and disclaimers should be observed; further the position of BIM execution plan, processes, standards, technologies and the model should be part of the contract (Kuiper & Dominik, 2013). Olatunji (2011) summarizes the BIM legal issues into six headings: Obligations (new sets of skills, integrated services, hardware, software their cost and benefits); Duty of care (model ownership, validity and usage, copyright issues, authorization of E-documents); Consideration (undefined standard remuneration, new sets of professional responsibilities, addendum to professional scales of fees); Jurisdiction (e-contracts, recognition, taxation laws and government policies, disclaimer clauses); Cyber security (snooping, theft, viruses, hacking); tools (interoperability, standardization, value). This shift from TPS to digital BIM system requires new skills that come with a big initial cost and with an absence of contracts guiding this it is unclear how parties will be compensated (Arshad et al., 2019).

Survey carried out in Alabama, United States questioning construction professionals on model management showed that most agreed that the model management should be the Architect's responsibility (Olsen & Taylor, 2017). There are professionals who propose the client to own the BIM model, while others object with the reason that the designers will use it to transfer to the client risks due to them (Olatunji, 2011).

According to Manderson et al. (2015), there is limited research done on interaction between BIM and TPS. This study reviews the Public Procurement and Asset Disposal Act and two standard forms of contract namely: the Joint Building Council (JBC) and International Federation of Consulting Engineers (FIDIC) to identify how the contractual issues picked from BIM contractual challenges are addressed in those contracts.

2.3.3 Legal and institutional framework for BIM adoption and implementation

In countries leading in BIM adoption such as USA and UK, government mandates have been the principal driving force; NBPs and key champions are the other contributing factors (McAuley et al., 2017). In Kenya, construction industry regulators, education institutions, professional bodies and individual professionals should be at the forefront in advocating for BIM adoption (Musyimi, 2016). The professionals' bodies include Engineers Board of Kenya (EBK), Institute of Engineers of Kenya (IEK), Board of Registered Architects and Quantity Surveyors (BORAQS), Architectural Association of Kenya (AAK), Association of Construction Managers of Kenya (ACMK), National Construction Authority (NCA), Institute of Construction

Project management of Kenya (ICPMK), Institute of Quantity Surveyors of Kenya (IQSK), Institute of Surveyors of Kenya (ISK). Other bodies include the county governments such as the Nairobi City County (NCC) which regulates construction activities in Nairobi (Nairobi City County, 2020). The government of Kenya should provide standards and regulations for BIM (Mutonyi & Cloete, 2018), to enable easier transition to BIM. Public procurement and Asset Disposal Act, the Joint Building Council and the International Federation of Consulting Engineers are the three main forms of contract used in Kenya for procurement.

2.3.3.1 Public Procurement and Asset Disposal Act

Public Procurement Regulation Authority (PPRA) which changed its name from Public Procurement Oversight Authority (PPOA) is mandated to monitor, assess and review the public procurement and asset disposal system in Kenya (The Republic of Kenya, 2020). The 2015 Act which is a document by the Republic of Kenya (2016) states in part 1:5 on conflicts with other Acts: (1) the Act prevails in case of any inconsistencies or other legislation except where procurement of professional services is governed by the Act of Parliament applicable for such services. It also states in part X: 151 on complex and specialized contract implementation team:

> "For every complex and specialized procurement contract, the accounting officer of a procuring entity shall appoint a contract implementation team which shall include members from the procurement function, and the requisitioner, the relevant technical department and a consultant where applicable" (p53A-71).

Public procurement and asset disposal Act 2015 interpretation of complex and specialized contracts "means contracts that include procurement where the terms and conditions of an agreement are different from standard commercial terms and conditions" (p53A-9). This study finds BIM system to be under this special provisions whereby the contract implementation team or a task force is needed to strategize on BIM adoption and implementation. The Public Procurement and Asset disposal Act is the ultimate regulation for procurement in Kenya. Therefore, it is an important document in the adoption of the lifecycle collaborative BIM and for BIM to function effectively and efficiently

2.3.3.2 The Joint Building Council (JBC)

The Joint Building Council (JBC) is a contract document formed by the Architectural Association of Kenya (AAK) and the Kenya Association of Building and Civil Engineering Contractors (KABCEC) partnership. The following clauses are used to give comparison with the BIM system.

Clause 7.10 states "the contract documents are to be taken as mutually explanatory of one another. For the purposes of interpretation, the priority of the documents shall be in accordance with the following sequence: The letter of award; the agreement and these conditions; the bills of quantities; the specifications; the drawings; the schedule and other documents forming part of the contract" (The Joint Building Council Kenya., 1999, p. 10). Whereas clause 7.2: The original contract documents are supposed to be in the Architect's and Quantity Surveyor's possession during construction and should be handed to the employer upon completion. Clause 7.9: Upon the Architects request, the Contractor should return all documents that bear the Architect's name that are in the Contractors possession. These protocols that have been used with the TPS, including ownership of documents and IP rights, are transferable but upon revision to accommodate the digital BIM system.

2.3.3.3 International Federation of Consulting Engineers (FIDIC)

FIDIC is an international organization responsible for standard forms of contract for consulting engineers. The following clauses give a comparison with the BIM system.

Clause 1.5 on priority of documents: The documents forming the contract are to be taken as mutually explanatory of one another. For the purposes of interpretation, the priority of the documents shall be in accordance with the sequence the contract agreement; the letter of acceptance; the letter of tender; the particular conditions; the general conditions; the specifications; the drawings; the schedules, the joint venture (JV) undertaking if necessary and any other documents forming part of the contract. If an ambiguity or discrepancy is found in the documents, the engineer shall issue any necessary clarification or instruction (FIDIC, 2017).

Clause 1.8 of FIDIC (2017) indicates that the contract documents shall be in the care of the employer, the contractor's document shall be stored with the contractor. If a party notices error of a technical nature, they should notify the responsible party. Clause 1.10 shows that when the Employer is using the Contractors documents, the Contractor shall retain copyright and other IP rights of his documents and the Employer is required to use these documents as per agreement and without sharing with a third-party without the Contractor's consent. Whereas clause 1.11 outlines the Contractors use of the Employers documents, whereby the Employer shall retain the copyright and other IP rights in specifications, drawings and other documents, the Contractor at his cost may copy and use them for the purpose of the contract but shall not share with a third party without the Employers consent.

Just as in the JBC, FIDIC does not accommodate the digital BIM, but it is clear on who owns what traditionally, thus even with the need to have BIM tailored standard forms of contract; therefore, previously successful protocols need updating to cater for the digital BIM.

2.3.3.4 The Situation of the Traditional Procurement System (TPS) in the Construction Industry.

Traditionally, Kenyan construction industry has been procured via design-bid-build, where the contractor will bid at the end of design phase (Wachira, Root, Bowen, & Olima, 2007). However, the method has been critiqued to be unable to cope with the complex and dynamic nature of the current construction industry as it is slow due to various closely related phases and especially the separation of design and construction stages, also due to disputes brought about by variations arising from design and scope changes and it seldom achieves a cohesive and unified project team more so because of the late introduction of the contractor to the team (Kong & Gray, 2006). In Kenya the practice has been to engage separate parties for each design stage, however there lacks coordination of the interface to cater for the newer contractual relationships (Pring, 2019).

Traditionally it was a norm to see consultants using different sets of blueprints divided into various disciplines such as architectural, structural, civil, landscape, electrical, mechanical and plumbing drawings; these consultants had to endure working through the bulky documents, which was a very time-consuming process (Olsen & Taylor, 2017). According to Turina, Radujkovic, & Car-Pusic (2008) many clients today are increasingly dissatisfied with the traditional approach and they actively seek alternative methods of procurement to meet their complex demands. The method of procurement selected influences Buildability (term used in UK) or Constructability (term used in USA); buildability is about reducing project uncertainty and risk through increasing efficiency in design and construction processes, having simpler contractual arrangements and improving project management. Further, the current trends point towards the client's desire to have a single point of management which will achieve constructability hence reducing risks and uncertainties and increase efficiency.

These emerging practices require to be researched as a basis for future action and policy formulation in the Kenyan construction sector and that there will be significant consequences arising from the shift in procurement practices on the Kenyan construction sector (Wachira et al., 2007). The present research confirms that this is a gap in need of filling. Factors that contribute to clients dissatisfaction in Kenyan construction industry include project exceeding timelines and budget, compromised quality, non-adherence to specifications, lack of feedback from participants, lack of involvement throughout the project and poor working relationship among stakeholders and business partners relationships (Gwaya, Masu, & Wanyona, 2014).

In road construction in Kenya, time is wasted to a magnitude of 50% for over 70% of projects carried out in Kenya (Seboru, 2015). This translates to cost and sometimes quality compromise. A study by Kogi & Were (2017) on factors affecting cost overruns in road projects found contract management, project schedule, resources and government policies to be the cause. For instance, Thika superhighway cost escalated by 30%, time extended by 2 years and the scope was greatly increased afterwards.

Study by Munyoki (2014) on factors influencing completion of construction projects in Nairobi found that project cost increased averagely at 13.5% and project duration increased by 33.6% and that project planning at all stages influenced completion of projects. This is true for most project and the study went further to recommend sensitization of stakeholders in construction projects implementation on expected delays and cost overruns. The study found that Design-Build and Public-Private Partnerships were likely to ensure the successful delivery of construction contracts followed by Design-Bid-Build.

Another study conducted by Oloo (2013) on influence of procurement procedures on Construction project performance in power plant construction at Kenya petroleum Refineries Limited Mombasa revealed that the cost of the project increased by 17% and completion time increased by 58.3% and also the procurement procedures used have a big influence to the construction project performance. Another study by Mbaabu (2012) on factors influencing road construction in Isiolo county, found that the project suffered loss of documentation and unwelcome external interferences of management of the contract. The mitigation given by the study included requesting consultants to manage their documentation and use of regulations to block external interferences from accessing roads projects.

While basing its argument on the above studies, this study finds that the TPS has time, money, information and transparency management challenges. Research done in 2014 on development of appropriate project management factors for construction industry in Kenya, recommended that BIM system should be used in construction projects to solve these challenges (Gwaya et al., 2014).

Kenyan vision 2030 was launched in year 2008 and one of the foundation pillars is infrastructure; the vision aims to transform Kenya into “a newly industrializing, middle income country providing a high quality of life to all its citizens in a clean and secure environment" (Kenya Vision 2030, 2008, p. https://vision2030.go.ke/). However, the impediment to vision 2030 is that the Kenyan construction industry is constrained by lack of a robust national construction regulatory framework to address new and emerging trends in building and construction project financing and development, construction business development, materials, and standards (Kenya Institute for Public Policy Research and Analysis, 2016). This impediment is there despite the major contributor to construction growth in Kenya being from public funding, which is over 80% of funding (Oxford Business Group, 2017), implying that the government institutions can control emerging trends.

2.4 Statistics used for the research data analysis

The inferential methods used for data analysis in this study were Correlation analysis, Regression analysis and Exploratory Factor Analysis (EFA). A correlation coefficient lies between +1.0 and -1.0, with a significance level of 0.05 (Hair, Black, Babin, & Anderson, 2014). A positive correlation means that when BIM improves, ECM improves, and a negative correlation means when BIM improves ECM decreases or reduces (Mugenda & Mugenda, 2003). This relationship is further analyzed by regression to show the effect of the independent variable on the dependent variables. The following equations are used where Y is the dependent variable and X is the independent variable and ε is a random error.

$$Y= \beta_0+ \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 \ldots\ldots.. \beta_k X_k + \varepsilon$$

Substituting,

$$Y= \beta_0+ \beta_1 C + \beta_2 TS + \beta_3 CR + \beta_4 QI + \beta_5 ROI + \varepsilon$$

Where,

Y is the dependent variable ECM

The independent variable is made up of components of BIM namely, X_1 Collaboration (C), X_2 Time saving (TS), X_3 is Cost reduction (CR), X_4 is Quality improvement (QI) and X_5 Return on Investment (ROI).

β_0 is the constant

β_1, β_2, β_3, β_4 and β_5 are the coefficients of the independent variable.

ε is a random error.

Exploratory Factor Analysis (EFA) was used in this study to make statements based on underlying factors responsible for a set of observed responses and Principal Component Analysis (PCA) as an extraction method aids in data reduction for ease of interpretation (Anna, 2010). The influence of BIM adoption on ECM has underlying factors of BIM adoption. The variables collaboration, cost reduction, time saving, quality improvement and ROI are the factors influencing adoption of BIM and effective ECM, they are however supported by awareness, leadership, education, training, education, and technology. The observed variables under these main variables need to be reduced in number into a few factors that account for the underlying variance in the measured phenomenon. The arrows represent loading which are the relationship between the item and the factors (Figure 3.2). The loadings range between -1.0 and +1.0 a strong relationship is closer to 1.0 positive or negative, highly correlated variables that describe the same thing form a pattern under a factor (Hair et al., 2014). According to Anna (2010) the regression model produced can be used for further analysis and is in the form:

$$F_{ij} = \beta_1 x_{i1} + \beta_2 x_{i2} + \dots + \beta_p x_{ip}$$

Where,

F_{ij} = Underlying factor

β = Factor Coefficient

x = Observed variable

The correlation Analysis and EFA attempts to answer the following research questions

EFA is used to compute underlying factors of variables under study where the number and nature of expected factors is unknown (Williams, Onsman, & Brown, 2010). The extraction method was PCA and Oblimin for oblique and varimax for orthogonal were the rotation method used. In the first round Oblimin was used, but upon satisfying that the rotation factors were orthogonal, the switch was made to varimax rotation. Orthogonal rotation factors are less correlated, factors are rotated at 90^0 from each other whereas, oblique rotation factors are more correlated and are not rotated at 90^0 (Child, 2006).

2.5 Theoretical Framework

This study uses four theories namely, contract theory, diffusion of innovation theory, technology acceptance theory, and system theory of management. These theories provide the underlying logic in terms of the key drivers, key outcomes and the underlying processes responsible for adoption and implementation of new technologies such as BIM.

2.5.1 Contract Theory

Contract theory is an economic theory that entails how economic actors organize their activities and develop a legal agreement in both foreseen and unforeseen cases. This theory seeks to measure interactions brought by contracting relations, they can either be complete and incomplete contract theories. In essence, all contracts are incomplete because they contain omissions and gaps this is because of future uncertainty, hence post contract transactions and renegotiations. (Foss & Klein, 2016). According to Smith (2004), Contract theories can be approached from two questions, namely analytic and normative; the analytic question is about contractual obligations whereas the normative questions justify the contractual obligation. In principal agent theory, a principal hires an agent to perform duties on his behalf and pays for costs and risks associated with the work given (Foss & Klein, 2016). The Kenyan government may need to have a body or an agent to foresee the BIM implementation and regulation. It is imperative that contracts being handled under the BIM system give a clear guidance on obligations, relationships, and considerations.

Relational contract theory recognizes contracts relationships that go beyond the original offer and acceptance but also includes the overall context of continuing relationships to cater for change and uncertainty (Frydlinger, Cummins, Vitasek, &

Bergman, 2016; Murray, 2002). The two distinctions are living contracts being the actual contractual relationship, and contracts at law being the legal tool that govern relations and disputes (Diathesopoulos, 2010). The BIM system is collaborative and continuing relationships; the period extends for the lifecycle of a project. BIM system needs its own living contract and contracts at law to enable adoption by the players and further giving guidance on ECM. The existing legal framework has made BIM deliverable difficult, because it does not address change brought by BIM in terms of skills, behaviour, tools, roles, cultures and product (Olatunji, 2014).

Constructs from the contract theory are contractual management, legal framework, partnerships, relational contracts, and continuing business relationships. The concepts derived include roles and responsibilities; guide, protocol and mandate; collaboration and teamwork. The variables derived are new roles and responsibilities; data management; standards, guidelines and regulations, time, cost and quality improvement; return on investment (ROI).

2.5.2 Diffusion of Innovation Theory

Diffusion is a process by which an innovation is communicated through certain channels over time among the members of a social system (Rogers, 1983). It explains the dynamics of why and how a new technology spreads (Succar, 2013). According to Sahin (2006), the four key elements in the diffusion innovations are the innovation, the communication channel, the time or rate of adoption, and the social system. Diffusion takes place in a social system and is therefore influenced by the social structure. BIM is an efficient innovation as compared to the previous systems, its implementation cannot be done in one phase, rather there are levels of acceptance leading to adoption and this is happening at varying rates. Awareness and knowledge are the early steps; key BIM champion could help in sensitizing and persuading construction players to adopt and implement BIM. In his book Rogers (1983) stated that adoption can be classified into innovators, early adopters, early majority, late majority, and laggards. The book further states, the innovation-decision process starts from knowledge, followed by persuasion, decision to adopt or reject, implementation and finally confirmation of either continuing to adopt, later adoption, discontinuance, or continued rejection.

This theory is adoption based. The construct from this theory is adoption of new technology, and the concepts include rate of adoption, decision making, communication channels, and social systems. The variables include leadership, technology, education, training, and awareness.

2.5.3 Technology Acceptance Model (TAM)

Acceptance of new technology by an individual is influenced by usefulness and ease of use. Theoretical constructs within TAM include: subjective norm, voluntariness, image, job relevance, output quality and result demonstrability (Dwivedi et al., 2017; Succar, 2013). This theory is adoption based and targets individuals, but it can also be applied to project teams. The construct derived from this theory is adoption of new technology. The concepts are systems and structure, job relevance, output quality and results and demonstrability. These leads to formulation of variables, namely technology, awareness, education and training.

2.5.4 System Theory of Management

An entity must be viewed as a system to fully understand the operation of the entity whereby a system means several interdependent parts functioning as a whole for an overall goal. The analysis of a system starts from a whole, part and their interrelationships (Certo & Certo, 2012). A system can be open or closed; a closed system is not affected by its environment it is mostly mechanical. Whereas an open system is affected by its environment hence an open system has inputs, processes, outputs and outcomes with shared feedback (Olum, 2004). BIM is an open system, where policy, process, and technology each with players and deliverables must be considered for its successful implementation. Inputs in the BIM and ECM relationship include technology, skills, government mandate, and stakeholder’s participation. Processes include planning, organizing, creating awareness, education, training, leadership and controlling whereas output include ROI and project success. This theory also focuses on the relationships between the parts and how they work together, how they are organized and how they interact with each other (Chikere & Nwoka, 2015). Subsystems in BIM; policy, process and technology fields cannot be separated, especially when managing engineering contracts, otherwise, the BIM system cannot deliver its objectives. Both BIM and ECM are closely correlated systems, they are open systems that need each other to achieve project success. Stakeholders cannot simply choose to pick their favourable BIM subsystems and expect to have a perfect ECM, there will be loopholes that will make the system not work effectively.

Every organization is dependent on its external environment, which is a part of a larger system within its industry (Weihrich, 2013). Thus, even though an organization sets up standards and guidelines to run BIM within its organization, it still needs to work with other partners to deliver projects and the circle of collaborators still needs a legal framework to operate in. The constructs from this theory are management system and interrelationships. The concepts are system and structures, inputs, processes and outputs. The variables include standards, guidelines, legal framework, leadership and technology.

2.5.5 Summary of The Theoretical Framework

After innovation of new technologies such as BIM, there follows different phases of acceptance over time among the parties they are intended for. However, the parties need to be sensitized through various means of awareness creation such as education and training. Visionary leadership is also crucial in giving guidelines and enabling technological capacity by putting the right infrastructure in place such as software, hardware, and internet. Awareness and knowledge of benefits of such technologies and how they are likely to solve problems in the old systems create curiosity among the parties leading to the acceptance and adoption. This then raises the challenges of systems and structures that will enable the new technology to perform optimally. Besides, the roles, relationships, responsibilities are affected and demand a contractual solution to take care of the legal risks envisaged. Figure 2.7 illustrates this narrative whereby the arrows show the forward progression of BIM from its recognition and acceptance to its implementation towards project success.

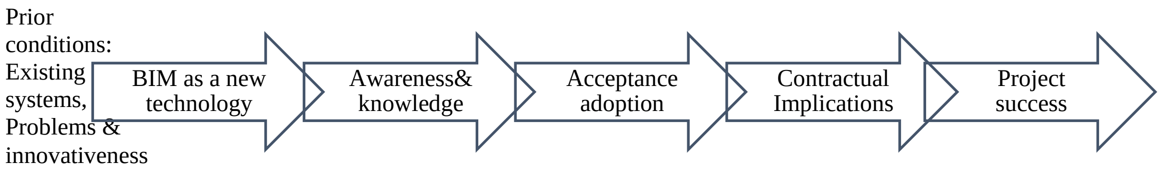


Figure 2.7: Theoretical perception of BIM and ECM

(Source: Certo & Certo, 2012; Chikere & Nwoka, 2015; Dwivedi et al., 2017; Olatunji, 2014; Olum, 2004; Rogers, 1983; Sahin, 2006; Succar, 2013; Weihrich, 2013)

2.6 Summary of Review and Literature Gap

The literature review presented the benefits and challenges of BIM adoption. It further showed the world and the Kenyan position regarding BIM. BIM conflicts with the Traditional Procurement System (TPS) which promotes fragmentation and adversary in the construction industry, whereas BIM promotes collaboration. Inefficient collaboration in TPS leads to poor quality delivery, time and cost overruns in the lifecycle of a project. Generally, information is lost, misplaced or scattered, and there is a danger of using obsolete versions. Impediment to BIM adoption includes lack of consensus and planning towards policy and legal framework for BIM implementation in Kenya, more so because of its collaborative nature that is changing relationships, roles, responsibilities and resulting risks.

The BIM system is in three fields: process field is about information and professionals delivering it, technology field covers software, hardware, network and companies developing them and policy is about rules, regulations and contracts and institutions that formulate them (S. Azhar et al., 2012; Kalinichuk, 2015; Succar, 2010a, 2013). The government's mandate, BIM champion and Noteworthy BIM Publications (NBPs) are the essential ingredients towards BIM adoption (McAuley et al., 2017). Additionally, the construction professionals need to align with BIM as it evolves towards achieving Integrated Project Delivery (IPD) (Smith, 2014a). Aligning procurement methods with BIM, BIM guidelines, BIM education, BIM data exchange to support collaboration, regulatory framework and piloting projects are the recurring themes where BIM implementation is in its formal stages (McAuley et al., 2017). Some of the new roles brought by BIM include BIM manager, BIM coordinator and BIM Modeler; these roles need to be developed through training and subsequently, the desired experience reached (Bosch-sijtsema & Gluch, 2019).

Research on BIM adoption, BIM's legal risks and contractual context for BIM has been carried out in developed countries, and the findings can be applied to most country scenarios (Arshad et al., 2019; S. Azhar et al., 2012; Borjeghaleh & Sardroud, 2016; Eadie et al., 2015; Kassem et al., 2014; Kekana et al., 2014; Khodeir & Nessim, 2017; Kumar & Hayne, 2016; Manderson et al., 2015; McAuley et al., 2017; Nicał & Wodyński, 2016; Olatunji, 2011; P. Smith, 2014b; Succar & Kassem, 2017). These countries have had to adapt their contracts to the collaborative BIM, and these has proven to be advantageous to the implementation process. The legal challenges identified need to be addressed contractually so BIM and ECM can benefit from each other in performance. These legal challenges are: Intellectual property rights, sharing of copyright data, professional liability, standard of care and professional negligence, new roles and their impact, processes, protocols, and responsibilities, model ownership, model management and admissibility of electronic-based documents, data security, data interoperability, legal validation of design, reviews and approvals, whether BIM model should be part of the contract, BIM standards and guidelines, condition of contracts and standard forms of contract, regulatory body, legislation and judicial precedence, cost compensation of BIM implementation process, claims and disputes, risk shifting and breach of duty to warn (Source: Arshad et al., 2019; Eadie et al., 2015; Kuiper & Dominik, 2013; Manderson et al., 2015; Olatunji, 2011; Olsen & Taylor, 2017). This study uses these legal issues to find out the level of their impact within the Kenyan context.

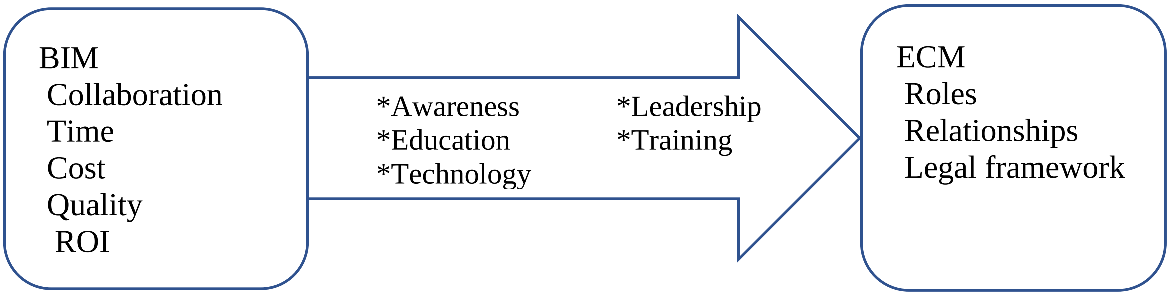
Comprehensive and customized research is recommended for developing countries to address localized perspectives (Bui et al., 2016). In Kenya, studies on BIM adoption have been carried out under different contexts and barriers to adoption identified (Kimani et al., 2018; Manza, 2016; Mutonyi & Cloete, 2018). Limited attention has been given to BIM implementation in infrastructure and facilities management projects in developing countries (Bui et al., 2016). Many disciplines have also not been included in a single research in terms of stratification. The study uses eight strata. It goes further to analyze the underlying factors to adoption and influence of BIM on ECM within Nairobi, Kenya.

The construction industry is unable to cooperate not because of lack of technological solutions but because there is no clear consensus on how to implement or use BIM and on how to handle legal contractual relationships and risks (S. Azhar et al., 2012; Nicał & Wodyński, 2016). Even though adoption is taking place in Kenya, there is a need to address the new processes that are leading to changing contractual roles, relationships, responsibilities and risks of stakeholders (Musyimi, 2016). BIM's effect on the existing procurement system leads to demand for the development of a legal and institutional framework that will enable the industry to adopt and implement BIM. Presently there lacks standards, guidelines and a legal framework that are centrally coordinated by the government.

The research gaps left by previous research and that the present research is focusing on are adoption within various disciplines in form of stratification; the underlying factors to adoption; changes in contractual relationships, responsibilities, roles and resulting risks; underlying factors of BIM's influence on ECM; and a framework to BIM adoption and implementation.

2.7 Conceptual Framework

BIM adoption enables effective and efficient collaboration, cost reduction, time saving, quality improvement and return on investment (ROI). These components of BIM make ECM easier. The conceptual framework is formulated from concepts derived from the constructs identified by the theoretical framework. Figure 2.8 illustrates the conceptual framework. BIM is the Independent Variable and ECM is the Dependent Variable. The relationship between BIM and ECM is strengthened by awareness, leadership, education, training, and technology as shown by the arrow. The arrow shows BIM adoption influence on ECM.



Independent Variables **Dependent Variables**

Figure 2.8: Conceptual Framework

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 Introduction

The methodology used to solve the research problem is presented in this chapter. The research design addresses the sample design, data collection methods, data analysis and presentation.

3.2 The Research Design

This research is descriptive in nature; it describes the characteristics of BIM and its influence on ECM. A survey research was used to collect data through self-administered questionnaires and in-depth interviews. This survey engaged Architecture, Engineering, Construction and Operation (AECO) industry players to find out their interaction with BIM and what their future hope for BIM in Kenya was. The research approach was both qualitative and quantitative. The primary data was collected through a survey of a sample population and the secondary data was collected from sample guides, protocols, and mandates from selected leading countries in BIM adoption and implementation. A pilot survey was carried out prior to the main data collection exercise.

3.2.1 Sample Design

3.2.1.1 Study Area

The study area was Nairobi County, which is the capital of Kenya it occupies an area of about 700 sq. Km. (Kiiru, 2015). Nairobi county was selected because a lot of Kenya's construction activities are concentrated in Nairobi (Kenya National Bureau of Statistics, 2019b). It has a higher population than any other counties at 4,397, 073; this high population makes it economically vibrant (Kenya National Bureau of Statistics, 2019a; Nairobi City County, 2020). According to Kenya National Bureau of Statistics (2018), the construction industry growth was 11.7% in 2015, 8.7% in 2016 and 9.5% in 2017. The value of private buildings issued with a certificate of occupancy by Nairobi City County (NCC) increased by 10.2% from KSh 77.7 billion in 2016 to

KSh 85.6 billion in 2017. Private buildings recorded as completed by NCC were 9 054, 10 268 and 11 202 in 2015, 2016 and 2017 respectively, whereas public buildings completed countrywide were 45, 1,062 and 1,164 in the three years, respectively.

Documented interviews of leading real estate companies showed that Nairobi is the development powerhouse or a regional hub of Kenya in real estate, with 95% of the investments concentrated in Nairobi (Kenya Report, 2016b, 2016a). Nairobi acts as a gateway to the East African market (Oxford Business Group, 2017).

3.2.1.2 Study Population

The study population is made up of consultants in the construction industry and the population is finite. These consultants are involved in construction processes in the lifecycle of a project. They include Engineers, Architects, Quantity surveyors, Construction Managers, Facilities Managers, Interior designers, Surveyors, Planning consultants, Clerk of works, Landscape Architects, health and safety consultants, Client representatives, Archeologist, Specialist contractors and various specialists that may be required.

The study utilized the consultants' team likely to be required on most projects from preconstruction to demolition. They are Civil and Structural Engineers, Construction Project Managers, Architects, Quantity Surveyors, Mechanical Engineers and Electrical Engineers, Contractors and Facility Managers (Hussin & Omran, 2009).

3.2.1.3 The Sampling Frame and Unit

The sample unit for this study was an individual consultant in the construction industry. A unit is the basic indivisible representation of a sample and a frame is the list of sampling units (Kothari & Garg, 2019). The sampling frame was made up of eight strata, namely: Civil Engineers, Architects, Construction Project Managers, Mechanical Engineers, Electrical Engineers, Quantity Surveyors, Contractors and Facility Managers. The population of the eight strata was 10,597 which was computed from numbers recorded by the respective professional bodies as shown in Table 3.1.

Table 3.1: The sample frame

	Professionals	Number	Source
1.	Civil Engineers	275	EBK website (Engineers Board of Kenya, 2019) - https://ebk.or.ke/registered-consulting-engineers/
2.	Construction Project Managers	128	ACMK website (Association of Construction Managers of Kenya, 2018) https://acmk.co.ke/registered-members/
3.	Architects	415	BORAQS website (Board of Registration of Architects and Quantity Surveyors, 2019) https://boraqs.or.ke/registered/architects
4.	Quantity Surveyors	290	BORAQS Website (Board of Registration of Architects and Quantity Surveyors, 2019) https://boraqs.or.ke/registered/qs
5.	Mechanical Engineers	32	EBK website (Engineers Board of Kenya, 2019) https://ebk.or.ke/registered-consulting-engineers/
6.	Electrical Engineers	51	EBK website (Engineers Board of Kenya, 2019) https://ebk.or.ke/registered-consulting-engineers/
7.	Contractors	9123	National Construction Authority office, Nairobi.
8.	Facility Managers	283	EARB website (The Republic of Kenya, 2019)
	Total	10,597	

3.2.1.4 The Sample Size and Sampling Technique

Sample size determination observed practicality of cost, time and efforts (Creswell, 2014; Mugenda & Mugenda, 2003; Walliman, 2011). The sample size was arrived at through estimating a percentage with a finite population using the formula shown on Table 3.2 (Kothari & Garg, 2019). This is a formula by the National Education Association of United States in the article ‘small sample technique’ (Krejcie & Morgan, 1970). The formula gave a sample size of 371.

Table 3.2: Sample size determination

$n = \dfrac{z_{\alpha/2}^2 \cdot p \cdot q \cdot N}{e^2(N-1) + z_{\alpha/2}^2 \cdot p \cdot q}$ therefore, $n = \dfrac{1.96^2 \cdot (0.5) \cdot (1-0.5) \cdot 10597}{0.05^2(10597-1) + 1.96^2 \cdot 0.5 \cdot (1-0.5)}$ Sample size = 370.76 =371	Where: - n = Size of sample N = Study population e = Acceptable error (±5%) p=Sample proportion (0.5) q = 1- p $z_{\alpha/2}^2$= the standard normal deviation set at 95% with a confidence level (=1.96)

A pre-calculated sample size table developed by Krejcie and Morgan in 1970, based on the same formula showed that for a population of between 10001 to 15000, the sample size was 375. The research adopted the calculated sample size of 371. This sample size gave a balance for practicality of cost, time and efforts.

The sample from the target population was determined in two steps. Step one was through stratified sampling method, with each stratum representing a profession. This method is applied in order to obtain a representative sample (Kothari & Garg, 2019). The second step was purposive sampling; the respondents were required to have been aware of BIM regardless of whether they had used it or adopted it, this measure was taken to avoid training respondents who had never come across BIM and to reduce non-responsiveness. Purposive sampling permits a researcher to use respondents that have information being researched (Mugenda & Mugenda, 2003). Those who were not aware of BIM were excluded in the survey. The study adopted equal representation to maximize the sample size of each stratum (Daniel, 2012; Mugenda & Mugenda, 2003). This led to allocation of 47 respondents per stratum, the total strata being 8 except for the Mechanical Engineers where the entire population was used.

Snowball sampling was used for the in-depth interview to select knowledgeable persons on the BIM subject. The first two respondents were referred from an Architectural firm in Nairobi. The firm had consulted with them on implementation of BIM, and they had helped set up the process. The references then continued through snowballing until it reached to 10 respondents. The method is useful when the required respondents with the required characteristics under study is not well known (Mugenda

& Mugenda, 2003). The knowledgeable persons were expected to have a deeper understanding of BIM knowledge and its influence. A sample size of 10 professionals was used and it was pegged on the factor of time and cost limitations. A sample of 5 to 50 is adequate for an in-depth interview, as recommended by Dworkin (2012). Other scholars recommend as few as 5 and as many as 60, though this should be guided by: saturation point, aim of the study, expertise in the chosen topic and studies that use more than one method of data collection (Mason, 2010; Vasileiou, Barnett, Thorpe, & Young, 2018).

3.2.2 Data Collection Methods

Primary data were collected from respondents using self-administered questionnaires and interview guides. This generated both quantitative and qualitative data. A letter of introduction from JKUAT and a research clearance permit issued by National Commission for Science Technology and Innovation (NACOSTI) were attached to the questionnaires for identification.

3.2.2.1 Questionnaire

Self-administered questionnaire with both structured and unstructured questions were distributed to respondents either through delivered hardcopy or E-mailed softcopy and as per respondent's preference. Structured questionnaires comprised of items that required respondents to rate or pick an answer from choices given. Unstructured questionnaires had items that required respondents to express themselves freely in a narrative.

3.2.2.2 In-depth Interview

In-depth interviews were conducted to get uninterrupted narratives and clarifications on the BIM situation in Nairobi and how BIM was influencing ECM. The respondents were knowledgeable persons in BIM. An interview guide was used in conjunction with probing questions where need arose. The sessions were digitally recorded using a recorder, after seeking for permission from the respondents. Short notes were also taken on a notebook; they included follow-up questions and key points.

3.2.3 Data Analysis and Presentation

The raw data for all the objectives were sorted, edited and coded for accuracy and consistency with other facts gathered and then systematically arranged according to objectives to facilitate analysis. This was followed by coding, where symbols representing measurable variables to data were utilized. The quantitative data were analyzed using the Statistical package for social science (SPSS) version 23, hence generating descriptive frequencies and charts. The coded qualitative data was arranged thematically based on repeated patterns of answers given by respondents. The themes are: BIM adoption, characteristics and benefits; Challenges of BIM adoption; The traditional systems of procurement and their challenges; The procurement Act and Standard forms of contract; BIM's influence on ECM, new roles, responsibilities and risks; and Noteworthy BIM Publications (NBPs).

Descriptive and Inferential analysis were employed. The methods used were Correlation analysis, Regression analysis and Exploratory Factor Analysis (EFA). A positive and a negative correlation shows that BIM improves or reduces the ECM performance respectively. This relationship is further analyzed by multiple regression to show the effect of the independent variable on the dependent variables.

Exploratory Factor Analysis (EFA) was used in this study to make statements based on underlying factors responsible for a set of observed responses and Principal Component. The number and nature of expected factors was unknown. The influence of BIM adoption on ECM has underlying factors of BIM adoption. The variables collaboration, cost reduction, time saving, quality improvement and ROI are the factors influencing adoption of BIM and effective and efficient ECM, they are however supported by awareness, leadership, education, training, education, and technology. The observed variables under these main variables needed to be reduced in number into a few factors that accounted for the underlying variance in the measured phenomenon. The arrows represent loading which are the relationship between the item and the factors (Figure 3.2).

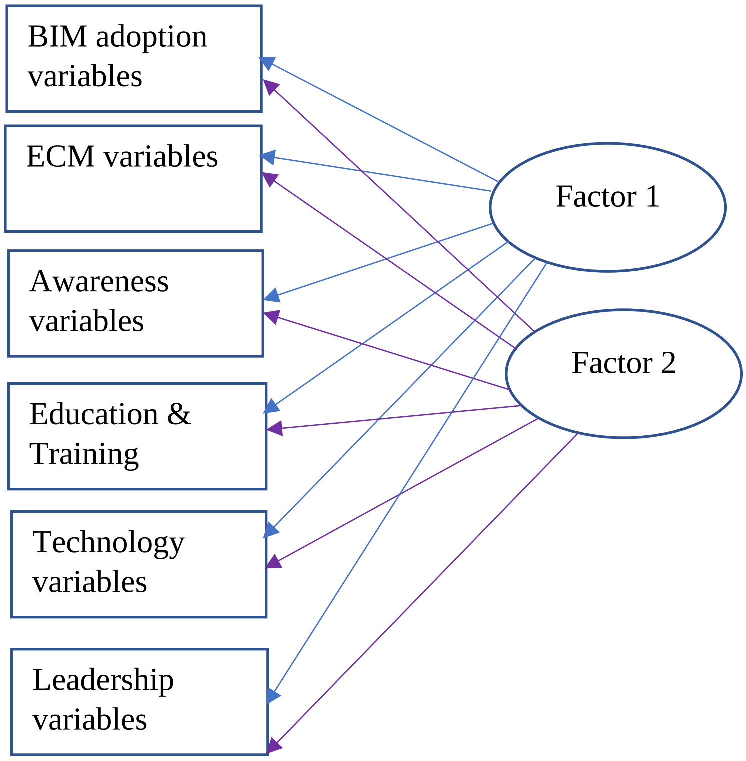


Figure 3.1: Underlying factors of BIM adoption and its influence of ECM

The research findings presentation is in form of tables and figures for quantitative data and narration for qualitative data.

3.2.3.1 Reliability Test

The degree of the measuring instrument to provide consistent results was checked by Cronbach's Alpha. Cronbach Alpha is a psychometric method that can measure internal consistency and it is expressed between 0 and 1 numbers (Tavakol & Dennick, 2011). The guide on Table 3.2 was used to measure the internal consistency. The pilot survey gave a Cronbach Alpha of 0.824, the reliability was then increased by having more respondents in the main survey.

Table 3.3: Cronbach Alpha for reliability analysis

- 0.90 and above shows excellent reliability
- 0.70 to 0.90 shows high reliability
- 0.50 to 0.70 shows moderate reliability
- 0.50 and below shows low reliability

(Source: Hinton, Brownlow, McMurray, & Cozens, 2004).

3.2.3.2 Validity

Validity is the accuracy and truthfulness with which an instrument measures what it was intended to measure (Mugenda & Mugenda, 2003). Content validity was checked before and after the pilot survey in preparation for the main survey. Content validity is the extent to which a measuring instrument provides adequate coverage of the research topic (Kothari & Garg, 2019). The instruments were found to have accurately represented and measured the constructs under study. Construct validity was checked based on the theoretical framework where the measurement was consistent with the theoretical expectations, that is, adoption of new technologies generally tends to demand for supporting systems and structures. Construct validity is the degree to which a measure confirms predicted correlations with other theoretical propositions (Kothari & Garg, 2019).

Internal validity was observed by selecting respondents with the required information for the survey. It depends on the degree to which extraneous variables have been controlled for in the study (Mugenda & Mugenda, 2003). Respondents for the in-depth interview could pick a favourable location and time of the meeting, this enabled them to calmly give information without feeling rushed. The respondents were given ample time to complete the questionnaires, hence ensuring external validity. Further, the population was representative enough for generalizable results that may apply to other counties' construction environment within Kenya.

3.2.4 Ethical Consideration Concerning the Research Subjects

The study was guided by social science research ethics. During data collection and analysis, confidentiality, truthfulness, anonymity, voluntary and informed consent were observed (Creswell, 2014; Mugenda & Mugenda, 2003; Walliman, 2011). Jomo Kenyatta University of Agriculture and Technology (JKUAT) through the Board of Postgraduate Studies (BPS) and Sustainable Materials Research & Technology Centre (SMARTEC) gave the approval for the research topic and an introduction letter. Upon application, a research permit was issued by National Commission for Science Technology and Innovation (NACOSTI).

All respondents were informed of the research topic and its purpose and were required to give their voluntarily consent towards participating in the survey. The respondents for questionnaire survey were not required to give their names during data collection. The In-depth interview required identifying of key personnel knowledgeable in the subject matter, prior to making appointments to meet them. The meetings were set at the convenience of the interviewees and their consent was required before recording the interview.

During analysis confidentiality was exercised, data were analyzed and interpreted in totality and there was no way of singling out a respondent from the data they gave. The data were used for the present research only.

3.2.5 Pilot Survey

The Pilot survey was carried out to check on reliability and validity of the study. The sample size was 5% of the main survey; there were 17 respondents for the self-administered questionnaire and 2 respondents for the in-depth interview. This was in accordance to Mugenda & Mugenda (2003) where a sample size between 1% and 10% of the main survey is considered adequate. Time and money were also put into consideration. The respondents included 3 Civil Engineers, 2 Construction Project Managers, 2 Architects, 2 Quantity Surveyors, 1 Mechanical Engineer, 2 Electrical Engineers, 2 Contractors and 2 Facility Managers.

In-depth interview lessons from the pilot survey included time management and interviewing tactics were learned and sharpened. Time for in-depth interview was established to be averagely one hour and it depended on how the interviewee chose to respond to the questions. This made it easier for the main survey, when communicating duration of the interview for scheduling purposes with interviewees. It also helped in removal of irrelevant questions and shift focus on important issues so that the scheduled interview time could be optimally used.

Data analysis methods included descriptive analysis, correlation analysis, regression analysis and EFA for quantitative data, whereas qualitative data were organized in themes. The pilot survey enabled revision of the research instrument; questions that were found to be ambiguous were revised and relevant suggestions from the respondents were incorporated.

3.2.6 The structure of the questionnaire

The study utilized a self-administered questionnaire. It was divided into five sections. Section A required background information of the respondents. Section B was on BIM adoption and was addressing objective 1; to assess BIM adoption in Nairobi Kenya. Section C was collecting information to address objective 2; to determine the underlying components of BIM adoption in Nairobi Kenya. Section D and E was tackling objective 3; to investigate the influence of BIM on Engineering Contract Management.

The questionnaire was based on Collaboration, Time, Cost, Quality and ROI which were the main variables of the study. They were broken down into simpler variables to enable collection of data that could be analysed. EFA utilized the variables as they appeared on the questionnaire, this was important in extracting the underlying factors. Analysis done using Pearson’s Correlation and Multiple regression, the collected data were regrouped to the respective original variable.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Introduction

The results and discussion of BIM Adoption and its influence on ECM are presented in this chapter. The reliability analysis, response proportion and the profile of the respondents are outlined. Objective 1 utilized Descriptive statistics and Narratives. Objective 2 utilized Freedman ranking test and Exploratory Factor Analysis (EFA). Whereas Descriptive statistics, Pearson's Correlation, Multiple regression and Narrative were used for objective 3. The relationship of the independent variable and dependent variable is analyzed, and the underlying factors of this relationship are extracted.

4.2 Reliability Analysis, Response Portion and respondents' profile

The study sought to assess BIM adoption, to determine the underlying components in BIM adoption, to investigate the influence of BIM on ECM in Nairobi Kenya and to formulate a BIM adoption and implementation framework. It was hypothesized that there are no underlying factors associated with BIM adoption, there is no relationship between BIM and ECM and there are no underlying factors of BIM's influence on ECM.

4.2.1 Reliability Analysis

A reliability analysis to check internal consistency of the questionnaire items shown on Appendix XI was done using Cronbach Alpha, the results are shown in Table 4.1. Cronbach Alpha is between 0 and 1 where 0.90 and above shows excellent reliability, 0.70 to 0.90 shows high reliability, 0.50 to 0.70 shows moderate reliability whereas, 0.5 and below shows low reliability (Hinton et al., 2004).

Table 4.1: Reliability analysis using Cronbach Alpha

	Cronbach's α	No. of Items	Reliability Status
BIM adoption	0.604	49	Moderate
Important components	0.942	26	Excellent
Influence of BIM on ECM	0.951	39	Excellent
All items	0.941	141	Excellent

4.2.2 Response Proportion

Out of the 252 questionnaires distributed, 175 were completed and returned accounting for a 69% return proportion. This was after two follow-up reminders, that helped improve the return proportion upwards. Potential respondents who could not participate upon being contacted were 123, this was because their understanding of BIM was low and were not confident to take part in the survey. Knowledgeable persons were the target respondents for the in-depth interview. Ten successful interviews were conducted, at which point the feedback begun to become repetitive. The interview stopped at 10 respondents because saturation point had been reached (Hennink, Kaiser, & Marconi, 2017).

4.2.3 Profiles of the respondents

The profiles of respondents are shown in Table 4.2 with the 8 target strata. The group for others comprised of a combination of the targeted disciplines whereby an individual is a professional and still handles extra duties in another field. These included 0.6% Architects & Contractors, 0.6% Electrical Engineers & Facility Managers, 1.1% Construction Project Managers & Contractors, 1.1% Civil Engineers & Construction project Managers, 0.6% Quantity Surveyors & Facility Managers, 0.6% Quantity Surveyors & Contractors, 1.1% Quantity Surveyors & Construction Project Managers: totaling 6.3%.

Table 4.2: Distribution of respondents

Respondents	Frequency	%	Cumulative %
Civil Engineers	32	18.3	18.3
Construction Project Managers	37	21.1	39.4
Architects	37	21.1	60.6
Quantity Surveyors	31	17.7	78.3
Mechanical Engineers	6	3.4	81.7
Electrical Engineers	14	8.0	89.7
Contractors	3	1.7	91.4
Facility Managers	4	2.3	93.7
Other (2 combinations)	11	6.3	100
Total	175	100.0	

Figure 4.1 shows the gender and education level of the respondents. The male gender represented was 85.1% and female was 14.9%, the male gender remains to be the majority in the construction industry. The vast majority 74.9% had a bachelor's degree, the rest 7.4% had a diploma and 17.1% had a master's degree. These academic qualifications showed that the respondents had the training in their area of practice and were eligible for this survey.

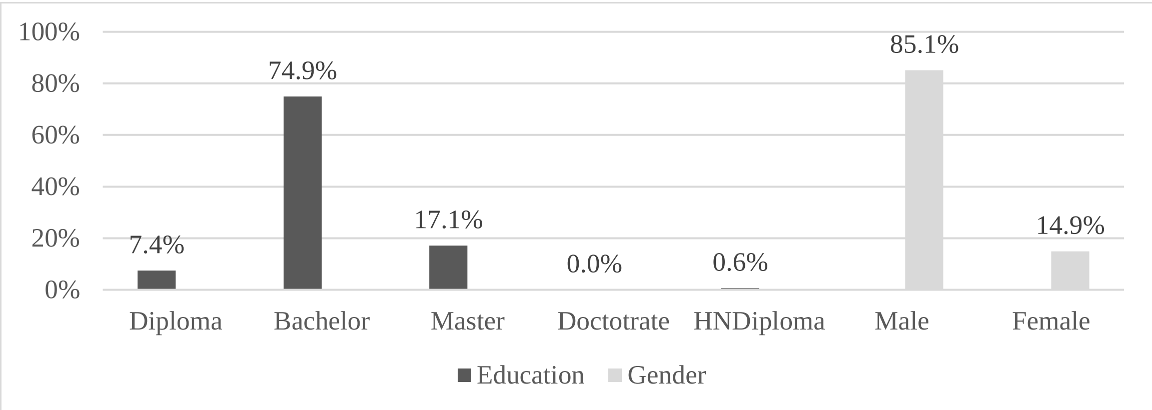


Figure 4.1: Respondents, profession and level of education

Figure 4.2 shows the respondent's employer was as follows: 88.6% were privately employed, 10.3% were in public service, 0.6% Public limited company and 0.6% nongovernmental organization. The respondents handled different types of projects within their organizations, these were as follows: 52% both publicly and privately financed projects, 37.7% were privately financed projects, and 9.1% were publicly financed project meaning the private sector was leading in adoption. The following is the number of technical staff in organizations that the respondents were working for; 39.4% had 0-5 technical staff, whereas the least figure was 13.1% with over 30 technical staff, this is as shown in Figure 4.2. To note is that some respondents stated the exact number in the group of over 30 technical staff as follows; 0.6% had 80, 1.1% had 100, 0.6% had over 1000 and 0.6% had 6000 technical staff.

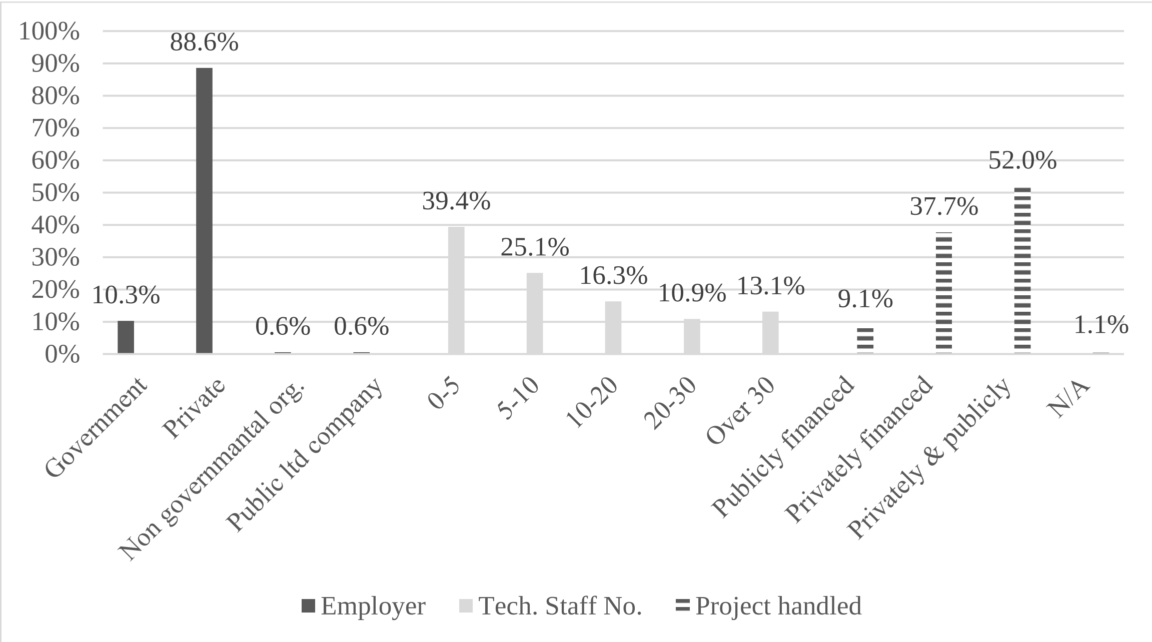


Figure 4.2: Employer, technical staff number and type of project handled

As shown in Figure 4.3. respondents' years of experience were: 36% had 0 to 5 years, and the least figure being 14.3% who had over 15 years of experience. Most of the respondents were in the 0 to 5 and 6 to10 years brackets of experience, implying younger population exposure to BIM hence their availability for the survey. Though the younger respondents were comfortable to participate in this survey, it however emerged that the number of years of experience does not really affect adoption, rather the employer is likely to influence adoption. On the other hand, having a larger number of younger respondents showed to some extent, that the older generation was not comfortable to adopting to new trends and technologies. The older generation being the policy makers this then translates to delayed BIM policy, because it will take time for the older generation to embrace BIM and BIM knowledge.

The number of years that the respondents had used BIM were: 67.4% for 0 to 5 years who were the majority and 9.7% had never used BIM. This indicates that BIM is relatively young in Nairobi Kenya because majority had used BIM for 0 to 5 years. Respondents indicated their BIM roles as: 52% were BIM user/modeler, 12% were BIM managers, 11.4% were BIM coordinators while 24.6% had no BIM roles. BIM experience is also in the younger bracket of 0 to 5 years, implying that BIM skills are very young, and they may need quality training to improve and increase the number. The number of years of BIM experience was found to be connected to the organization one is in, those in public institutions recorded lower BIM experience as compared to those in the private institutions.

As shown in Figure 4.3 most respondents were BIM users at 52%, some were BIM managers at 12% and others were BIM coordinators at 11.4% the remaining 24.6% did not have a BIM role. Presence of BIM managers in an organization indicates adoption of BIM.

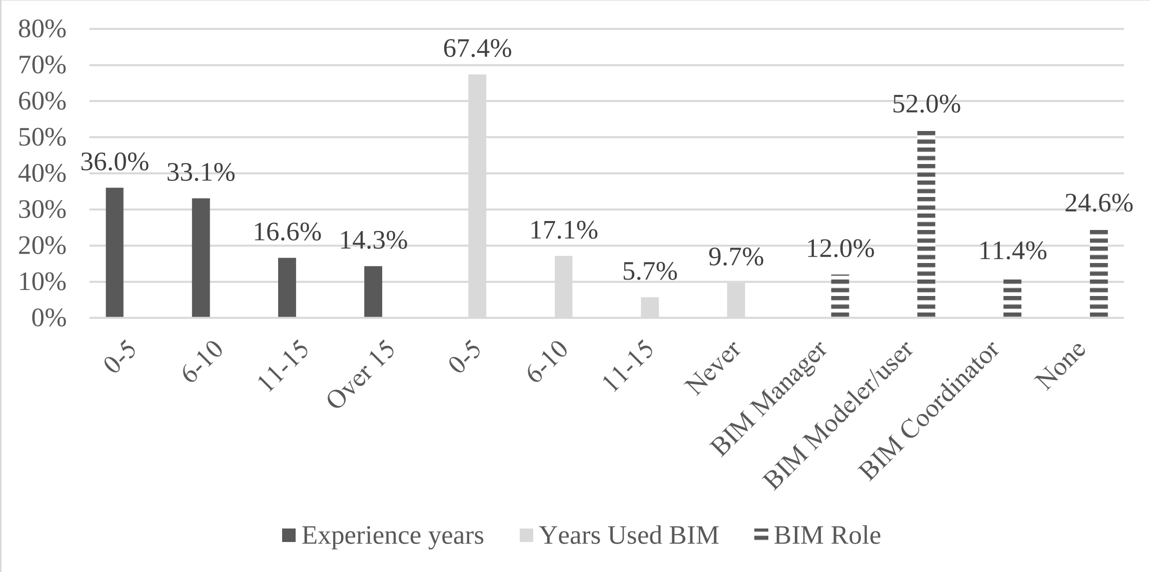


Figure 4.3: Number of years of Experience, years used BIM and BIM role

4.3 Results and Discussion for Objective 1: Adoption of BIM in Nairobi, Kenya.

Figure 4.4 shows that 56.6% of the respondents had adopted BIM, 18.9% had not and 23.4% were planning to adopt, 1.1% were on ongoing adoption. Though many had adopted BIM, the majority thought that BIM is a software. This was treated as an indicator of a gap in BIM knowledge.

Amongst the professionals, Architects had the highest adoption rate at 70.3% while Quantity Surveyors had the least at 38.7%. In overall adoption Architects were leading at 14.9% followed by Construction Project Managers at 12%, and Civil Engineers at 8.6% whereas at the bottom were Contractors and Facility Managers at 1.7%. (Table 4.3).

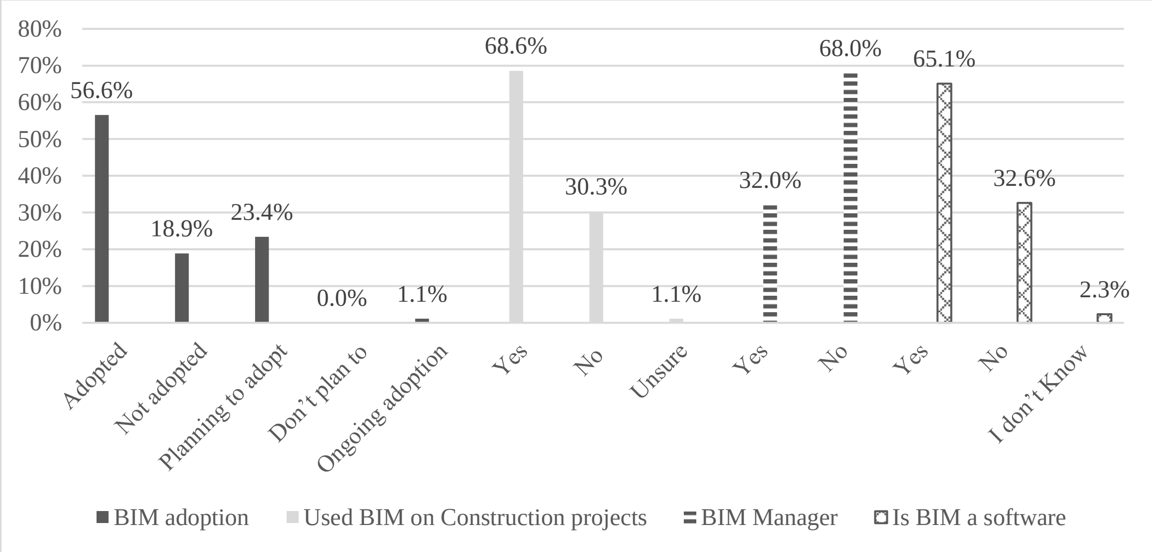


Figure 4.4: Level of BIM adoption and understanding

Table 4.3: Adoption distribution

Respondents	Frequency	%	Adoption per profession %	Overall adoption %
Civil Engineer	32	18.3	46.9	8.6
Construction Project Manager	37	21.1	59.5	12
Architect	37	21.1	70.3	14.9
Quantity Surveyor	31	17.7	38.7	6.9
Mechanical Engineer	6	3.4	66.7	2.3
Electrical Engineer	14	8.0	64.3	5.1
Contractor	3	1.7	100	1.7
Facility Manager	4	2.3	75	1.7
Other (2 combinations)	11	6.3	45.5	2.9
Total	**175**	**100.0**		**56.6**

The following definition was given on the questionnaires: BIM is a digital innovation and consists of a set of technologies, processes and policies based on an intelligent 3D model enabling Architecture, Engineering construction and operation stakeholders to effectively collaborate throughout the lifecycle of the facility (Autodesk, 2019; Succar, 2009). The respondents were required to choose from strongly agree, agree, uncertain, disagree and strongly disagree. As per Figure 4.5, 96% of the respondents agreed to this definition, 3% were uncertain and 1% did not agree. Contradictory feedback to these figures were given when they were asked if BIM is a software; because as shown in Figure 4.4 only 32.6% knew that BIM is not a software, 65.1% thought that BIM is a software and 2.3% did not know what to think. It should be noted that BIM is not a software, implying that the number that rightfully knew this should have matched that of adoption. Hence this information pointed to BIM knowledge gap. This indicated a gap in BIM knowledge.

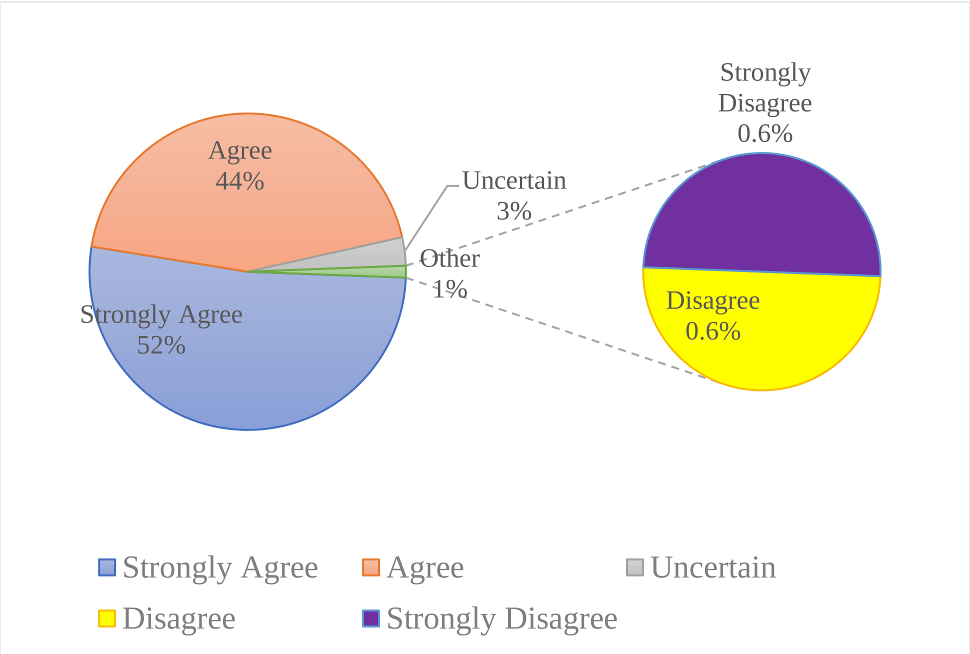


Figure 4.5: Definition of BIM

The respondents who had a BIM Manager were 68% and those who did not have were 32%. Having a BIM manager is a strong indication of complete or ongoing BIM adoption. The survey also found that 68.6% of the respondents had already used BIM on construction projects, 30% had not and 1.1% were unsure.

It was established that BIM was being confused for a software, that is, there were respondents who were using a software facilitating BIM system and were confusing it for BIM. Table 4.4 shows a crosstabulation of how many of those who had adopted BIM were calling BIM a software. The crosstabulation shows that 62.6% of those who had adopted BIM thought BIM is a software and 36.4% thought BIM is not a software. 63.6% of the respondents who had not adopted BIM thought that BIM is a software and 27.3% thought BIM is not a software.

Table 4.4: Crosstabulation of BIM adoption and whether BIM is a software

		Is BIM a software			
		Yes	No	I do not know	Total
Have you adopted BIM in your organization	Yes	62.6%	36.4%	1.0%	100% -99 No.
	No	63.6%	27.3%	9.1%	100% -33 No.
	Planning to Adopt	70.7%	29.3%	0.0%	100% -1 No.
	Partial/ongoing adoption	100%	0%	0%	100% - 2 No.
Total		65.1% 114 No.	32.6% 57 No.	2.3% 4 No.	100% 175 No.

Appendix I shows the preferred BIM software as stated by respondents. It emerged that Autodesk was the most popular brand and specifically Revit software. Graphisoft was the second most preferred brand and the software of choice was ArchiCAD. Out of 389 recorded usages of the various software illustrated in Appendix I. there was 57.8% preference for Autodesk, 13.6% for Graphisoft, 7.9% MS project, 1.8% for Prokon, 1.5% for Tekla and others 20.3% in terms of usage and not number of respondents.

Software companies and sellers whose main aim is to sell their products, seemed to have created a gap that had led some professionals to think that BIM is a software. To note, though Quantity Surveyors seemed to be among the consultants not adopting

BIM faster they also seemed to be exposed to many more software as compared to the other disciplines.

The respondents were also asked at what stage of BIM adoption they were at. Figure 4.6 shows that 29.1% were in stage 0, 28.6% were in stage 1, 29.7% were in stage 2, and 12.6% were in stage 3.

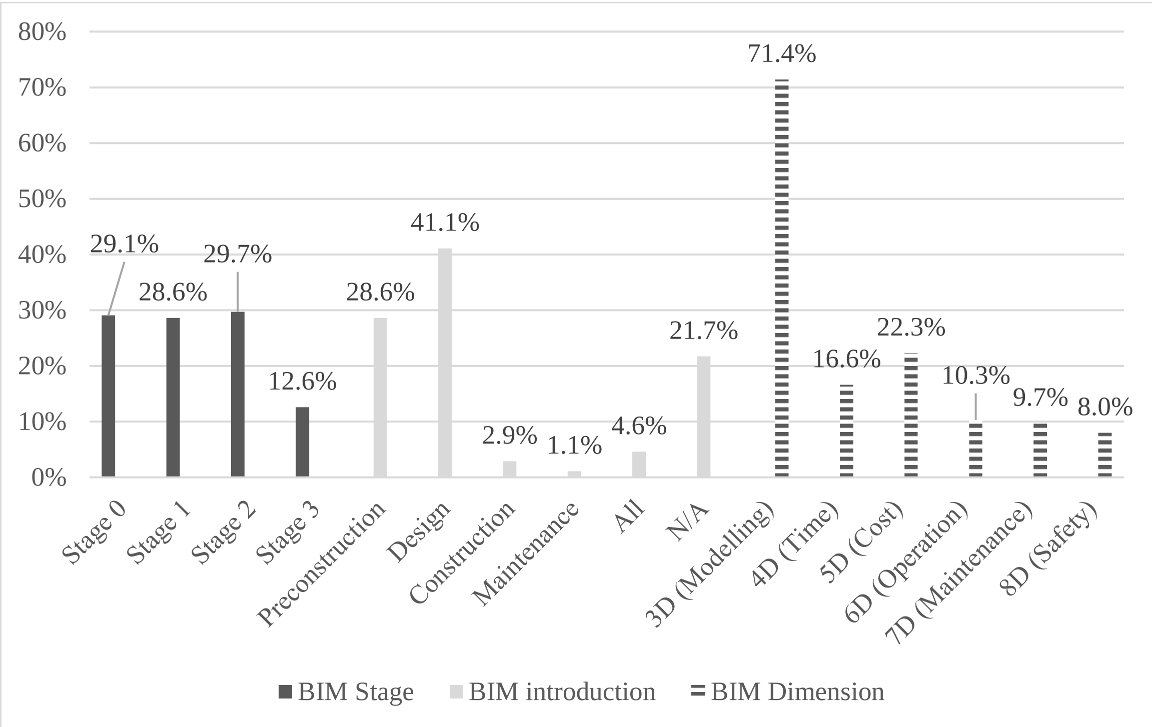


Figure 4.6: BIM adoption; Stages, Dimensions and Introduction to projects

Stage 0 means pre-BIM, or respondents who had not yet adopted BIM, whereas stage 1 is object-based modelling, stage 2 is model-based collaboration and stage 3 is network-based integration. These results show that the majority of the respondents were at stage 1, 2 and 3. Musyimi (2016) findings showed that Pre-BIM had 40%, stage 1 had 60%, stage 2 had 0% and stage 3 had 0%. Wambui (2018) findings showed that stage 1 had 50%, stage 2 had 45.56%, stage 3 had 4.44%, however the author did not report stage 0. This implies that from year 2016 till 2020 there has been a progressive growth in BIM adoption maturity in Nairobi. This growth was recorded within the private companies which in spite of the Government lack of guidance, they still look for strategies to implement BIM in their projects this corroborates Arshad et al. (2019) findings. The private sector in Kenya was found to be leading in BIM adoption, whereas in the public sector is still silent. It will be good for the private sector to continue pushing for BIM adoption.

On BIM dimension the majority 71.4% mainly use BIM for 3D (modelling), the least proportion at 8% used 8D (safety). Majority of respondents introduced BIM at 41.1% at design stage, while 21.7% did not use BIM in any stage. Implying that all dimensions of BIM were being explored but 3D remains the most popular and 3D was mainly used at the design stage.

Figure 4.7 shows that there were 29.1% respondents with college BIM education even though there lacks a BIM curriculum, those who had not received BIM education were 78.6%. Kenyan research and educational centres are not including BIM in the curriculum, this affects the technical capacity that could be used to advance skills in the job market.

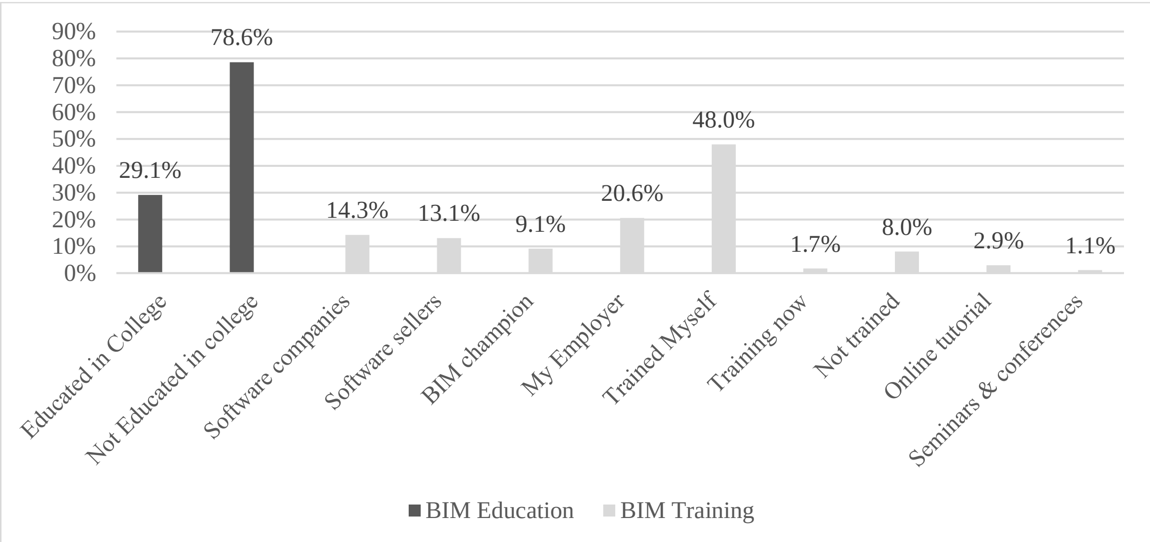


Figure 4.7: BIM education and training

At the job market, 48% were self-trained and 20.6% were trained by the employer, some of whom were already self-trained while 8% were not trained. Proper training lacks due to either employers' lack of interest or lack of skilled trainers. The study established, on job BIM training seemed to be the way most professionals were gaining knowledge and awareness on BIM.

The respondents were asked to rate how BIM has benefited their organization, Figure 4.8 shows on top of the list as improved resource allocation at 48%, followed by improved client relations at 39.4%, efficiency at 1.1%, improved quality at 1.1%, improved collaboration and design coordination at 0.6%, improved measurement at 0.6%, unwillingness to adopt at 0.6% and no tangible benefits at 0.6% was among the reasons rated lowest.

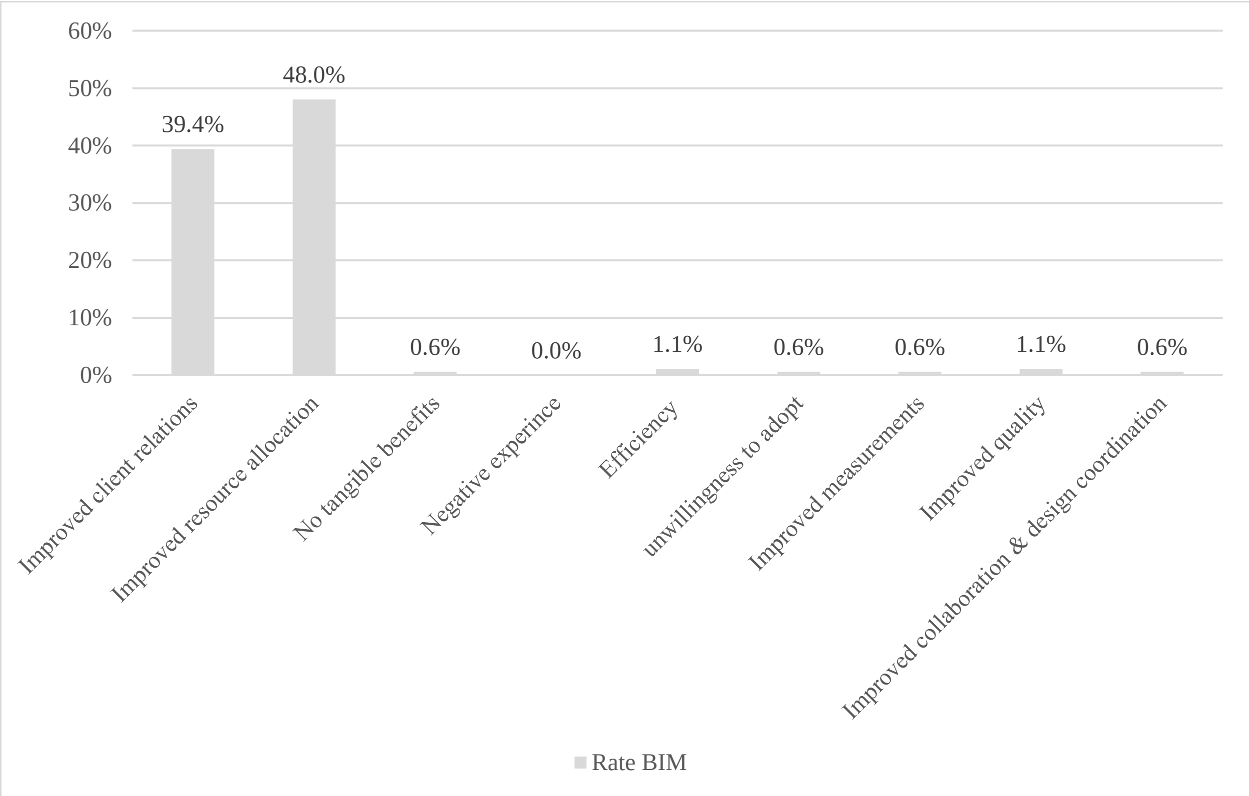


Figure 4.8: Organizational BIM rating by respondents

The respondents who had not adopted BIM gave the following reasons for not adopting and as indicated in Figure 4.9; 17.7% said lack of training, 12% said there was no client requirement, 9.7% lack of standards and guidelines, 9.1% BIM implementation process was too expensive, 8% cited lack of policy, 4.6% were satisfied with existing system, 4.6% did not understand BIM, 4% reported that BIM was too complicated and 0.6% cited that top management did not understand BIM.

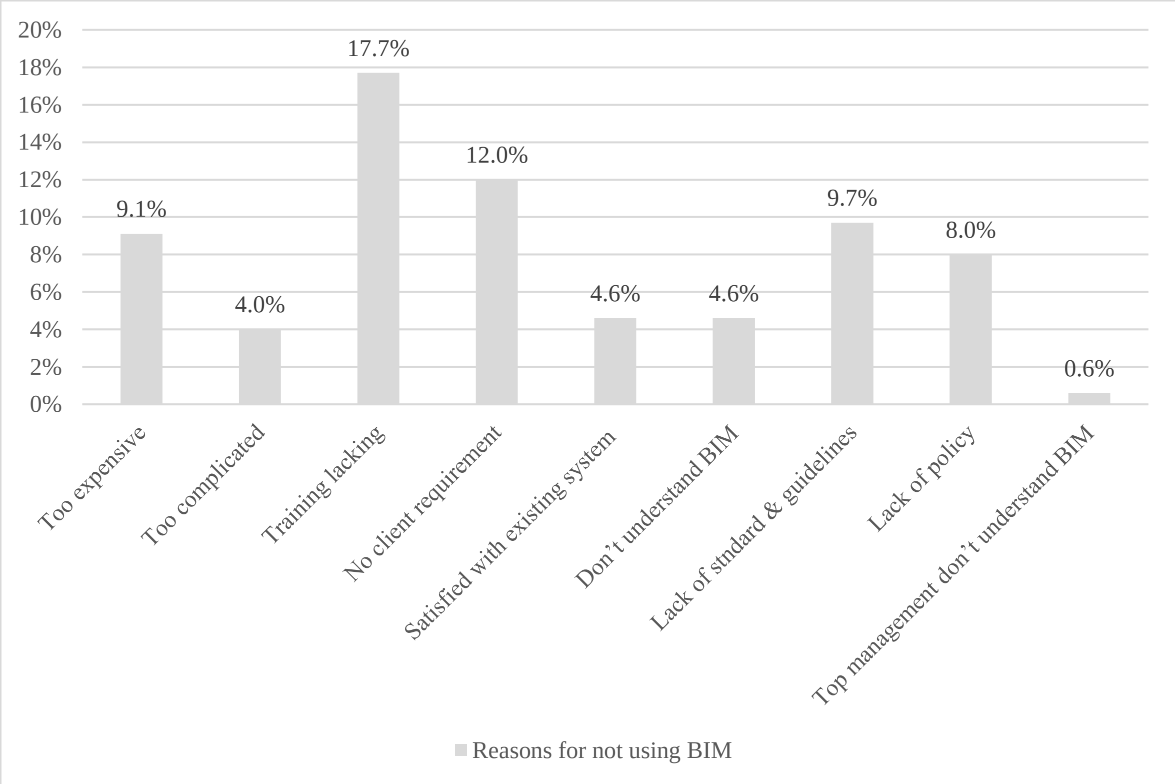


Figure 4.9: Reasons for not using BIM

The following standard forms of contract were identified by the respondents as the ones used for construction projects, they are shown in Figure 4.10.

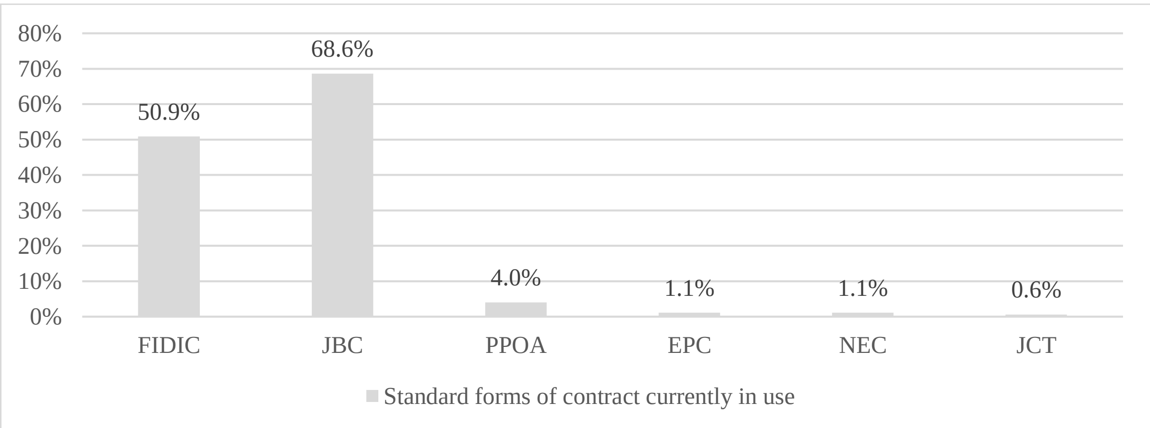


Figure 4.10: Standard forms of contract currently in use in Nairobi Kenya.

The most used was Joint Building Council (JBC) at 68.6%, followed by International Federation of Consulting Engineers (FIDIC) at 50.9%.

The Traditional Procurement System (TPS) performance was also checked, respondents were asked whether it had failed the client's expectations. As shown in Figure 4.11, 54% agreed that the system had failed the client, 29% disagreed, while 17% were uncertain. Figure 4.12 shows the most preferred method of procurement to have been Design-Bid-Build (DBB) at 39% followed by Design-Build (DB) at 26% and the Management Contracting at 22%, Public-Private-Partnership at (PPP) 6%, Joint venture (JV) at 4%.

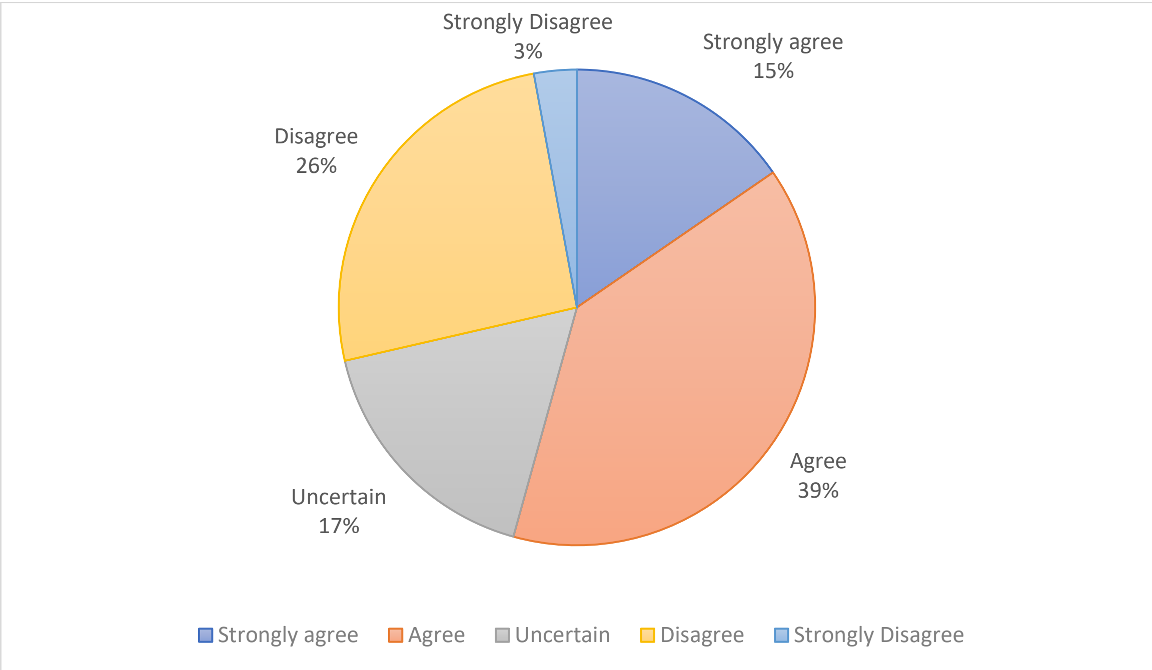


Figure 4.11: The Traditional Procurement System had failed the client

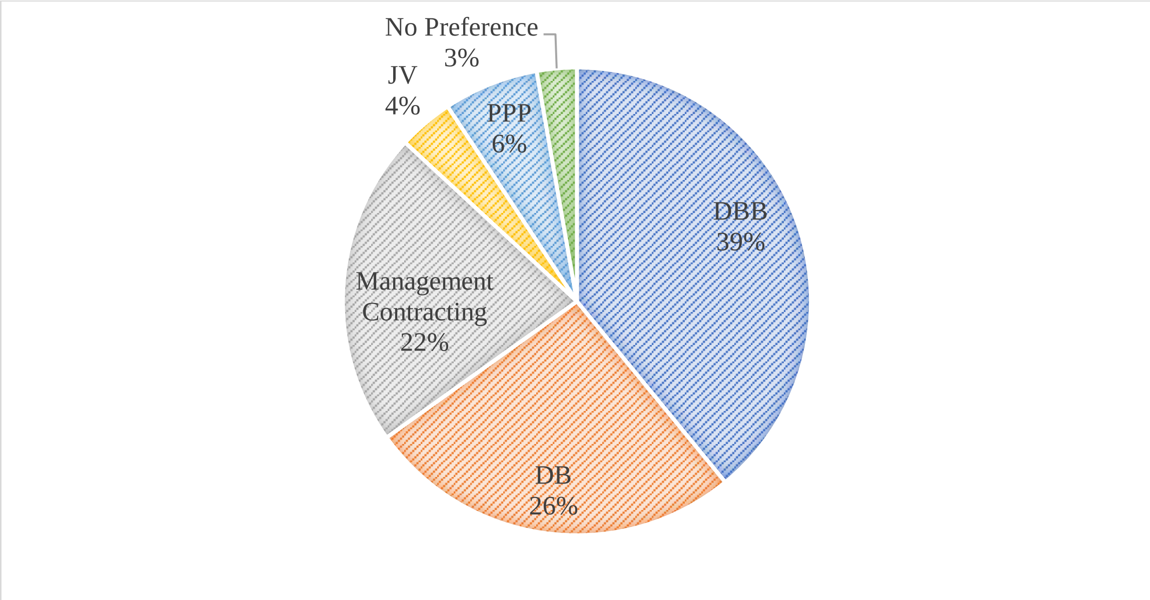


Figure 4.12: Preferred method of procurement in Nairobi Kenya

4.3.1 Matters that affect BIM adoption in Nairobi Kenya

The respondents raised several concerns to answer to the unstructured questions. Table 4.5 illustrates the results whose explanation follows the Table.

The high cost of implementation was mentioned 20.8% as compared to all the subtopics listed here. Cost of implementation and maintenance of BIM was said to be high; firms were spending up to KSh.400,000 yearly subscription fee per license for software, this cost did not include cost for hardware, software, internet, cloud collaboration, cloud storage and training. The smaller companies are affected more than the bigger companies. Capital investment was found to be out of reach, but respondents also said that it depended on the assessor's point of view, because it becomes affordable in the long run due to project's time reduction and ability to use a smaller workforce. Software's yearly licenses were said to be expensive, but on the other hand more work could be done in a year, translating to 50% more projects, with less human resource, shorter design period, and the profit is used to cover the cost of the license.

Table 4.5: Matters that affect BIM adoption in Nairobi, Kenya.

	Number of times it was mentioned by respondents in relation to the other topics	
	Frequency	percentage
High cost of implementation	57	20.8%
Training challenges	38	13.9%
Lack of Awareness and knowledge	36	13.1%
Lack of contractual guidance	29	10.6%
Lack of Skills	23	8.4%
Change resistant attitude	18	6.6%
Lack of Understanding	16	5.8%
Collaboration challenges	13	4.7%
Education challenges	9	3.3%
Technology challenges	8	2.9%
Complexity of BIM	7	2.6%
Lack of Leadership	5	1.8%
Sensitization challenges	4	1.5%
Transparency benefit	3	1.1%
Size of project	3	1.1%
Lack of Case studies	1	0.4%
BIM champion challenges	1	0.4%
Contractors unwillingness	1	0.4%
Uninformed clients	1	0.4%
Lack of Government mandate	1	0.4%
	274	100%

The construction industry lacks proper training, this rated at 13.9%. There are limited training centres and this contributes to inadequate capacity building. It was also opined that as it has been the norm for the employer to offer industrial training, currently, they in addition provide BIM training, in most cases those graduates having never heard or interacted with BIM. Sensitizing the industry about BIM will push the parties to seek training, once the demand is secured, more training centres are likely to fill this gap. This corroborates Musyimi (2016) findings, whose research was also based in Nairobi, where training was mainly carried out by software sellers who would end up promoting their product. This training challenges have caused confusion between BIM the system and a software supporting the BIM systems as was shown by the results of this study.

Lack of awareness and knowledge appeared 13.1% as compared to all the subtopics listed here. The respondents opined that there lacks enough information and industry awareness of BIM capabilities, in addition its benefits may not be known and where they are known they are not readily explored. This lack of knowledge on how to operate BIM, and the nature of benefits has affected how BIM is perceived. Even though cost was highly cited to be a barrier to adoption, the upside is not known to professionals, the upside being that in the long run BIM is cheaper, it gives a positive ROI. Case studies should be carried out to verify the ROI results caused by BIM adoption. T N Kimani et al. (2019) also found that there was limited BIM knowledge in Nairobi.

Lack of contractual guidance was mentioned 10.6% as compared to all the subtopics listed here. According to the respondents, there lacks industry-wide standards and guidelines even the professional bodies have not given directives on this issue. Further there lacks government policy, legal framework, and regulations to define documentation and contractual obligations in the digital environment. Additionally, there is no compulsory inclusions in the building code. It was also stated that; the procurement act is not favouring BIM and that it needed to be revised. The 2015 Act revised in 2016 document states in part 1:5. on conflicts with other Acts: (1) the Act prevails in case of any inconsistencies or other legislation except where procurement of professional services is governed by the Act of Parliament applicable for such services. Since the Act is superior, revising it gives the industry a legal means through which to implement BIM. Though the respondents blamed, the Traditional Procurement System (TPS), some of them opined that in its context BIM works better with design-build method.

Lack of skills was raised 8.4% as compared to all the subtopics listed here. The respondents opined that Nairobi and Kenya at large has inadequate BIM skills and BIM experience. There is also ignorance of skill affiliated to BIM hence resulting to improper use of BIM. Creation of awareness leads to seeking the knowledge required through quality training and BIM curriculum. Further awareness arouses curiosity towards the new technology, and this leads to adoption.

Change resistant attitude was raised 6.6% as compared to all the subtopics listed here. As per respondents' there is a section of the industry players who are not receptive of new technologies, they prefer to ‘wait and see’. This was based on comparison between fresh graduates and professionals who were nearing retirement age, the latter group was reported to be hesitant towards new technologies and trends. Younger people are more receptive to technological change as compared to older people. It was also stated that established firms with capacity are reluctant to adopt BIM either due to unwillingness or are comfortable with the existing TPS. Manza (2016) and Musyimi (2016) found change resistant attitude was affecting BIM adoption.

Lack of understanding was mentioned 5.8% as compared to all the subtopics listed here. Lack of understanding was strongly mentioned in the in-depth interview as the main hinderance of BIM adoption and implementation. The players in the construction industry lack understanding of what BIM is and what its full capabilities are. Further, they have a misconception that it is difficult to use BIM. It was further stated that this low understanding will delay reaping of BIM’s benefits, for if BIM is not used appropriately it will not give back the intended benefits. Waigwa (2016) stated that BIM in Kenya is still associated with software.

Collaboration challenges was mentioned 4.7% as compared to all the subtopics listed here. It was opined that, there was limited network transmission band-width to enable real time collaborations with other professions; there lacks industry-wide initiative. This is because few consultants have adopted BIM, and those who have, they use their own templates and use other drawings to overlay, hence hindering full coordination and collaboration. It was further stated that, fragmentation in the construction industry contributes to lack of proper coordination and hence hindering full collaboration, this corroborates with findings by Musyimi (2016) that the fragmentation divided the disciplines making them too independent hence hindering collaboration. Nevertheless, some consultants have started insisting on working with players and more so contractors who have adopted BIM.

Education challenges was mentioned 3.3% as compared to all the subtopics listed here. it was opined that BIM was not included in the curriculum, or there was delayed introduction of BIM programs where an attempt has been made to teach BIM. The education system is derailing adoption of BIM in the country, universities, and research centres should change this by facilitating learning, opening computer labs, having joint ventures with software companies and buying genuine software licenses. It was also stated that, outdated methods of mainly using T-squares and drawing boards were still being used to teach. Students would get a culture shock once they enter the job market, they get shocked by the level of technology they would need to catch up with. Respondents also suggested that Education on BIM and other new technologies should start in secondary schools whereas universities and research centres should advance the secondary education and encourage innovations of software. In addition, they should open modern computer labs; have Joint Ventures with software companies and buy genuine software licenses for already prices for the African market are subsidized. Without this measure it was stated that technology will phase out people who are resisting its changes.

Technological challenges were mentioned 2.9% as compared to all the subtopics listed here. According to respondents, there is low level of acceptance of technology whereby the minimum requirement for BIM adoption is hardware, software and internet when put together. The choice of the right software is interrupted by trends and at the same time software companies are not making it clear that their software is not equal to BIM. Interoperability of software is still not understood, some professionals feel that one type of software should be used across the board. The use of pirated/unlicensed software are discouraging online usage, hence limiting collaboration. It was also stated that use of outdated computer hardware and software coupled with low level of digital literacy is a challenge facing BIM adoption. Further, pirated software cannot give full benefit, but licensed software incorporates additional benefits such as back-ups and working from the cloud, sharing knowledge, and exchanging libraries from all over the globe.

Complexity of BIM was raised 2.6% as compared to all the subtopics listed here. It was opined that, BIM required a lot of research and input at the start of a project hence need for proper planning, consultants who are used to shortcuts find this to be tedious and prefer to stick to old ways they are comfortable with. However proper education and training were seen as a mitigation measure towards demystifying this belief.

Lack of leadership was raised 1.8% as compared to all the subtopics listed here. It was opined that the industry is led by rigid people without vision who do not appreciate emerging technologies. Professional bodies are not safeguarding professionals instead, unqualified personnel are left to practice illegally, forcing professionals to charge less, hence lowering professional rates. Hence low returns that hinder adoption of genuine technology. There are inflexible employers who pressure their employees to finish projects within a timeline making it harder for concerned professionals to learn new technologies these employers are comfortable with doing things in the old ways. Musyimi (2016) also found there was lack of government agency to lead the process of BIM adoption. This gap in leadership has made it harder even for technology enthusiasts working in this rigid organizations to get BIM training.

Sensitization challenges was raised 1.5% as compared to all the subtopics listed here. The respondents claimed that there is lack of sensitization of BIM in the construction industry and there is poor marketing of the various BIM supporting software. Lack of sensitization translates to lack of awareness leading to hinderance to BIM adoption.

Transparency benefit of BIM was mentioned 1.1% as compared to all the subtopics listed here. According to the respondents, transparency is frowned upon. One of the contributing factors was credited to consultants' laziness in finishing work; BIM does not encourage unfinished work, it is transparent. Drawings in BIM are informed, there are no shortcuts, nor assumptions for one cannot get away with ignorant details, unlike the pre-BIM system where over-estimation was common on the bills of quantities to cover up errors of omissions in poorly done drawings. It was further stated that there were hidden interest and corrupt deals that have matured in the construction industry, the idea that these could be exposed by transparency in BIM is terrifying to corrupt parties. The brighter side is that this transparency discourages corrupt deals hence saves resources. Ndemo (2015) corroborates this by stating that Kenyan leadership and corrupt cartels were against systems that encourage transparency and that help fight corruption.

Size of project was mentioned 1.1% as compared to all the subtopics listed here. It was opined that most consultants reserve use of BIM for big projects, there is a misconception in the industry that BIM is not cost effective on small projects. Having the right knowledge on BIM will mitigate this misconception. Whereas lack of case studies was mentioned 0.4% times as compared to all the subtopics listed here. Respondents opined case that there were no case studies done on BIM projects in Kenya and that there is need to do them because they could be used to guide in adoption. Lack of these case studies also means lack of proving the positive business value this corroborates Nicał & Wodyński (2016). In addition, case studies could boost the BIM knowledge and help in understanding the BIM system.

BIM champion challenges was mentioned 0.4% as compared to all the subtopics listed here. Respondents stated that Kenya lacks major BIM champions, there are a few individuals who are attempting to champion but they lack capacity or a favourable platform. McAuley et al. (2017) stated having a BIM champion in a country is one of the key ingredients towards BIM adoption.

Contractor unwillingness was mentioned 0.4% as compared to all the subtopics listed here. It was opined that contractors were not willing to adopt BIM and that in most cases they were being forced by circumstances whereby, its either they conform or to lose the job. There are those contractors that employ a ‘wait and see’ attitude and others are forced to conform because of available business opportunities, however according to Smith (2014b) this reluctant attitude is no longer seen as a viable option.

Uninformed clients were mentioned 0.4% as compared to all the subtopics listed here. According to respondents, clients are not well informed, so they lack a basis to demand BIM on their projects. Very few clients are aware of BIM and this group insist on working with consultants who are on the BIM platform. Most of these informed clients are international private developers, whereas majority of the local clients do not know BIM.

Lack of Government mandate was mentioned 0.4% as compared to all the subtopics listed here. The respondents opined that, lack of government mandate and policy of

BIM was reported to be a big hinderance to BIM adoption. This is the Kenyan situation, it is worth to note that worldwide this point is seen as one of the major barriers of BIM implementation, because where governments have mandated BIM, positive BIM results have been witnessed (McAuley et al., 2017). This finding corroborates; Musyimi (2016); Manza (2016); Waigwa (2016) and Pring (2019) who all stated that lack of government involvement in Kenya is a major hindrance in BIM adoption.

4.3.2 How the Traditional Procurement System (TPS) had failed the client.

The respondents were asked how the TPS had failed the client. Unstructured data was collected and analyzed into themes as illustrated on Table 4.6. The themes are explained in subtopics following the Table.

Table 4.6: Performance of the Traditional Procurement System

	Number of times it was mentioned by respondents in relation to the other topics Frequency	Percentage
Cost overruns	25	19.4%
Time consuming	23	17.8%
Adversarial relationships	21	16.3%
Quality issues	19	14.7%
Accountability and transparency challenges	15	11.6%
Planning and Scheduling challenges	9	7%
Rigid to technology	7	5.4%
Flexibility challenges	3	2.3%
Client’s Knowledge and exposure	3	2.3%
Buildability challenges	1	0.8%
Liability issues	1	0.8%
International competitiveness	1	0.8%
Loss of drawings	1	0.8%
	129	100%

Cost overruns was mentioned 19.4% as compared to the other subtopics mentioned here. Respondents opined that cost uncertainties and unpredictable final cost, as a consequence of inadequate information provided by professionals, resulting to variations and claims that could have been avoided. Furthermore, areas of cost saving that could have benefited the client are overshadowed by these inefficiencies rendering value engineering exercise not as successful as it should be. This findings corroborates research done by Munyoki (2014), Seboru (2015), and Kogi & Were (2017) who illustrated instances of cost overruns in construction projects in Kenya.

Time consuming aspect was raised 17.8% as compared to the other subtopics mentioned here. According to respondents TPS has always been time consuming because design stage is separate from construction stage. This sometimes results to failure to deliver projects within agreed timelines. This wasted time results to withholding other possible projects in order to solve issues of the ongoing projects. Time wasted translated to a cost hence contributing to cost overruns.

Adversarial relationship was raised 16.3% as compared to the other subtopics mentioned here. The respondents opined that the system has a failed protocol system with too many independent project teams that affect client's coordination. This is worsened by design stage being separate from construction stage. The poor or lack of collaboration between professionals, lead to inefficiencies. The structure of TPS contributes to misinterpretation of the value sought after by the client. Lack of proper coordination and use of 2D drawings are the biggest contributors for in most cases the client does not understand the 2D drawings. Though coordination challenges were reported to be the major contributor to the system failure, some respondents opined that if the method was to be run well the client would never mind the use of TPS, but again those loopholes are hard to seal.

Quality issues was mentioned 14.7% as compared to the other subtopics mentioned here. According to respondents the method delivers poor quality results, the client does not get value for money. The division of design and construction stages create discontinuity of the process, sometimes the team is replaced by a new team which may not have been handed all the required documentation, this results to duplication of efforts. Quality is also compromised when incompetent contractors are procured through lowest bidder policy, but they may not necessarily have the capacity to execute projects.

Accountability and transparency challenges was mentioned 11.6% as compared to the other subtopics mentioned here. The responded stated there are loopholes to allow consultants to collude and steal from the client; it is easy for the procuring entity to manipulate the procurement process. This corroborates findings by Mbaabu (2012), where one of the mitigation measures was to block politicians from accessing road construction projects.

Planning and scheduling challenges was raised 7% as compared to the other subtopics mentioned here. It was stated that, it has many uncertainties, lacks proper projections and its reactionary and not proactive. This uncertainty causes over-estimation of resources making the project more expensive. This is true also because of design stage being separate from the construction stage.

Rigidity to technology was mentioned 5.4% as compared to the other subtopics mentioned here. It was opined that TPS is rigid and does not seem to be adopting to the changing technology. TPS has been known to operate with hardcopies and mainly 2D drawings, this norm has created a comfort zone for some industry players, in that as technological trends evolve, TPS still remains faithful to outdated trends and not receptive to future trends. Flexibility challenges were mentioned 2.3% times as compared to the other subtopics mentioned here. Slow decision making and management of price from design stage to construction is a challenge and it ends up attracting conflicts, especially, where finances are limited to managing the available resources.

Client's knowledge exposure was mentioned 0.8% as compared to the other subtopics mentioned here. It was opined that it probably is the only system most clients are exposed to and in most cases the client does not fully understand how construction contracts work. This sometimes results to lack of trust especially if the consultants fall short on their obligations. All this may lead to complex legal issues which could have been avoided if the system were transparent.

Buildability challenges was mentioned 0.8% as compared to the other subtopics mentioned here. Respondents stated that the contractor has been excluded in giving his opinion on what is executable leading to complex and un-executable designs hence rework which result to cost and time overruns. The construction industry in Nairobi is fragmented, design and construction stages are treated as two separate stages, this therefore follows that some errors are noticed during actual construction when it is too late to avoid reworks.

Liability issues was mentioned 0.8% as compared to the other subtopics mentioned here. It was opined that in case of poor project performance, compensation for the client is in most cases not taken seriously. BIM being transparent, all issues can easily be traced back to the responsible parties hence allowing for fair compensation strategies if need arose.

International competitiveness was raised 0.8% as compared to the other subtopics mentioned here. According to respondents, TPS is slowly becoming less competitive on an international scale, the focus seems to be shifting to BIM and integrated project delivery. Turina et al. (2008) findings corroborate, where it stated that many clients are increasingly dissatisfied with the traditional approach and seek alternative approaches to meet their dynamic demands.

Loss of drawings was mentioned 0.8% as compared to the other subtopics mentioned here. It was opined that data is easily misplaced, due to coordination issues, use of hardcopy drawings, use of 2D drawings and due to adversarial relationships. It is normal to look for drawings and any other data and fail to locate them. This corroborates findings by (Mbaabu, 2012), that consultants would turn up in meetings and find some contractual documents missing. TPS generally has always worked with bulky hardcopies that could be difficult to store and keep up with, this is magnified by the fragmented nature of the construction industry.

The Traditional Procurement System (TPS) and lack of understanding were found to be among the biggest hinderance to BIM adoption. Achievement of all the benefits of collaborative BIM is hindered by TPS and its adversarial nature. Unfortunately, there is no clear formula of adopting BIM in Nairobi, in other counties in Kenya and in most countries because of lack of standards and guidelines this finding supports (S. Azhar et al., 2012; Kimani et al., 2019; Manza, 2016; Musyimi, 2016). Where BIM has worked well the government has been involved this corroborates (McAuley et al., 2017). Though in Nairobi, some private organizations have taken the initiative to adopt BIM ahead of government directives, it should be noted that this group prepare procurement contracts, standards, and guidelines on an ad-hoc basis. These pioneering initiatives are likely to influence other reluctant observers where competitiveness is a factor determining winning of tenders. This was depicted by Succar & Kassem (2017) as one of the models used across the world to aid adoption. The recurring themes found and that need action are awareness, standards, guidelines, government mandate, procurement system, education, training and technology this corroborates (McAuley et al., 2017).

4.4 Results and Discussion for Objective 2: Underlying components in BIM adoption

The objective was to determine underlying factors of BIM adoption in Nairobi, Kenya. Friedman ranking test and Exploratory Factor Analysis (EFA) were used to analyse the results of this objective. The research sought to find out the important components of BIM that makes professionals want to adopt BIM. To analyse the factors the study used 26 variables based on characteristic benefits of BIM and other external factors. They were rated using a 5-point Likert scale range from; 1= very important, 2= important, 3= uncertain, 4=less important, 5= Not important.

4.4.1 Ranking of the important components in BIM adoption

The Friedman Ranking test was used to rank the variables in importance as per respondents preference. This test compares the mean ranks between the related variables (Lowry, 2012; Friedman, 1937; Laerd statistics, 2013), the results are tabulated in Table 4.7. It appeared that collaboration component was very important to most professionals adopting BIM followed by intelligent 3D visualization, improved accuracy, and clash detection in that order.

The results from Table 4.7 indicate that the BIM components are significant in its adoption χ^2 (25) = 421.019, p=0.000. This shows that there is a difference with ranking than would be expected by chance only. The null hypothesis being that there is no difference in ranking between observed and expected.

Table 4.7: Important component in BIM adoption

Rank	Important component in BIM adoption	Mean Rank
1.	Collaboration	10.84
2.	Intelligent 3D visualization	11.17
3.	Improved accuracy	11.17
4.	Clash detection	11.28
5.	Better coordination	11.56
6.	Time saving	11.98
7.	Buildability	12.10
8.	Quality Improvement	12.10
9.	Improved communication	12.22
10.	Transparency	12.61
11.	Cost saving	12.62
12.	Real time capabilities	13.05
13.	Better decision Management	13.06
14.	Consistent lifecycle information	13.19
15.	Risk Management	13.67
16.	Sustainability	15.05
17.	Improved Customer client relationship	15.27
18.	Improved facility management	15.37
19.	Energy analysis	15.39
20.	Safety Management	15.50
21.	Return on investment	15.90
	External factors	
1.	Size of a project	13.65
2.	Technological capabilities	14.83
3.	Pressure to remain competitive	15.62
4.	Financial cost of adoption	15.83
5.	Top management support	15.95

Test Statistics - Friedman Test	
N	175
Chi-Square	423.019
Df (degree of freedom)	25
Asymptotic Sig.	.000

4.4.2 Underlying factors of the important component in BIM adoption

This study computed the underlying factors in BIM adoption. Exploratory Factor Analysis (EFA) was used because the number and nature of factors expected were not known (Williams et al., 2010). The extraction method used was Principal Component Analysis (PCA) and the rotation method was varimax with Kaiser Normalization. PCA is suitable in EFA as a data reduction technique, it enabled compression of the large number of variables within BIM adoption and it is suitable when no priori theory or model exists (Williams et al., 2010). It gave the underlying factors which were manageably interpreted (Neill, 2008). Prior to deciding on varimax rotation, Oblique rotation was run, and the findings showed that factors correlation was less than 0.5 meaning they were orthogonal in nature, hence the decision to use Varimax rotation.

The correlation matrix displaying the relationships between individual variables 95% of the variables had a correlation coefficient above 0.30 (Williams et al., 2010) hence the suitability of EFA for data analysis. Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy was 0.907, a KMO above 0.5 is satisfactory (Hair et al., 2014). Bartlett’s test of sphericity was significant at $\chi^2 = 2743.280$, $p<0.001$, meaning that the correlation matrix of the variables in the dataset diverges significantly from the identity matrix. This test result is shown on Table 4.8. The diagonals of the anti-image correlation matrix were also over 0.8. Communalities were above 0.4 as indicated in Appendix II. hence confirming that each variable shared some common variance with the factor it loads under, hence all variables were retained (Yong & Pearce, 2013). This was to satisfy that EFA was a suitable method of analysis.

KMO tests the suitability of factor analysis, the measure is between 0 and 1, values closer to 1 are better, whereas Bartlett’s test of sphericity assessed that the variables are significantly correlated and tests the hypothesis that the correlation matrix is an identity matrix (Kothari & Garg, 2019).

Table 4.8: KMO and Bartlett's test for significant factors in BIM adoption

KMO and Bartlett's test		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.907
Bartlett's Test of Sphericity	Approx. Chi-Square (χ^{2})	2743.280
	df	325
	Sig.	.000

Number of factors to retain were determined by three approaches: Kaiser criterion, the Scree test and parallel analysis. The Kaiser criterion suggests retaining all factors that are above the Eigenvalue of 1 (Kaiser, 1960). Table 4.9. shows part of a table on the total variance explained the full table is shown in Appendix III. The factors with Eigenvalue greater than 1 were 5 factors, which were accounted for by 63.936% cumulative variance, with each accounting for 42.6%, 7.4%, 5.4%, 4.6% and 3.9% of the variance, respectively. Eigenvalue indicates the relative importance of each factor in accounting for the particular set of variables being analyzed (Kothari & Garg, 2019).

Table 4.9: Total variance explained for significant factors in BIM adoption

	Initial Eigenvalues			Extraction Sums of Squared Loadings		
Component	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	11.079	42.612	42.612	11.079	42.612	42.612
2	1.919	7.381	49.992	1.919	7.381	49.992
3	1.415	5.443	55.435	1.415	5.443	55.435
4	1.202	4.624	60.059	1.202	4.624	60.059
5	1.008	3.877	63.936	1.008	3.877	63.936
6	0.984	3.785	67.721			
7	0.879	3.381	71.102			
8-26	Omitted	by author				
Extraction Method: Principal Component Analysis.						

The scree plot was used as a second determinant of the number of factors to be retained. The scree plot retained two factors, as shown in Figure 4.13. A scree plot is the plot of Eigenvalues against the factor numbers. The vertical line accounts for larger amounts of total variance, at the bend and the horizontal section accounts for smaller and smaller amounts of total variance. Number of factors to be retained are shown above where the plot forms an elbow. The scree plot underestimated the number of factors to be retained to 2 factors hence the decision not to use its estimated factors.

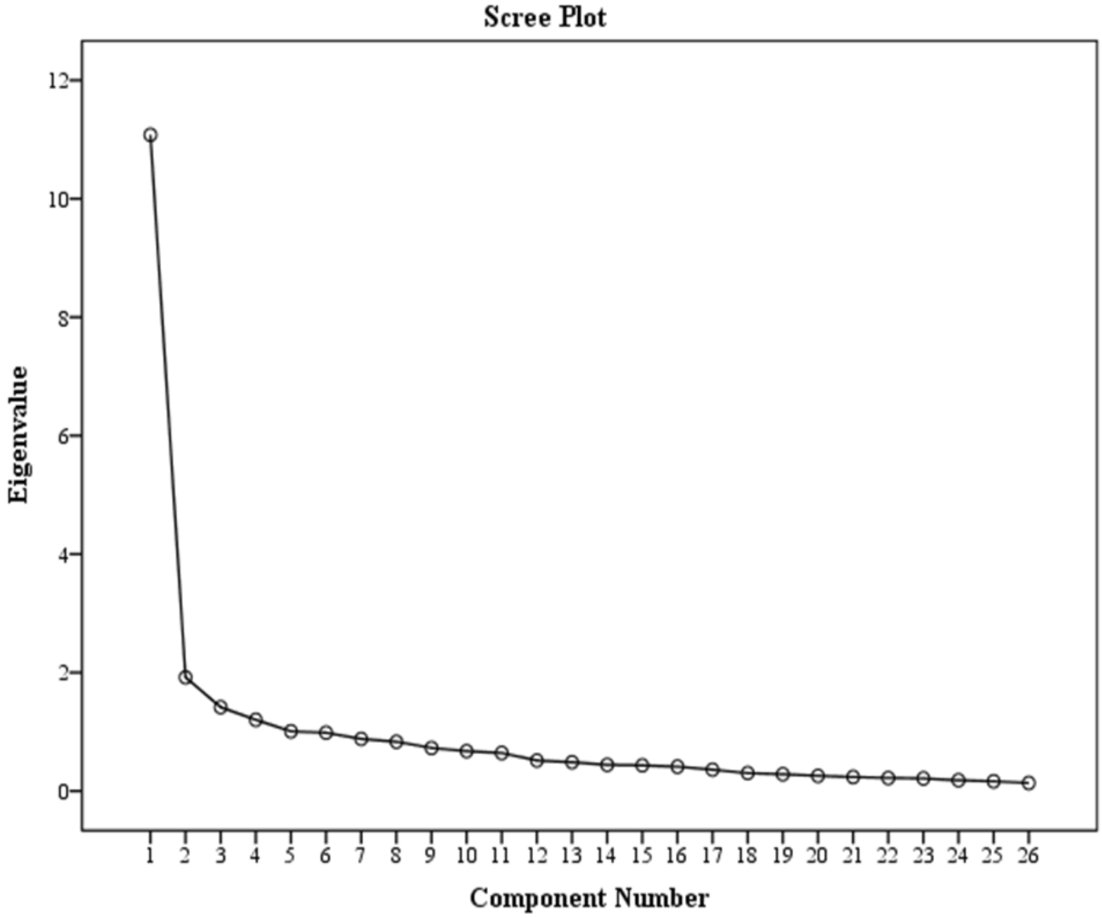


Figure 4.13: Scree plot for underlying BIM factors

The Parallel analysis method was the third method used to determine factors whereby 2 factors were retained. Parallel analysis was done by a web engine and it compares actual Eigenvalues from PCA with random order Eigenvalues from the engine, the factors retained have a higher Eigenvalue than those generated by the engine (Patil, Singh, Mishra, & Donovan, 2017). Table 4.10. shows part of the results, Appendix IV indicates the full version. The decision made based on actual values surpassing the web engine values is shown on the same Table (Williams et al., 2010).

Table 4.10: Parallel analysis for significant factors in BIM adoption

Component or Factor	Mean Eigenvalue	Percentile Eigenvalue	Calculated Eigenvalue (Kaiser Criteria)	Decision
1	1.803069	1.926773	11.079	Retain
2	1.672844	1.754450	1.919	Retain
3	1.568458	1.635770	1.415	Not retain
4	1.483207	1.555569	1.202	Not retain
5	1.406531	1.460730	1.008	Not retain
6	1.344156	1.389507	0.984	Not retain
7 - 26	Omitted by	Author		Not retain

Based on the three methods used, it was decided that 5 factors be retained as per Table 4.9 where the 5 factors have Eigenvalue greater than 1. This decision is supported by Comrey & Lee (1992), that it is better to err on the side of extracting too many factors rather than too few this is because the character of the remaining factors is distorted by intrusion of variance from the factors excluded and not retained in the final solution (Comrey & Lee, 1992). The scree plot and the parallel analysis methods underestimated the factors.

The test was done again with a preset fixed number of the five factors and the results are shown on Table 4.11. The loadings range between -1.0 and +1.0 a strong relationship is closer to 1.0 positive or negative, highly correlated variables that describe the same thing form a pattern under a factor (Hair et al., 2014). Factor labels proposed were efficiency for factor 1, versatility for factor 2, Competitiveness for factor 3, intelligence for factor 4 and transparency for factor 5. Internal consistency was examined for items under each factor; Cronbach's Alpha values were 0.902 for Factor 1 inferring excellent reliability, 0.864 for factor, 0.816 for factor 3, 0.741 for factor 4 and 0.717 for factor 5; high reliability was inferred for factors 2,3,4 and 5.

Table 4.11: EFA summary on underlying factors in BIM adoption

Factor	variable	Loading factor	Factor Coefficient
Factor 1: Efficiency % variance explained = 42.612 Eigenvalue = 11.079 Cronbach's Alpha = 0.902 N = 9	Better coordination	.734	.238
	Collaboration	.724	.249
	Improved communication	.686	.245
	Cost saving	.670	.221
	Better decision management	.626	.180
	Time saving	.610	.168
	Quality improvement	.608	.216
	Clash detection	.607	.165
	Buildability	.510	.061
Factor 2: Versatility % variance explained = 7.381 Eigenvalue = 1.919 Cronbach's Alpha = 0.864 N = 6	Sustainability	.759	.325
	Energy analysis	.722	.328
	Improved facility management	.594	.170
	Financial cost of adoption	.576	.181
	Safety management	.556	.152
	Risk management	.512	.123
Factor 3: Competitiveness % variance explained = 5.443 Eigenvalue = 1.415 Cronbach's Alpha = 0.816 N = 6	Size of a project	.714	.403
	Pressure to remain competitive	.713	.346
	Technological capabilities	.669	.273
	Top management support	.543	.182
	Improved customer client relationship	.524	.177
	Consistent lifecycle information	.502	.173
Factor 4: Intelligence % variance explained = 4.624 Eigenvalue = 1.202 Cronbach's Alpha = 0.741 N = 2	Real-time capabilities	.795	.481
	Intelligent 3D visualization	.706	.405
Factor 5: Transparency % Variance explained = 3.877 Eigenvalue = 1.008	Transparency	.728	.518
	Return on Investment	.545	.343
	Improved accuracy	.472	.255

Factor	variable	Loading factor	Factor Coefficient
Cronbach's Alpha = 0.717 N=3			
KMO = 0.907, Bartlett's χ^2 = 2743.280, p < 0.001 Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization. a. Rotation converged in 14 iterations.			

Regression models based on the coefficient matrix shown on Appendix V. are produced are as follows.

$$F_{ij} = \beta_1 x_{i1} + \beta_2 x_{i2} + ... + \beta_p x_{ip}$$

Efficiency = β_1.238 Better coordination + β_2.249 Collaboration + β_3.245 Improved communication + β_4.221 Cost saving + β_5.180 Better decision management + β_6.168 Time saving + β_7.216 Quality improvement+ β_8.165 Clash detection+ β_9.061 Buildability

Versatility = β_{10}.325 Sustainability + β_{11}.328 Energy analysis + β_{12}.170 Improved Facility management + β_{13}.181 Financial cost of adoption + β_{14}.152 Safety management + β_{15}.123 Risk management

Competitiveness = β_1.403 Size of a project + β_2.346 Pressure to remain competitive + β_3.273 Technological capabilities + β_4.182 Top management support + β_5.177 Improved customer client relationship + β_6.173 Consistent lifecycle information

Intelligence = β_1.481 Realtime capabilities + β_2.405 Intelligent 3D visualization

Transparency = β_1.518 Transparency + β_2.343 Return on investment + β_3.255 Improved accuracy

All coefficients were positive; implying when the variables improve then the factor also improves in performance. These models are saved for use in further analysis as recommended by Anna (2010).

Figure 4.14 shows a chart of the ranked variables from Table 4.7 shown against the underlying factors; variables under efficiency ranked highest followed by intelligence and transparency, whereas versatility and competitiveness variables ranked at the bottom. This indicates that as much as BIM adoption is taking place there are some aspects of BIM that are largely unexplored beyond immediate ones. All factors were interpreted as below.

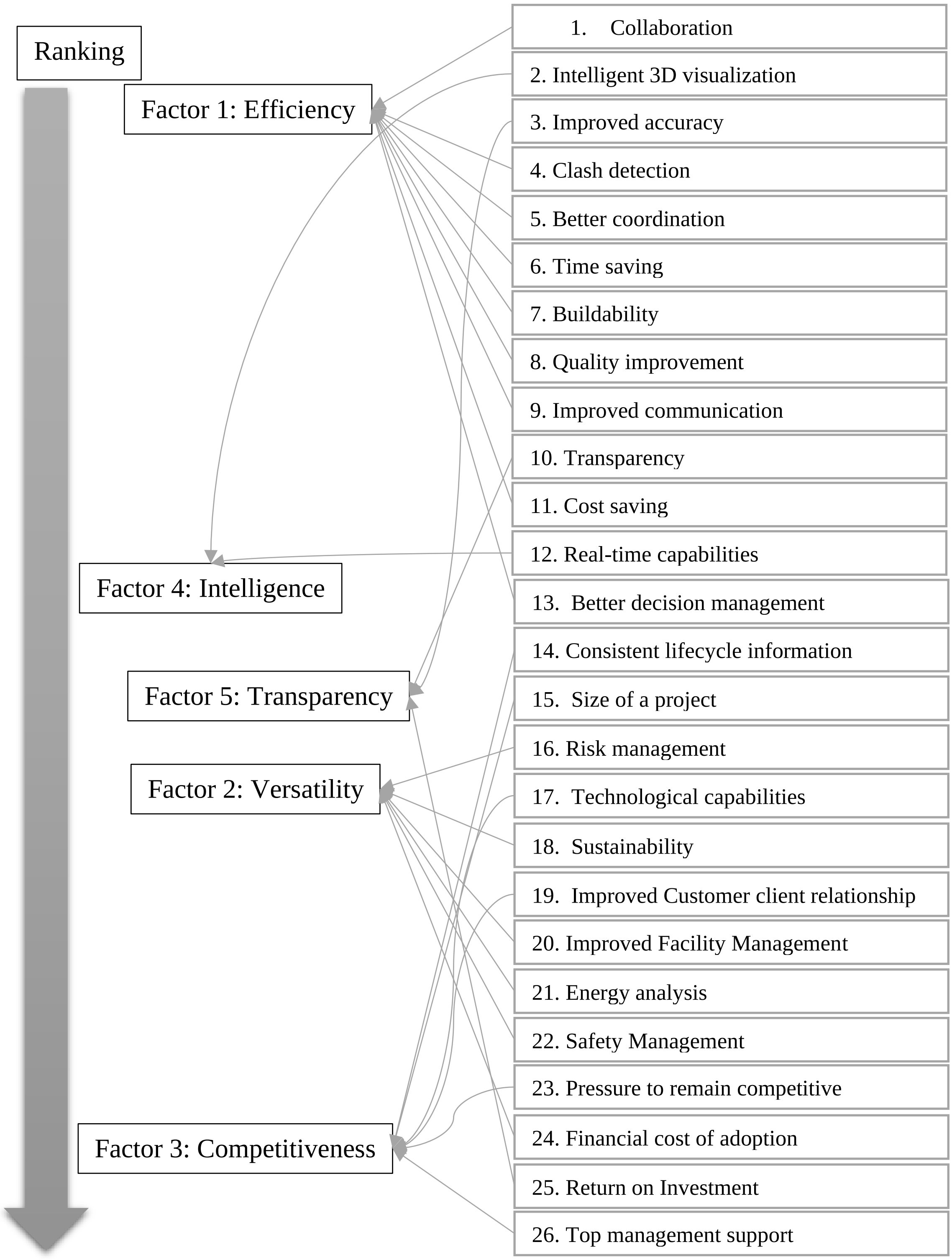


Figure 4.14: Variable ranking of underlying components in BIM adoption

Factor 1 – Efficiency: This factor was made up of the following 9 variables in order of loading, better coordination, collaboration, improved communication, cost saving, better decision management, time saving, quality improvement, clash detection, and buildability. Professionals in the industry are interested in how to efficiently carry out their responsibilities while saving on resources this are the immediate advantages of adopting BIM. The factor is also geared towards effective collaboration which is a big challenge in the Kenyan fragmented construction industry. The team members including the contractor and facility manager give their input early hence reducing on reworks. Collaboration enables saving of resources. In this regard, awareness needs to be increased to enable adoption for the benefits to be useful to the industry. If collaboration is effective it in turn enables resource saving this corroborates (Musyimi, 2016). These benefits make contract management process easier and effective.

Factor 2 – Versatility: Versatility comprises of the following 6 variables in order of loading, sustainability, energy analysis, improved facility management, financial cost of adoption, safety management, and risk management. Other than the primary benefits, there are other benefits that come with improved technical know-how of BIM use and they come as a secondary requirement for making the decision to adopt. Sustainability and energy analysis loaded highest, notably, green construction is an important topic globally. These processes that have been traditionally difficult to conduct are easily executed through computer simulation. Risk management, especially safety which is a big challenge in the construction industry is well analyzed and mitigated in time. Financial cost of adoption is recoverable through the efficiency power of BIM. It is up to the stakeholders to abandon the outdated techniques of executing projects and embrace the versatility in BIM this corroborates (Grzyl et al., 2017). Consequently, training of skills is key to bring understanding into the industry of how BIM brings versatility in the industry.

Factor 3 – Competitiveness: Competitiveness comprises of the following 6 variables in order of loading, size of a project, pressure to remain competitive, technological capabilities, top management support, improved customer client relationship, and consistent lifecycle information. Size of a project was found to be dictating use of BIM, this variable loaded highest because to be competitive at an international scale

BIM is a requirement. Further, there is pressure to remain competitive on technological capabilities, top management support in BIM implementation will ensure competitiveness, ultimately ensuring improved customer client relationship, BIM ensures competitiveness with its ability to ensure consistent lifecycle information. Stakeholders who are used to carrying out small sized projects argue that BIM could be too expensive and complex to adopt in their situation. However, the global view shows that clients and trends are moving towards complexity which resonates technological advancement regardless of the size, therefore players must aim at remaining competitive or risk losing out on jobs. Competition has become borderless and the Kenyan professionals and contractors can become competitive enough to compete with international ones this corroborates (P. Smith, 2014b), for BIM has become the global benchmark for competitiveness. The forward looking client seeks better ways of addressing the dynamics in the industry and the technological advancements eliminates methods that are detrimental to future trends this supports (Turina et al., 2008; Wachira et al., 2007). BIM helps the client to understand their projects better, consultants who have adopted BIM are chosen to execute such client's projects, the non-adopters loose-out on such projects. Consequently, the top management input is important. There is need to invest in education and proper training to aid optimal BIM usage because policy, process, and technology must work together to enable competitiveness.

Factor 4 – Intelligence: The intelligence factor was made up of 2 variables as follows in order of their loading, Real-time capabilities, and intelligent 3D visualization. Information is shared in real-time and there is no danger of working on superseded drawings. BIM's intelligent 3D visualization with simulation capabilities helps the team to appreciate their product prior to construction, and through all stages of a project's lifecycle. This is consistently maintained in the lifecycle of the project hence the cost of a project at operation and maintenance stage is greatly reduced as compared to how it is with TPS. Though TPS has attempted to incorporate BIM for visualization, as has been practiced in Nairobi Kenya it is important to note that the benefits of BIM are reaped when BIM system is adopted in totality this corroborates (Musyimi, 2016).

Factor 5 – Transparency: This factor comprises of the following 3 variables in order of their loading, transparency, return on investment and improved accuracy. BIM enables transparency because real-time data is accessible to relevant parties, there is no room for misunderstandings or loopholes that facilitate over pricing and chances for corrupt deals are greatly reduced by transparent BIM. This plus other BIM benefits ensure positive ROI. Improved accuracy in the transparent environment and cuts down on waste. In TPS records and drawings sometimes get lost, BIM mitigates this because it is an information management tool in the lifecycle of a project. Transparency in ICT may help in curbing corruption this corroborates (Ndemo, 2015); auditing can efficiently be carried out.

4.5 Results and Discussion for Objective 3: The influence of BIM on ECM

The influence of BIM on ECM was analyzed using Descriptive analysis, Correlation analysis regression analysis, Exploratory Factor Analysis (EFA) and qualitative analysis were used to analyse the results of this objective.

The new Roles that have been brought about by BIM were found to be BIM Manager, BIM Coordinator, BIM Modeler, BIM Consultant and BIM Champion this was recorded by 83.3%, 76%, 72.6%, 72.6% and 2.9% of the respondents, respectively. Figure 4.15 illustrates that BIM has influenced ECM, showing that 72% of the respondents reported it had influenced ECM, 5% disagreed while 23% were uncertain.

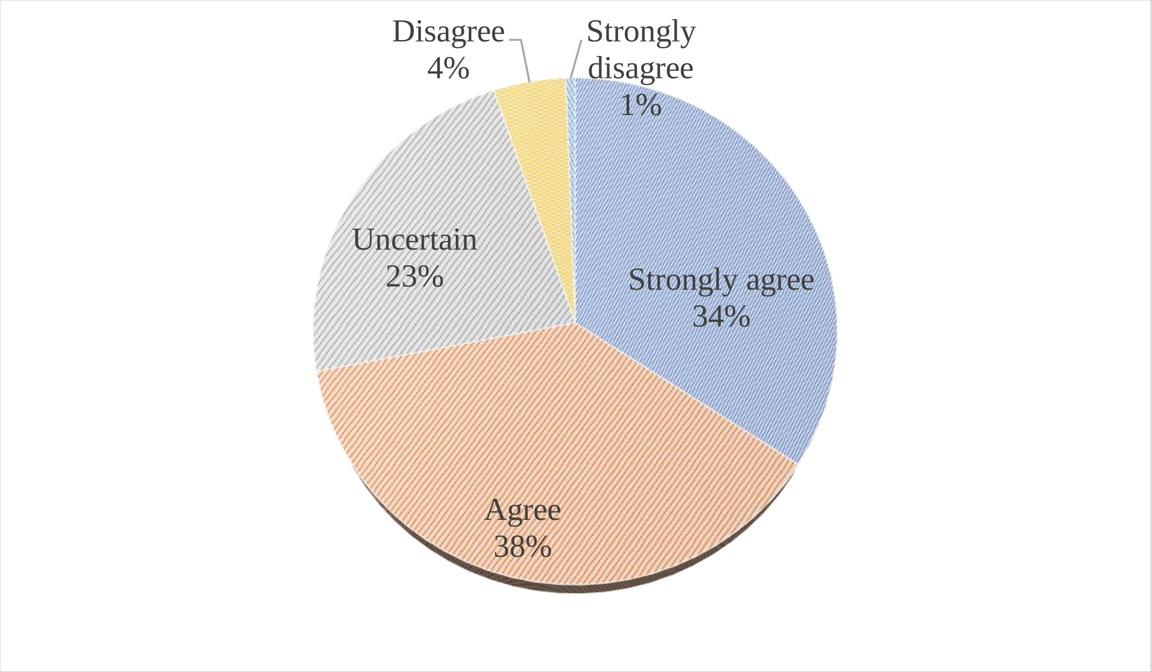


Figure 4.15: BIM influence on ECM

The definition of influence in the context of this paper is to have an effect or change on how something develops or behaves. BIM adoption and implementation has an effect in the development of ECM in response. Collaborative BIM creates new roles, relationships, responsibilities all with legal implications, therefore a legal framework purposely for the BIM system is required. There is need for increased awareness, BIM knowledge because when the benefits are made clear, ECM becomes easier within the BIM system. Notably, the construction industry will benefit from reduced risks, improved relationships, resource saving, and achieve business benefits.

4.5.1 Correlation of BIM's influence on ECM

Pearson correlation (*r*) was carried out to examine the relationship between BIM characteristics namely, collaboration, Time saving, Cost reduction, quality improvement, ROI being the independent variables and ECM the dependent variable. A positive correlation means the two items under test affect each other in a way that when one improves the other also improves and a negative correlation means that when one factor increases the other reduces.

Collaboration was significant and positively correlated to ECM, r (173) = 0.453, $p <$ 0.01. Time saving was positively correlated to ECM, r (173) = 0.439, $p < 0.01$. A complete list of correlations is on Table 4.12. BIM components combined were positively and significantly correlated to ECM, r (173) = 0.493, $p < 0.01$, that is, when BIM adoption improves ECM improves in terms of time saving, cost reduction, quality improvement, better collaboration hence positive ROI and project's success. When the adoption increases, the effect on ECM becomes more pronounced. This relationship was further analyzed using multiple regression whereby two models were generated.

Table 4.12: Correlation for BIM components and ECM

Pearson's Correlation for BIM components [Collaboration (C), time saving (TS), cost reduction (CR), quality improvement (QI) and return on investment (ROI)] and ECM (N= 175)

		ECM	C	TS	CR	QI	ROI
ECM	*r*	1					
Collaboration (C)	*r*	.453**	1				
Time saving (TS)	*r*	.439**	.800**	1			
Cost reduction (CR)	*r*	.431**	.691**	.661**	1		
Quality improvement (QI)	*r*	.376**	.690**	.659**	.667**	1	
ROI	*r*	.411**	.620**	.550**	.701**	.614**	1

**. Correlation is significant at the 0.01 level (2-tailed).

4.5.2 Regression of BIM's influence on ECM

A multiple regression was carried out to examine the relationship between BIM components and ECM. The regression model was:

$$Y= \beta_0+ \beta_1 C + \beta_2 TS + \beta_3 CR + \beta_4 QI + \beta_5 ROI + \varepsilon \quad \text{...Equation 4.1}$$

Where, Y is the dependent variable ECM, β_0 is the constant. The independent variable is made up components of BIM namely, X_1 Collaboration (c), X_2 Time saving (TS), X_3 is Cost reduction (CR), X_4 is Quality improvement (QI) and X_5 Return on Investment (ROI). β_1, β_2, β_3, β_4 and β_5 are the coefficients of the independent variable. Whereas ε is a random error. Table 4.13 show two regression model summary.

Multiple regression Model 1

Model 1 (Table 4.13) shows that collaboration was more significant as compared to the other variables in improving ECM. The other independent variables were subtracted because their influence on ECM was at a lower level. Collaboration accounted for 20.5% of the variance of performance of ECM. ANOVA (Table 4.14) was used to test the significance of the regression model. It indicates that the model was significant at F (1,173) = 44.668; $p < 0.05$. This explained a significant amount of variation in the dependent variable.

The following regression equation was formed based on the coefficient Table 4.15:

ECM = 11.626 + 1.017 Collaboration……………………………………Equation 4.2

The positive value of collaboration indicates that the collaboration aspect of BIM improves the performance of ECM.

T-test (Table 4.15) was performed to test the two-tailed hypotheses that there is a significant relationship between collaboration and ECM. The T-test was t (174) = 6.68; $p < 0.05$. This showed that, collaboration was significant in improving the performance of ECM.

Multiple regression Model 2

Model 2 (Table 4.13) shows that collaboration and ROI were more significant as compared to the other variables in improving ECM. The other independent variables were subtracted because their influence on ECM was less impactful. Collaboration and ROI together accounted for 23.3% of the variance of ECM performance. ANOVA

(Table 4.14) was used to test the significance of the regression model. It indicates that the model was significant at $F\ (2,172) = 26.058$; $p < 0.05$. This explained a significant amount of variation in the dependent variable.

The following regression equation was formed based on the coefficient Table 4.15:

ECM = 10.748 + 0.724 Collaboration + 1.506 ROI ……………………...Equation 4.3

The positive value of collaboration and ROI indicates that the collaboration and ROI aspects of BIM together improve ECM performance.

T-test (Table 4.15) was performed to test the two-tailed hypotheses that there is a significant relationship between collaboration and ECM. The T-test was $t\ (174) = 3.786$; $p < 0.05$. Another hypothesis test was that there is a significant relationship between ROI; for ROI was $t\ (174) = 2.475$; $p < 0.05$. This showed that, both collaboration and ROI are significant in improving the performance of ECM.

Therefore, model two was more suitable than model 1 because it accounted for more variance that explained improvement of the performance of ECM.

Table 4.13: Model summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.453[a]	.205	.201	5.95915
2	.482[b]	.233	.224	5.87279

a. Predictors: (Constant), Collaboration
b. Predictors: (Constant), Collaboration, ROI

Table 4.14: Analysis of variance (ANOVA[a])

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	1586.231	1	1586.231	44.668	.000[b]
	Residual	6143.483	173	35.511		
	Total	7729.714	174			
2	Regression	1797.489	2	898.744	26.058	.000[c]
	Residual	5932.225	172	34.490		
	Total	7729.714	174			

a. Dependent Variable: ECM
b. Predictors: (Constant), Collaboration
c. Predictors: (Constant), Collaboration, ROI

Cost, time and quality were deleted from the list of individual predictors because their contribution as individual variables was not significant as compared to when they were combined. The variables cost reduction was significant, but its prediction of ECM was below that of collaboration and ROI. Time saving and quality improvement prediction was not significant. However, when the 5 components, that is collaboration, ROI, time, cost and quality were combined as one variable under BIM, the prediction was; BIM significantly predicted ECM scores, β = 0.349, t (173) =7.462 p < 0.001. BIM also explained a significant proportion of variance in ECM performance, R^2 = 0.244, F (1, 173) =55.686, p < 0.001

Table 4.15: Regression Coefficients[a]

		Unstandardized Coefficients		Standardized Coefficients		
Model		B	Std. Error	Beta	t	Sig.
1	(Constant)	11.626	1.287		9.032	.000
	Collaboration	1.017	.152	.453	6.683	.000
2	(Constant)	10.748	1.317		8.160	.000
	Collaboration	.724	.191	.322	3.786	.000
	ROI	1.506	.609	.211	2.475	.014

a. Dependent Variable: ECM

The first model showed that collaboration is significant in improving the performance of ECM. The second model showed that collaboration and ROI together were significant in improving the performance of ECM. Model 2 was therefore considered to be more suitable in explaining how BIM influences ECM. Therefore, collaboration and ROI were found to have more influence on ECM as compared to time saving, cost reduction and quality improvement. The influence of BIM on ECM was further analysed using Exploratory factor analysis (EFA).

4.5.3 Underlying factors of influence of BIM on ECM

Exploratory factor analysis (EFA) was carried out with Principal Component Analysis (PCA) as the extraction method the primary purpose being to compute the latent factors of influence of BIM on ECM. This analysis used EFA because the number and nature of expected factors was unknown (Williams et al., 2010). 5-point Likert scale was used to measure the 75 variables.

The majority variables had a correlation coefficient of above 0.30, hence the suitability of EFA. Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy was KMO = 0.872, a KMO above 0.5 is satisfactory (Hair et al., 2014). Bartlett's test of sphericity was significant at $\chi^2 = 9575.289$, $p < 0.001$, which indicates a significant correlation among variables (Table 4.16). Communalities were above 0.5 (Appendix VI) hence confirming that each item shared some common variance with other items hence all variables were retained (Yong & Pearce, 2013). This proved that Factor analysis was a suitable method of analysis.

Table 4.16: KMO and Bartlett's test of influence of BIM on ECM

KMO and Bartlett's Test		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.872
Bartlett's Test of Sphericity	Approx. Chi-Square	9575.289
	Df	2775
	Sig.	.000

Three methods were used to determine number of factors to be retained: Kaiser criteria, the Scree test, and Parallel analysis. Table 4.17 shows the Kaiser criteria where, out of the 75 variables computed, 73.504% cumulative variance accounted for the 18 components with Eigenvalue greater than 1, the full list is presented in Appendix VII. Hence Kaiser criteria overestimated the factors. A scree plot (Figure 4.17) presented 2 factors before the first elbow and 3 more before the second elbow making a total of 5 factors. Hence it underestimated the number of factors to be retained. A parallel analysis was then conducted, resulting to 7 factors retainment. Table 4.18 shows the summary, and the full list is in Appendix VIII.

Table 4.17: Total variance explained for influence of BIM on ECM

	Initial Eigenvalues			Extraction Sums of Squared Loadings		
Component	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	22.703	30.271	30.271	22.703	30.271	30.271
2	4.626	6.168	36.439	4.626	6.168	36.439
3	3.830	5.106	41.545	3.830	5.106	41.545
4	3.314	4.419	45.964	3.314	4.419	45.964
5	2.545	3.393	49.357	2.545	3.393	49.357
6	2.075	2.766	52.123	2.075	2.766	52.123
7	1.887	2.516	54.639	1.887	2.516	54.639
8	1.618	2.157	56.796	1.618	2.157	56.796
9	1.510	2.013	58.809	1.510	2.013	58.809
10	1.462	1.949	60.759	1.462	1.949	60.759
11	1.404	1.871	62.630	1.404	1.871	62.630
12	1.310	1.746	64.377	1.310	1.746	64.377
13	1.301	1.734	66.111	1.301	1.734	66.111
14	1.240	1.653	67.763	1.240	1.653	67.763
15	1.133	1.510	69.274	1.133	1.510	69.274
16	1.091	1.455	70.729	1.091	1.455	70.729
17	1.058	1.410	72.139	1.058	1.410	72.139
18	1.024	1.365	73.504	1.024	1.365	73.504
19	.988	1.317	74.821			
20	.925	1.233	76.054			
21-75	Omitted	by author				

Extraction Method: Principal Component Analysis.

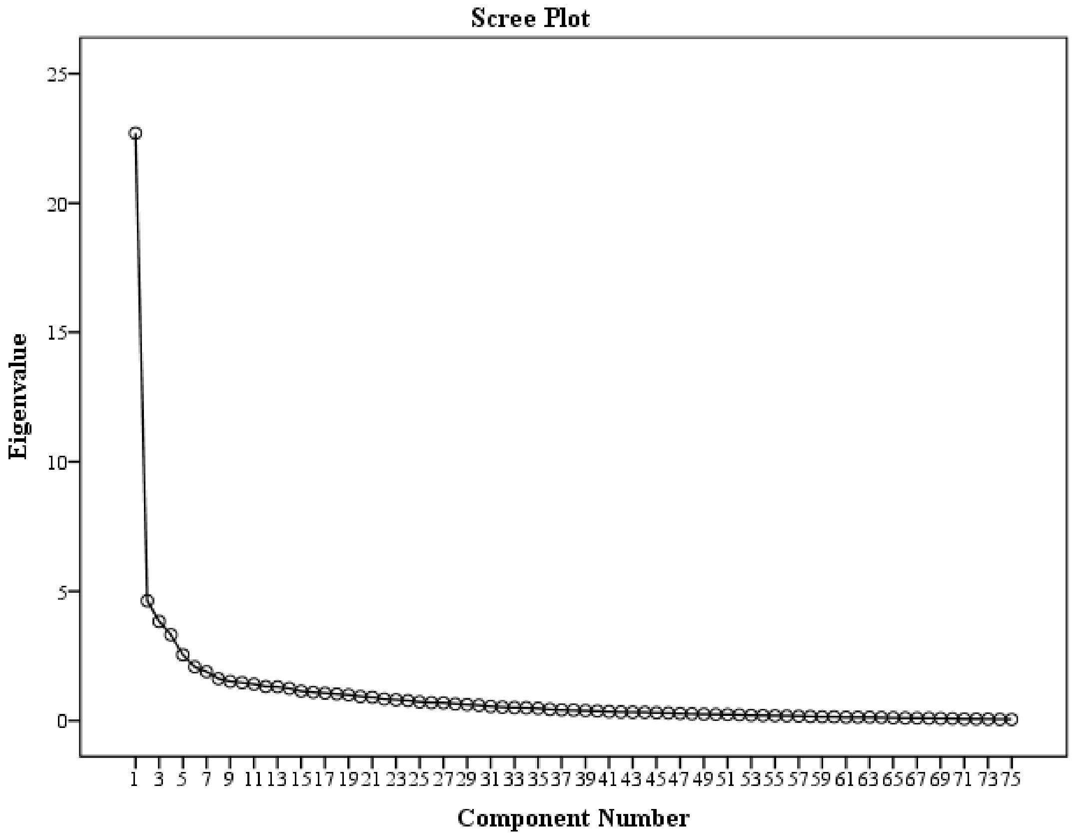


Figure 4.16: Scree plot of BIM influence on ECM

The decision was made to conduct the test again with a preset fixed number of 7 factors. This resulted to 54.4% cumulative variance being accounted for by preset factors. By Oblimin rotation the correlation of the 7 factors was below 0.5 implying they were not highly correlated, hence the need to change from oblique rotation to orthogonal rotation by varimax. The factor analysis was conducted again under varimax rotation.

Table 4.18: Parallel analysis for influence of BIM on ECM

Component/factor	Mean Eigenvalue	Percentile Eigenvalue	Calculated Eigenvalue (Kaiser Criteria)	Decision
1	2.027918	2.109525	22.703	Retain
2	1.944076	2.005931	4.626	Retain
3	1.880338	1.925693	3.830	Retain
4	1.827315	1.867672	3.314	Retain
5	1.784450	1.826314	2.545	Retain
6	1.740780	1.789314	2.075	Retain
7	1.699345	1.736520	1.877	Retain
8	1.662571	1.694751	1.618	Not retain
9	1.626509	1.655897	1.510	Not retain
10	1.592867	1.630366	1.462	Not retain
11-75	1.559097-0.317981	1.594474-0.342128	1.104-0.049	Not retain

The internal consistency for the seventh factor was very poor but upon deleting two variables it improved to 0.592. But having two variables in a factor did not seem to communicate a clear latent factor, this prompted another factor analysis to be run with fixed numbers of 6 factors instead of 7. One variable was deleted for failing to attain a minimum set loading of 0.3. The results are indicated in Table 4.19.

Table 4.19: EFA summary on underlying factors of BIM Influence on ECM

Factor	variable	Loading factor	Factor Coefficient
Factor 1: Legal implications % variance explained = 30.271 Eigenvalue = 22.703 Cronbach's Alpha = 0.933 N = 15	Data security (BLegalR7)	.759	.122
	Processes and responsibilities (BLegalR6)	.743	.113
	Professional liability (BLegalR3)	.731	.121
	Legislation and judicial precedence (BLegalR13)	.695	.108
	Data interoperability (BLegalR5)	.694	.109
	Sharing of copyright data (BLegalR2)	.691	.116
	Intellectual Property Rights (BLegalR1)	.672	.118
	Cost compensation (BLegalR8)	.663	.095
	Standard of care and professional negligence (BLegalR10)	.660	.100
	Admissibility of electronic-based document (BLegalR12)	.654	.093
	Lack of BIM standards (BLegalR9)	.632	.113
	Model management (BLegalR11)	.632	.094
	legal validation of design (NCC submissions) (BLegalR14)	.582	.075
	Condition of contracts (e.g. FIDIC) (BLegalR4)	.532	.061
	It is necessary to have contractual guidelines to guide in BIM adoption (BIMECM2)	.448	.041
Factor 2: Awareness and knowledge % variance explained = 6.168 Eigenvalue = 4.626 Cronbach's Alpha = 0.939 N = 16	BIM makes dispute resolution easier (BECM16)	.736	.123
	BIM improve good working relationship (BECM12)	.724	.126
	BIM helps to reduce variations (BECM14)	.701	.118
	BIM improves quality (BECM11)	.687	.120
	BIM improves decision management process (BECM4)	.686	.111
	BIM improves communication in the construction team (BECM3)	.680	.105
	BIM facilitates positive ROI (BECM10)	.663	.104
	BIM helps to reduce claims (BECM15	.654	.100
	BIM reduces cost of a project (BECM8)	.646	.112
	BIM aids in early problem detection (BECM13)	.626	.090
	BIM makes real time correction of information easy at any stage of a project (BECM6)	.620	.091
	BIM facilitates effective coordination (BECM2)	.615	.086
	BIM reduces cost of operation and maintenance of a facility (BECM9)	.592	.082

	BIM enables the construction Team to work together effectively and efficiently (BECM1)	.584	.086
	BIM enables faster execution of a project hence saving time (BECM7)	.560	.079
	BIM aids in clash detection of construction element as designed by different professionals (BECM5)	.520	.069
Factor 3: Efficiency	Better coordination (BC11)	.731	.128
	Collaboration (BC6)	.705	.144
	Clash detection (BC13)	.675	.120
% variance explained = 5.106	Improved accuracy (BC4)	.630	.108
	Time saving (BC7)	.628	.107
Eigenvalue = 3.830	Improved communication (BC12)	.609	.097
	Buildability (BC5)	.609	.112
Cronbach's Alpha = 0.915	Intelligent 3D visualization (BC1)	.578	.116
N = 14	Cost saving (BC8)	.557	.082
	Realtime capabilities (BC2)	.554	.101
	Better decision management (BC15)	.547	.070
	Transparency (BC3)	.529	.079
	Quality improvement (BC9)	.499	.077
	BIM definition (BA)	.484	.105
Factor 4: Versatility	Safety management (BC17)	.644	.160
	Improved facility management (BC19)	.617	.143
% variance explained = 4.419	Return on investment (BC10)	.609	.155
	Risk management (BC16)	.593	.132
Eigenvalue = 3.314	Improved customer client relationship (BC18)	.582	.145
	Sustainability (BC21)	.572	.129
Cronbach's Alpha = 0.889	Financial cost (BC23)	.544	.124
N = 11	Top management support (BC22)	.507	.109
	Energy analysis (BC20)	.498	.107
	Technological capabilities (BC24)	.459	.090
	Consistent lifecycle information (BC14)	.390	.054
Factor 5: Mandate and leadership	Government should adopt their procurement processes to suit collaborative BIM (BIMECM7)	.671	.165
	NCC submissions may require BIM model in future (BIMECM8)	.623	.161
% variance explained = 3.393	Government needs to make BIM implementation compulsory (BL4)	.609	.161
Eigenvalue = 2.546	BIM requires a new set of standards forms of contract (BIMECM4)	.587	.138
Cronbach's Alpha = 0.831	Existing forms of contract should be modified to suit BIM (BIMECM3)	.533	.116
N=12	Construction contracts are competitively awarded to both local and international firms depending on BIM capabilities (BIMECM6)	.513	.097

	There is need for regulatory body mandated by the government (BIMECM9)	.492	.116
	The digital BIM model should be recognized as a contract document (BIMECM5)	.487	.081
	There are case studies done on BIM projects in Kenya (BL7)	.450	.138
	The traditional procurement has failed to meet client's expectations (BIMTPS)	.445	.141
	Stakeholders are willing to pioneer in BIM adoption (BL5)	.361	.111
	There are written materials to guide BIM implementation (BL6)	.307	.082
Factor 6: Competitiveness % variance explained = 2.766 Eigenvalue = 2.075 Cronbach's Alpha = 0.671 N=6	My organization has standards and guidelines on BIM adoption (BL2)	.675	.271
	My organization has engaged a BIM consultant to help in BIM adoption (BL1)	.539	.203
	Pressure to remain competitive (BC25)	.528	.216
	BIM has influenced/impacted engineering contract management (BIMECM1)	.421	.136
	BIM hardware must be recommended by the type of software in use (Tech)	.409	.156
	Size of a project (BC26)	.313	.123

KMO = 0.872, Bartlett's χ^2 = 9575.289, $p < 0.001$
Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization.
a. Rotation converged in 8 iterations.

Regression models based on the coefficient matric shown on Appendix IX. are produced and are as follows.

$$F_{ij} = \beta_1 x_{i1} + \beta_2 x_{i2} + ... + \beta_p x_{ip}$$

Factor 1 - Legal implication = β_1 (BLegalR7) 0.122 + β_2 (BLegalR6) 0.113 + β_3 (BLegalR3) 0.121+ $\beta 4$ (BLegalR13) 0.108 + β_5 (BLegalR5) 0.109 + β_6 (BLegalR2) 0.116 + β_7 (BLegalR1) 0.118 + β_8 (BLegalR8) 0.095 + β_9 (BLegalR10) 0.100 + β_{10} (BLegalR12) 0.093 + β_{11} (BLegalR9) 0.113 + β_{12} (BLegalR11) 0.094 + β_{13} (BLegalR14) .075 + β_{14} (BLegalR4) 0.061 + β_{15} (BIMECM2) 0.041

Factor 2 - Awareness and Knowledge = β_1 (BECM16) 0.123 + β_2 (BECM12) 0.126 + β_3 (BECM14) 0.118 + β_4 (BECM11) 0.120 + β_5 (BECM4) 0.111 + β_6 (BECM3) 0.105 + β_7 (BECM10) 0.104 + β_8 (BECM15) 0.100 + β_9 (BECM8) 0.112 + β_{10}

(BECM13) 0.090 + β_{11} (BECM6) 0.091 + β_{12} (BECM2) 0.086 + β_{13} (BECM9) 0.082 + β_{14} (BECM1) 0.086 + β_{15} (BECM7) 0.079 + β_{16} (BECM5) 0.069

Factor 3 - Efficiency = β_1 (BC11) 0.128 + β_2 (BC6) 0.144 + β_3 (BC13) 0.120 + β_4 (BC4) 0.108 + β_5 (BC7) 0.107 + β_6 (BC12) 0.097 + β_7 (BC5) 0.112 + β_8 (BC1) 0.116 + β_9 (BC8) 0.082 + β_{10} (BC2) 0.101 + β_{11} (BC15) 0.070 + β_{12} (BC3) 0.079 + β_{13} (BC9) 0.077 + β_{14} (BA) 0.105

Factor 4 - Versatility = β_1 (BC17) 0.160 + β_2 (BC19) 0.143 + β_3 (BC10) 0.155 + β_4 (BC16) 0.132 + β_5 (BC18) 0.145 + β_6 (BC21) 0.129 + β_7 (BC23) 0.124 + β_8 (BC22) 0.109 + β_9 (BC20) 0.107 + β_{10} (BC24) 0.090 + β_{11} (BC14) 0.054

Factor 5 - Mandate and Leadership = β_1 (BIMECM7) 0.165 + β_2 (BIMECM8) 0.161 + β_3 (BL4) 0.161 + β_4 (BIMECM4) 0.138 + β_5 (BIMECM3) 0.116 + β_6 (BIMECM6) 0.097 + β_7 (BIMECM9) 0.116 + β_8 (BIMECM5) 0.081 + β_9 (BL7) 0.138 + β_{10} (BIMTPS) 0.141 + β_{11} (BL5) 0.111 + β_{12} (BL6) 0.082

Factor 6 - Competitiveness = β_1 (BL2) 0.271 + β_2 (BL1) 0.203 + β_3 (BC25) 0.216 + β_4 (BIMECM1) 0.136 + β_5 (Tech) 0.156 + β_6 (BC26) 0.123

All coefficients were positive; implying when the variables improve then the factor also improves in performance. These models are saved for use in further analysis as recommended by Anna (2010).

The factors have been interpreted as below.

Factor 1 - Legal implications: This factor constitutes 15 variables as follows and in order of their loadings: data security, processes and responsibilities, professional liability, legislation and judicial precedence, data interoperability, sharing of copyright data, intellectual Property Rights, cost compensation, standard of care and professional negligence, admissibility of electronic-based document, lack of BIM standards, model management, legal validation of design, condition of contracts, and it is necessary to have contractual guidelines to guide in BIM adoption.

BIM operates in a digital environment unlike TPS that operates with hardcopy documentation and whose management is physical, security of data thus becomes an immediate concern as people implement BIM. Being a new system in Kenya, BIM lacks judicial precedence, hence the need for laws to enable effective ECM. Data interoperability was an implication because consultants use different types of software and require collaborating digitally. Sharing of copyright data and intellectual property rights have a very thin line in the digital BIM. The implementation process comes with a cost implication, ways of recovering the cost incurred were unclear. Further, BIM environment is transparent with each design component meaning something to a professional, so standard of care becomes a collective responsibility, professional negligence is reduced, and admissibility of electronic based document is managed by the BIM manager. Currently there lacks standards to oversee this, but with formulation of standards it will make model management easier. Legal validation of design by the Nairobi City County (NCC) is currently being done online with 2D digital drawings, NCC is yet to adopt BIM. Condition of contracts in use favour the traditional hardcopy system and not the digital BIM system. The legal implication findings and discussion corroborates findings by (Arshad et al., 2019; Eadie et al., 2015; Kimani et al., 2019; Kuiper & Dominik, 2013; Manderson et al., 2015; Musyimi, 2016; Olatunji, 2011). Legal Implications created by BIM do not have contractual guidelines that help safeguard parties and processes, this confirms the system theory of management and Contract theory, whereby BIM as a new technology requires systems and structures to support it for optimal performance.

Legal implications will ensue where the systems and structures of the day are meant for existing systems and are not expandable to accommodate new trends and technologies. The BIM system is digital, intelligent, real-time and it is collaborative in the lifecycle of a project; these aspects are not relatable to the TPS.

Factor 2 - Awareness and knowledge: This factor constitute the following 15 variables in order of loading: BIM makes dispute resolution easier; BIM improves good working relationship; BIM helps to reduce variations; BIM improves quality; BIM improves decision management process; BIM improves communication in the construction team; BIM facilitates positive ROI; BIM helps to reduce claims; BIM reduces cost of a project; BIM aids in early problem detection; BIM makes real time correction of information easy at any stage of a project; BIM facilitates effective coordination; BIM reduces cost of operation and maintenance of a facility; BIM enables the construction team to work together effectively and efficiently; BIM enables faster execution of a project hence saving time; and BIM aids in clash detection of construction element as designed by different professionals. These variables depict benefits of BIM, being aware and having knowledge of BIM through education and training this point corroborates (Kimani et al., 2019; Waigwa, 2016), followed by proper use of the BIM system through its collaborative nature improves the performance of ECM.

Factor 3 - Efficiency: Efficiency comprise of the following 14 variables in order of loading, Better coordination; Collaboration; Clash detection; Improved accuracy; Time saving; Improved communication; Buildability; Intelligent 3D visualization; Cost saving; Realtime capabilities; Better decision management; Transparency; Quality improvement; and BIM definition. These variables outline the benefits of BIM which enable efficiency in projects. These findings corroborates the various benefits outlined by various researchers including (Bosch-sijtsema & Gluch, 2019; Succar, 2010b; Xu et al., 2014). These benefits are the primary reason for BIM adoption and are geared towards collaboration that enhances ECM performance.

Efficiency of the BIM system is the primary reason arousing curiosity leading to adopted, these are benefits that makes ECM processes easier to handle. The team collaborate from early on hence eliminating unnecessary rework at the same time saving on resources.

Factor 4 - Versatility: Versatility constitute of the following 11 variables in order of loading, Safety management; Improved facility management; Return on investment; Risk management; Improved customer client relationship; Sustainability; Financial cost; Top management support; Energy analysis; Technological capabilities; and Consistent lifecycle information. BIM has more benefits than it is originally thought to have this finding collaborates (Nowak et al., 2016) findings. Versatility in BIM increases effectiveness in ECM, coordination of those aspects of a construction project that were traditionally separate from design, are centrally managed. For instance, Safety management is a major concern in construction sites, BIM real-time monitoring, evaluation and analysis ensures mitigation measures are put in place in time, this applies to risk management in general. Further, positive ROI realized by professionals and clients, leads to, improved customer client relationship.

Versatility of the BIM system shows that BIM is not narrow in its benefits but geared towards sustainability and it is adaptable to many functions and activities that were traditionally tedious to execute, ignored or were simply overlooked.

Factor 5 - Mandate and leadership: This factor constitutes the following 12 variables in order of loading, Government should adopt their procurement processes to suit collaborative BIM; NCC submissions may require BIM model in future; Government needs to make BIM implementation compulsory; BIM requires a new set of standards forms of contract; Existing forms of contract should be modified to suit BIM; Construction contracts are competitively awarded to both local and international firms depending on BIM capabilities; There is need for regulatory body mandated by the government; The digital BIM model should be recognized as a contract document; There are case studies done on BIM projects in Kenya; The traditional procurement has failed to meet client's expectations; Stakeholders are willing to pioneer in BIM adoption; and There are written materials to guide BIM implementation

The government procurement process does not favour the BIM system and being a new technology, this lack of government involvement in turn hinders countrywide implementation. NCC submissions processes currently are digital however the county has not adopted BIM. Standards forms of contract are not in BIM favour, BIM model is not recognized as part of the contract documentation, lack of BIM standardization cause disharmony in the construction industry in Nairobi, and competitiveness of international contracts become a challenge for consultants who have not made an attempt to move to the BIM platform this corroborates (Kimani et al., 2019; Musyimi, 2016; Waigwa, 2016). Lack of case studies and NBPs are factors slowing down all rounded BIM uptake. This factor ensues from legal implications, that demand mandates and leadership from the Government as the principal agent the conclusion mirrors the contract theory and system theory of management.

Mandate and leadership as pertain to the BIM system is that the system require legislation muscle for it to perform well. The procurement Act and the standard forms of contract and leadership at various levels contribute to the effective BIM system. The government mandate is the crowning factor, for it will give the momentous push of adoption and implementation of BIM in Nairobi and Kenya at large.

Factor 6 - Competitiveness: Competitiveness comprise of the following 6 factors in order of loading, My organization has standards and guidelines on BIM adoption; My organization has engaged a BIM consultant to help in BIM adoption; Pressure to remain competitive; BIM has influenced/impacted ECM; BIM hardware must be recommended by the type of software in use; and Size of a project. An organization having standards and guidelines on BIM and engaging a BIM consultant is a good indicator of international competitiveness in ECM. Pressure to remain competitive shows that progressive trends are themselves full of pressure to stay at the top, additionally, the necessary technological tools must be put in place. BIM ensures competitiveness in delivery of ECM to an international standard; this implies that the Kenyan industry should put structures and systems to aid contract management.

Competitiveness is key globally in the current times, construction tenders' disregards physical borders but look for effectiveness and efficiency. Outdated methods are a great disadvantage to players in the industry. The BIM system is the epitome of what the industry needed to solve its dynamics and growing complexity towards efficient contract management. Technological sophistication demands for matching techniques of executing projects.

4.5.4 Opinion on BIM adoption and its influence on ECM in Nairobi Kenya

This section addresses objective 3, it presents results and discussion from the in-depth interviews. It was found that BIM adoption level in Kenya is still low due to shallow understanding of BIM. This argument was based on observations made by the respondents from their interactions in the construction industry. The descriptive statistics showed the adoption rate of 56.6%, it also showed that though 96% of the respondents knew what BIM is, only 33% rightfully stated it is not a software, 65%

believed that BIM is a software and the remaining 2% did not know whether it is a software or not. Where 62.6% of those who had adopted BIM believed BIM is a software the trend is similar for the non-adopters 63.6%, those planning to adopt 70.7% and those who had partially adopted 100%. The low level of adoption, according to qualitative feedback, was because of high cost of implementation, lack of proper training, lack of awareness and knowledge, lack of contractual guidance, lack of necessary skills, change resistant attitude and lack of understanding. Other factors include education curriculum failure to include BIM, complexity of BIM, lack of leadership, inadequate sensitization, size of projects dictating adoption, lack of case studies and lack of BIM champions. Further, Contractors unwillingness to adopt, client's failure to require BIM, inflexible employers, unfavourable procurement rules, rigid traditional procurement system and lack of government mandate are other reasons of low adoption level. These low numbers contribute to difficulty in collaboration.

The respondents opined that BIM complements professional work, other benefits include, time and cost saving, generative designs, and real-life simulation. Complex projects design can be handled without having to expand the workforce. Additionally, lifecycle information storage and management make operation and maintenance easier and cost effective.

According to the respondents, BIM has influenced contract management by making it easier. Additionally, BIM facilitates, collaboration, improved quality, business benefit, positive ROI, easier decision making, clash detection, early problem detection in professional relationships. It also makes it easier for parties to appreciate design components, reduces adversarial relationships, it eliminates inconsistencies and abortive works. Bills of quantities are more accurately done, it gives transparency, empowers clients to appreciate real-time 3D visualization. Enables risk management through early identification and mitigation. There is emergence of new roles such as BIM manager, BIM coordinator and BIM Consultant.

The respondents from the in-depth interview gave opinions on BIM adoption and its influence on ECM. Table 4.20 illustrates them in themes which are explained below the Table.

Table 4.20: BIM opinions from In-depth Interview

	Number of occurrences/responses in relation to the number of respondents. Total number of respondents are 8	
	Frequency	Percentage
Opinion on BIM adoption		
a. BIM adoption	7	87.5%
b. Data management in BIM	7	87.5%
c. BIM helps in clash detection	7	87.5%
d. Client easily appreciate the model	7	87.5%
e. Other benefits	7	87.5%
How BIM has influenced ECM	8	100%
How BIM has affected the current standard forms of contract and the public procurement and asset disposal Act	5	62.5%
Government role in BIM adoption	8	100%
Early entrance of the contractor in the BIM system	8	100%
Facilities management role in the BIM system	8	100%
Noteworthy BIM publication	8	100%

4.5.4.1 Opinion on BIM Adoption

BIM adoption is taking place in Kenya. 100% of the respondents who participated in the in-depth interview stated that BIM is still new, and most of the industry players do not want to be bothered with new technologies. However, if the government of Kenya being the biggest employer in the industry, could move a step towards adoption, it could aid in convincing others to adopt BIM. They further stated that a BIM policy will be important in BIM implementation. It was evident that the public sector has not embraced BIM, but the private sector is open to BIM and is in fact leading adoption.

It was also opined that comparably engineers and architects have a higher adoption as compared to other stakeholders. Further, though total adoption may take time, it is the inevitable future, currently most international jobs have made BIM a requirement this is especially true because of the green agenda. BIM helps in energy analysis and issues such as water, sewerage, lighting, and heating can be tackled easily through computer simulation.

It was also opined by 87.5% of the respondents of the in-depth interview, that BIM makes collaboration easier, however all consultants have not yet adopted it hence hindering efficient and effective collaboration. Some consultants already have started insisting on working with contractors on BIM platform. Hence contractors are looking for BIM skilled people to help them implement it in their companies. The Procurement Act contributes to the uptake of BIM, this was stated by 62.5% of the respondents of the in-depth interview. The Act is superior to all other contractual guidelines; hence the Act creates a hinderance because it does not recognize BIM. The ideal situation would be to incorporate the contractor at design stage, of which the procurement act does not support. It is easier to embrace BIM in the private sector, because some clients prefer to work with contractors they have proven can deliver, the official tendering is in most cases used to gauge the price for negotiation purposes with their preferred choice of a contractor

4.5.4.2 Data management in BIM

87.5% of the respondents of the in-depth interview stated that BIM is a data management tool. It is also a Lifecycle information storage tool enabling the operation and maintenance easier and cost effective. It is possible to do cloud-based data management and especially if internet speed improved to 5G, there will be no need to host licenses inhouse the software companies could host them and this will further enable collaboration within a common cloud-based platform. The respondents noted that a BIM file encourages rich data; the project is information-rich, this encourages productivity and it also becomes easier to track information exchange without a lot of paperwork and physical movement. Additionally, files are not lost easily nor is there a danger of working on superseded files.

It was also opined that a BIM manager is an important role, they manage data and gives permission to various categories of rights. They regulate the collaboration by use of work sets concept whereby, different professionals are given permission to work on a component as per their discipline's requirement.

The respondents also mentioned that though BIM has advantages there were also insecurity fears: fear of hacking. But they also stated that it is trusted that security is assured by the cloud provider and there is also an option of working from servers with cloud back up. Data is not lost easily; the server or cloud adequately ensure this. Access of data is through permission by the BIM manager, and once changes are made a notification is sent to the rest of the team. It was also opined that the Intellectual Property (IP) rights will not be any different from how they were with pre-BIM, there will always be a thin line of IP ownership for both BIM and pre-BIM systems. Data sharing across various disciplines using different software is done through open BIM or Industry Foundation Classes (IFC).

4.5.4.3 Other Benefits of BIM as presented by the respondents

BIM helps in clash detection; this was stated by 87.5% of the respondents who took part in the in-depth interview. The respondents stated that BIM is an intelligent tool that can pick up errors, incomplete and incompatible errors from the team can be detected, this prompts the user to then make the necessary adjustments early enough prior to going to construction. According to 87.5% of the respondents who took part in the in-depth interview, the client appreciates the model, 3D visualization of the model gives clients a quick understanding of what is being designed and they appreciate the computer simulation. This in turn makes it easier to convince other clients to join the BIM platform leading to more clients getting to understand BIM. Informed clients now require BIM on their projects, and some ask outrightly if a consultant has adopted BIM; there are consultants who have qualified for international jobs done locally because of being on the BIM platform.

All the 100% in-depth interview respondents opined that BIM helps to reduce waste, hence saving money. It also helps in pointing out errors in design, for example it does not forget a washer or bolt for a pipe connection. Another example stated was that the cost per kilometre of road construction is expensive in Kenya as compared to advanced countries who have adopted the BIM technology, where BIM has been used the saving was said to be approximately up to 60% in comparison to the Kenyan situation. These findings corroborates Seboru (2015) that time is wasted for up to a magnitude of 50% on construction of Kenyan roads which translates to costs. It was also stated that, BIM makes working environment more interactive, by use of generative designs that give optimal alternatives of engineering and architectural works. It also enables simulation before actual construction. It complements the professionals and allows them to be creative and take bigger risks; it does not take away from the professional but enhances the professional.

4.5.4.4 How BIM has influenced ECM

100% of the respondents that took part in the in-depth interview opined that where the BIM system has been tested in Nairobi, it has made ECM easier, through financial savings, transparent data, reduced chances of claims and variations and real-time update of integrated software. It was also stated that the quality is better with BIM than pre-BIM, the level of documentation and detailing is high quality and ability to use alternative materials and generative designs has made a professional's life easier.

The respondents opined that there are business benefits and it becomes easier to take bigger and more challenging jobs without struggling as compared to pre-BIM. They further stated that it will take a while to measure ROI, but it is likely to pay-off based on size of projects which now BIM helps handle more easily. It was opined that BIM's collaborative nature brings all points on the table earlier for better decision making. It also enables early problem detection within professionals' relationships, and so they are sorted out early enough. It helps in clash detection hence eliminating rework during construction. BIM helps in risk management whereby risks are identified early enough even before going to site hence mitigation measures are put in place early enough.

According to the respondents BIM has improved relationships and responsibilities: Professionals are no longer working in isolation and every part of the model means something to all the professionals hence they must understand and factor it in their respective designs and installations. Further BIM makes consultants interact more hence saves on time and money, it also helps to eliminate abortive works and adversarial relationship. In addition, it makes complex work easier to execute, hence giving more time to do more projects, however it should be noted that the human aspect cannot be eliminated; it complements the professional. BIM saves time by reducing time spent in design and construction through effective collaboration hence eliminating abortive works and it is less time consuming and utilizes less work force as compared to pre-BIM. It saves on cost because abortive works are eliminated, and quantities are done more accurately.

BIM allows transparency, there are no misunderstandings because of the information-rich model. The model is saved in the cloud, its transparent and following up is easier, and inconsistent revisions becomes a thing of the past with BIM. Even the client has access to the model and can follow through. The client understands easily and can appreciate the output model of all architectural and engineering drawings including plumbing and electrical works.

4.5.4.5 How BIM has affected the current standard forms of contract and the Public Procurement and Asset Disposal Act

According to 62.5% of the respondents who took part in the in-depth interview, there was need for amendments to the standards forms of contract, because currently there is no BIM specific document due to few collaboration partners. The old system depends on hardcopies; hence the digital BIM needs to be catered for legally. It was also suggested that consultants could also draft a form of agreement (it could be borrowed from advanced countries specifically UK) and edited to suit specific projects.

4.5.4.6 The Government role in BIM adoption

All 100% of the respondents in the in-depth interview agreed that the government is important in BIM adoption and implementation. The respondents opined that a policy is needed, they cited those countries known to be ahead in BIM such as UK already had a policy in place. This will aid in bringing about accountability in the construction industry and in addition, speed up adoption. They further said that it would make sense to borrow what advanced countries have done and edit to suit Kenyan environment.

The respondents opined that the government of Kenya has not created a conducive environment for BIM adoption. It is not keen on technological trends in the construction industry so long as the consultants deliver. The likely scenario is that no one will tell consultants when to join BIM, but the world’s big economies will push for new trends to benefit their projects, and in order to survive the rest of the world will be forced to adopt to the new trends. Most of these decisions are likely to be guided by climate change issue; no one will force the policy; the international trends will force adoption because players want to get those international jobs.

The respondents also opined that it will be important to have a BIM regulatory body to give proper direction to the whole country. However, the regulatory body will need people who are well trained in BIM, Kenya lacks well trained professionals most of them are half baked. With a regulatory body it will be possible to introduce BIM education in Primary, and secondary schools and tertiary institutions. Other respondents opined that a regulatory body is not needed if an umbrella body that governs all professional bodies and associations is put in place and this will make it easier to regulate BIM and other emerging trends in the construction industry.

4.5.4.7 Early entrance of the Contractor in the BIM system

According to the respondents 100% of the respondents who took part in the in-depth interview stated that collaboration of all parties from early stages of the project is advantageous. Though all parties and especially majority of the contractors were not yet on BIM platform. Some respondents, however felt that, consultants should not abandon being the professionals they are supposed to be because of collaborative BIM, and that they are obligated to sort out all possible errors and mistakes early and avoid the need to sort out their inefficiencies with the contractor. Other respondents thought that this step could be radical for Kenya, but recommended use of consortiums as an alternative to this. Generally, it was opined that having the contractor join the team early is the ideal situation: To check on buildability and by the time actual construction begins buildability issues would have been resolved in the digital model. Leading to reduced request for information (RFI).

The respondents stated that, in current times BIM works well in private than in public sector, and in most of those cases the process had been based on trust. This were instances where the contractor tendered at design and is left to go all the way to construction while developing the model together with consultants, a BQ is also developed and negotiation based on market price. However, for government projects where lowest bidder strategy is employed this may not work unless the procurement act is revised.

Given the above, two stage contracting may work well, that is, procuring a contractor for design phase and the second stage at construction phase. Design and build also works well with the contractor's early involvement.

4.5.4.8 Facility Management role in the BIM system

It was opined by 87.5% of the respondents that the operation & maintenance (O&M) is no longer separate from the construction process, as-built drawings are accurately done and readily available for use by the facility management, this eliminates reactive O&M. The facility management connects to the design information which they use to execute their duties unlike in pre-BIM where, they would carry a sample component to a supplier to get a replacement; BIM facilitates availability of all information including specifications in the model. The knowledgeable clients in Nairobi who have knowledgeable Facility Managers have been seen giving their input based on availability or practicability of components specified and end user friendly aspects. Other respondents opined that it will take a while for Facility Managers to embrace BIM, and that there are projects they participate in but mainly as the client's representative, but they are largely seen to lack awareness and knowledge of BIM and they shy away from BIM related inputs.

4.5.4.9 Noteworthy BIM Publications (NBPs)

75% of the in-depth interview respondents said that NBPs were not available, there was mainly reliance on word of mouth, in-depth discussions, and individual research from international literature. The remaining 25% said that they had come across NBPs in Kenya that were in form of newspaper articles, thesis and paper publications by university students and occasional articles published in the magazine journals by various professional bodies. Generally, however, the country relies on NBP from countries that have made BIM adoption mandatory.

4.5.4.10 Changing Roles, Responsibilities and Relationships

100% of the in-depth interview respondents said BIM adoption is affecting the traditional relationships; the BIM relationships are collaborative and not adversarial. The team is assembled earlier, and the risk management is handled in time. Responsibilities remain the same except that BIM complements the various professions through computer simulation. New roles identified complement the traditional roles they include BIM manager, BIM consultant and BIM coordinator. The change from the TPS to the BIM system requires standards, guidelines, policy and a legal framework to enable contract management.

4.6 Hypotheses Testing

Three hypotheses for this study were tested. Hypothesis 1, the null hypothesis (H_0) was there are no underlying factors associated with BIM adoption. Whereas the scientific hypothesis (H_a) was there are underlying factors associated with BIM adoption.

H_0: $\rho = 0$

H_a: $\rho \neq 0$

α = 5% (2 tailed)

The Bartlett's test of sphericity was significant at $\chi^2 = 2743.280$, $p<0.001$, which indicates a significant correlation among variables. Since p is smaller than α the null hypothesis is rejected. Therefore, there are underlying factors associated with BIM adoption.

For hypothesis 2, the null hypothesis (H_0) was there is no relationship between BIM and ECM. Whereas the scientific hypothesis (H_a) was that there is a relationship between BIM and ECM.

H_0: $\rho = 0$

H_a: $\rho \neq 0$

α = 5% (2 tailed test)

BIM was positively and significantly correlated to ECM, $r(173) = 0.493, p < 0.01$, that is, when BIM improves ECM improves in terms of time saving, cost reduction, quality improvement, better collaboration hence positive ROI. Since p is smaller than α the null hypothesis is rejected. Therefore, there is a relationship between BIM and ECM.

Hypothesis 3, the null hypothesis (H_0) was: there are no underlying factors of BIM's influence on ECM whereas the scientific hypothesis (H_a) was that there are underlying factors of BIM's influence on ECM.

H_0: $\rho = 0$

H_a: $\rho \neq 0$

$\alpha = 5\%$ (2 tailed test)

Bartlett's test of sphericity was significant at $\chi^2 = 9575.289$, $p < 0.001$, which indicates a significant correlation among variables. Since p is smaller than α the Null hypothesis is rejected. Therefore, there are underlying factors of BIM's influence on ECM.

4.7 Objective 4: BIM adoption and implementation framework

The objective was to formulate a BIM adoption and implementation framework. This objective uses results from objective 1, 2 and 3. BIM is affecting relationships, responsibilities and resulting risks. The study indicates that awareness, knowledge, leadership, education, training, and technology are important in BIM adoption and implementation process. As much as standards and guidelines are needed, a BIM policy, the government mandate and legal framework are important, but also, they should be enforced. These recurring themes corroborates findings by (McAuley et al., 2017) and the themes fit in BIM policy, process and technology fields; this corroborates findings by (S. Azhar et al., 2012; Kalinichuk, 2015; Succar, 2010a). The management role is important in adoption and implementation process. Figure 4.17 represents the management action plan towards BIM adoption and implementation this corroborates (Succar & Kassem, 2015). On the first level there should be creation of awareness where the management role offers encouragement. On the second level education, training and technology should actively be used. On the third level mandate and enforcement should be asserted through a regulatory body. The management role on the second and third levels should plan, organize, influence and control the process. The feedback gotten should be used to strengthen the implementation process.

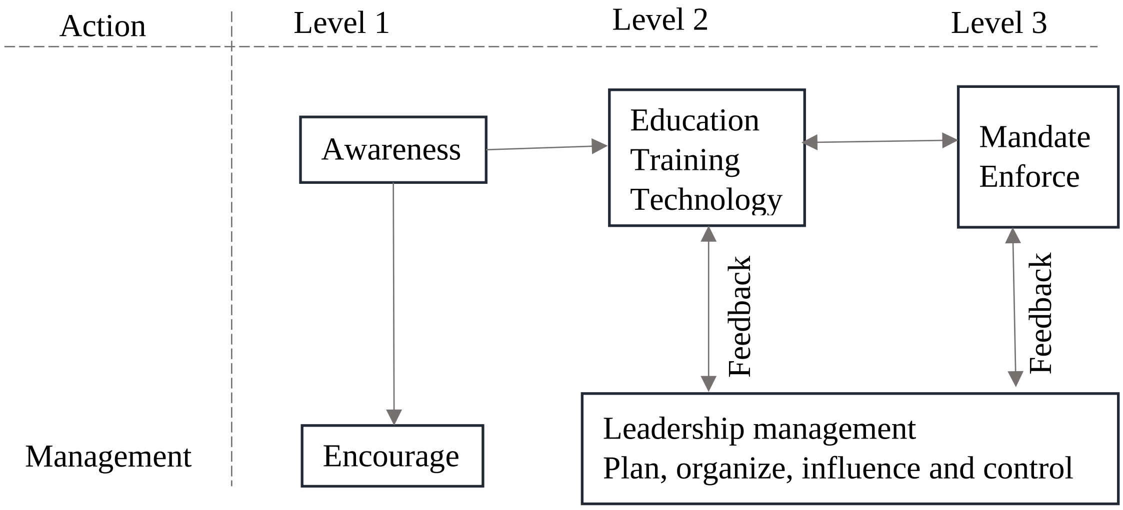


Figure 4.17: Implementation action chart

The BIM Adoption and implementation Framework is divided into BIM fields and the milestone assessments should be based on BIM stages. BIM Fields are policy, process, and technology. The fields are divided into players and deliverables. BIM stages are Stage 1- Object based modelling; stage 2 – Model based collaboration; stage 3 – Network-based integration.

Policy field: Players are education and research centres, Regulation bodies and policy makers. Whereas deliverables are education programmes, Standard, guidelines, policy, legal framework, regulations, benchmarking, case studies and national piloting programmes.

Process Filed: Players are professionals (individuals and organizations) and deliverables are drawings and documentation.

Technology field: Technology developers are players and hardware, software and internet are the deliverables

Figure 4.18 presents the BIM Adoption and Implementation Framework.

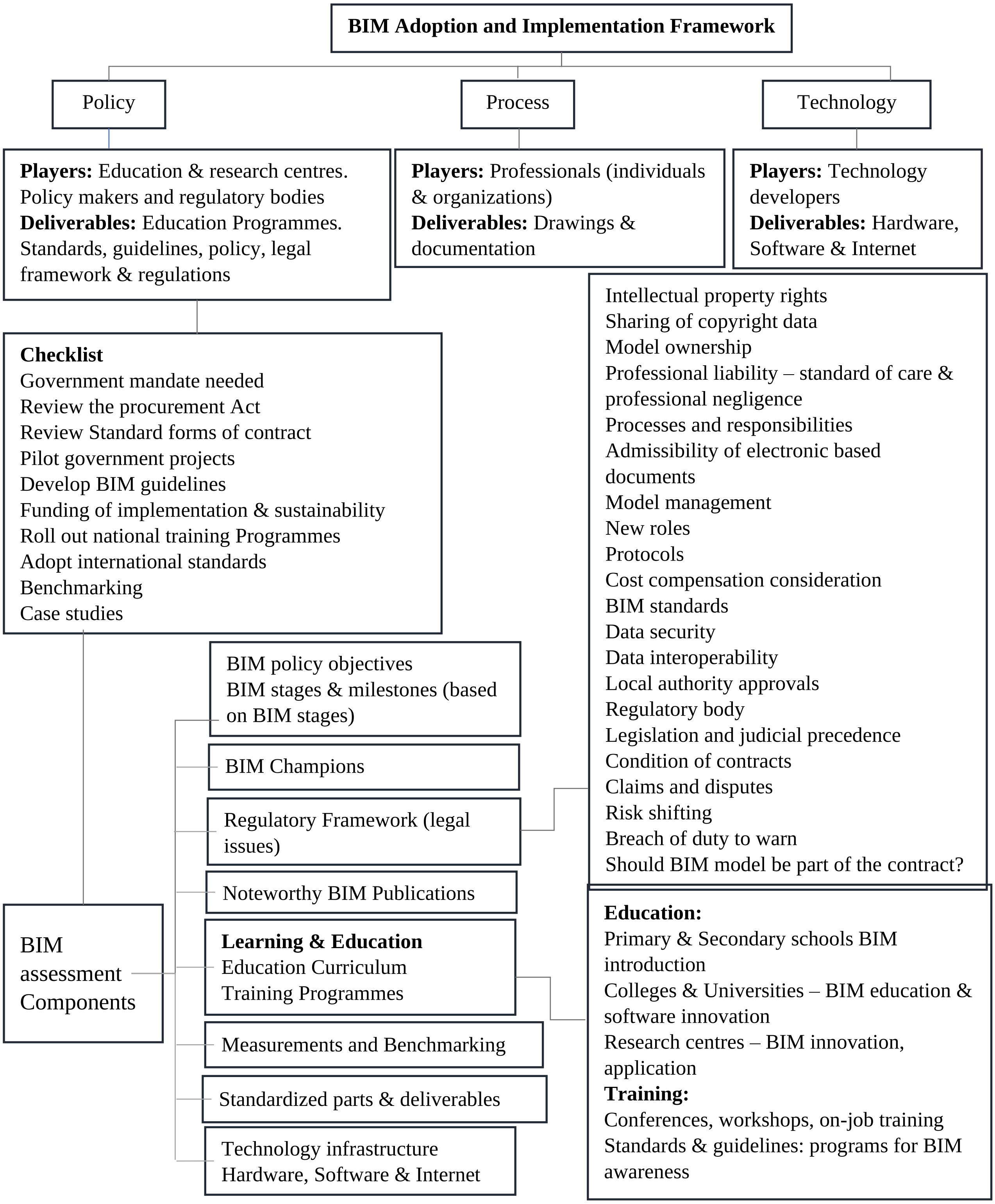


Figure 4.18: BIM Adoption and Implementation Framework

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

This chapter gives conclusions and recommendations of the research on BIM adoption and the influence of BIM on ECM. It also outlines areas for further research.

5.2 Conclusion

The study objectives were to assess BIM adoption, to determine the underlying components in BIM adoption, to investigate the influence of BIM on ECM in Nairobi Kenya and to formulate BIM implementation framework. The hypothesis testing showed that there were underlying factors associated with BIM adoption, there was a relationship between BIM and ECM and there were underlying factors of BIM's influence on ECM.

There were theoretical implications based on theories used in this study. The Diffusion of Innovation theory showed that BIM as a new technology is adopted at varying rates, the benefits are the pull factors. BIM innovation seems to be conforming to the theoretical structure beginning from innovators, early adopters, early majority, late majority, and laggards. The non-adopters were seen to be hesitant and though they gave many reasons of not adopting, they rated BIM favourably, which showed that it will be a matter of time before making their decision. Further, the study supports Contract theory and System Theory of Management whereby for BIM's influence on ECM and towards optimal performance, policy and technology cannot be separated. The legal framework should be functional and in line with corresponding systems and structures. The research findings also conform to the Technology Acceptance Model theory whereby acceptance of new technologies is influenced by usefulness and ease of use, however, for the case of Nairobi Kenya understanding of BIM and cost of adoption of BIM was found to contribute greatly.

There were methodological implications, even though the study used known methods. For instance, at sampling a combination of stratified sampling and purposive sampling were applied to get an equal representation of respondents from the eight selected strata and at the same time meet the requirement of BIM awareness. The study was based on actual experiences and opinions of parties aware of BIM. Structured and unstructured data targeted aimed at getting rated responses and get uninterrupted and unstructured responses. The descriptive analysis gave the results as received, whereas inferential statistics gave more meaning to the results and sought underlying factors from the responses given. Correlation and regression analysis were used to check the degree of association of BIM and ECM. Whereas Exploratory Factor Analysis (EFA) was used for data reduction and to compute underlying factors relevant to the study, this led to formation of regression equation for areas of further analysis.

5.2.1 Objective 1: To assess BIM adoption in Nairobi Kenya.

Adoption was found to be progressive, whereby 56.6% had adopted BIM, and with most of the industry players planning to adopt. Majority of the respondents were in BIM stages 1 and 2, and 3D was widely used as compared to the other dimensions. The main hinderance found to BIM adoption was lack of understanding of what BIM is; respondents were still confusing BIM for software; however, BIM is a system. The Traditional Procurement System (TPS) was found to conflict with BIM, hence inhibiting optimum performance of BIM. In Nairobi, some private organizations had taken the initiative to adopt BIM ahead of government directives, they prepare procurement contracts, standards and guidelines on an ad hoc basis. To note also, the younger generation were the majority adopters, this then affects the implementation process being that the older generation are the majority policy makers in the country.

Other hinderances to BIM adoption were found to be cost of implementation, Traditional Procurement System, rigidity in leadership, fear of corrupt and hidden interest being exposed by transparent BIM, change resistant attitude, training and education challenges, complexity of BIM and size of projects. In addition, lack of the following impeded adoption: knowledge and awareness, understanding, contractual guidance, BIM skills, case studies, BIM champion, and client’s initiative.

The recurring themes from the findings are awareness, standards, guidelines, government mandate, procurement system, education, training and technology. Awareness, knowledge and understanding of BIM was low and technology and technological capabilities of the consultants need improvement. Education and training were found to be important in BIM sensitization. The government has a crucial role of giving guidelines and providing leadership in BIM adoption and implementation. Ultimately, adoption and implementation require awareness of what BIM is, leadership to give guidance, education to build technical capacity, training to advance the skills and necessary technology to execute the BIM process.

5.2.2 Objective 2: Underlying components in BIM adoption

The objective was to determine underlying components in BIM adoption in Nairobi, Kenya. The hypothesis tested showed that there are underlying factors associated with BIM adoption. The underlying factors that were found in BIM adoption were efficiency, versatility, competitiveness, intelligence, and transparency.

Efficiency aids BIM adoption and it is geared towards collaboration; it reflects immediate benefits that are easily communicated to users and understood. Versatility factor supports adoption; it is about the numerous secondary benefits of BIM that players are likely to seek for after the primary needs have been adequately met and processes that have been traditionally difficult to conduct are easily executed through computer simulation. Competitiveness factor supports BIM adoption, competition has become borderless and clients and trends are moving towards complexity that resonates technological advancement the Kenyan consultants must keep up with the international trends to get jobs.

The intelligence factor is in support of BIM adoption. Through the computer simulation, all the planning and analysis is done before construction. Though TPS has attempted to incorporate BIM for visualization, as has been practiced in Nairobi Kenya, however it is important to note that the benefits of BIM are reaped when BIM system is adopted in totality. Whereas the transparency factor supports and hinders BIM adoption at the same time, ambiguity, errors, and misunderstandings are reduced because everyone is reading from the same model. Overpricing is not feasible, and the client can follow through all steps with ease. Together with the advantage of BIM ensuring continuity and consistency in information management, transparency then leads to positive ROI.

5.2.3 Objective 3: The influence of BIM on ECM in Nairobi Kenya

The objective was to investigate the influence of BIM on ECM in Nairobi, Kenya. On the contractor's early involvement, the study found out that as the industry waits for the mandate, Design and build procurement maybe used for BIM projects. Alternatively, two stage contracting may also work well, that is, procuring a contractor for design phase and the second stage at construction phase.

It emerged that BIM improves ECM; when time, cost, quality, collaboration, and ROI improve, ECM improves and becomes effective and efficient. The variables that are more significant in this relationship were found to be collaboration and ROI. Hypothesis tested showed that there is a relationship between BIM and ECM. Another hypothesis tested showed that there were underlying factors of BIM's influence on ECM. The underlying factors found in BIM and ECM relationship were legal implications, awareness and knowledge, efficiency, versatility, mandate and leadership, and competitiveness. Further, new collaborative relationships have been created such as contractor's and facility manager's early involvement in the project, inevitably, new risks are bound to emerge that require to be handled by the BIM system and not the traditional system.

Legal implications brought about by BIM system demands a legal framework that is contractually viable for its optimal performance. Efficiency of the BIM system is the primary reason arousing curiosity leading to adoption, these are benefits that makes ECM processes easier to handle. Versatility of the BIM system shows that BIM is not narrow in its benefits, it is adaptable to many functions and activities that were traditionally tedious to execute, ignored or were simply overlooked. Mandate and leadership factor depict importance of leadership at various levels such as firm, professional bodies, regulatory bodies, in both private and public capacities. The government mandate is the crowning factor, for it will give the momentous push of adoption and implementation of BIM in Nairobi and Kenya at large. Competitiveness is key globally in the current times, construction tenders' disregards physical borders but look for effectiveness and efficiency. Technological sophistication demands for matching techniques of executing projects.

5.2.4 Objective 4: BIM adoption and implementation framework

The objective was to formulate a BIM adoption and implementation framework. This study findings establish that raising BIM awareness is important so that policy, process and technology can work together towards BIM adoption and implementation to enable effective and efficient ECM. Policy covers legal framework, regulatory bodies, education and research centres. Process covers various traditional consultants and the new roles and relationships brought by BIM. Technology covers capacity in software, hardware and network. Thus, the study formulated a BIM adoption and implementation framework.

5.3 Study Output

The Study output was two journal publications and one conference presentation. With the following titles:

1. Journal Publication: Influence of Building Information Modelling (BIM) on Engineering Contract Management in Nairobi, Kenya. Publisher: Scientific Research Publishing (SCIRP). Journal: World Journal of Engineering and Technology (WJET). Volume 8, No.3 August 2020. Website: https://www.scirp.org/journal/paperinformation.aspx?paperid=101723. (Appendix XIV)

2. Journal Publication: Underlying factors guiding Building Information Modelling (BIM) adoption in Nairobi, Kenya. Publisher: Jomo Kenyatta University of Agriculture and Technology (JKUAT). Journal: Journal of Sustainable Research in Engineering (JSRE). Volume 6, No.2 12th December

2020. Website: https://jsre.jkuat.ac.ke/index.php/jsre/article/view/103/106. (Appendix XIV)

3. Conference Presentation: Factors Affecting Building Information Modelling (BIM) Adoption in Nairobi Kenya. 6th October 2020- JKUAT online platform. Sustainable Research and Innovation (SRI) conference. (Appendix XIV)

5.4 Recommendations

The government with its advantage of being the biggest construction industry employer, should mandate BIM and adopt its procurement process to suit collaborative BIM. This will ensure Kenyan consultants are equally competitive as their international counterparts towards winning construction contracts. A regulatory body mandated by the government is important to help with standardization of BIM within the country, through creating standards and guidelines and providing standard forms of contract. Case studies on BIM projects and NBPs will be important in guiding stakeholders in BIM adoption and systematically abandon the TPS, which is not receptive to technological advancement. Legal validation of the digital model by the Nairobi County Council (NCC) can only function through a mandate which will ensure systematic migration from TPS that mainly uses hard copies and 2D digital drawings.

There is need for a well-structured BIM education curriculum; research and education centres should invest in BIM education from primary schools, secondary school, tertiary institutions and university level this will enable innovation by Kenyans. The government of Kenya should invest in this process, this will eliminate half-baked professionals and promote the country’s professionalism and competitiveness in the global space. Kenya needs to defect from passive observers who wait to consume what the rest of the world innovates instead it should export innovation to the international market, and this comes down to policy. Additionally, Kenyan Noteworthy BIM Publications (NBP) should also be encouraged, for this will help accelerate innovation.

Awareness and knowledge of BIM is essential, the industry should start by changing the mindsets of stakeholders this should especially target the older generation, who are the policy makers in the country. The stakeholders should know that BIM exists, and that it is beneficial in making ECM efficient and effective. Industry wide adequate training by skilled professionals is recommended to elevate BIM understanding levels, this will ensure that BIM adoption goes beyond the custom of utilizing 3D visualization and clash detection to include efficiency and effectiveness of running ECM. Training will also ensure international competitiveness. The construction industry should focus on developing its procurement standards towards Integrated Project Delivery (IPD), for that is where international trends are headed to. Processes need to be revised, responsibility and liability should be assigned to the right professionals, which should include the new skills brought by BIM.

5.5 Area for further research

The present research was based on Nairobi county's BIM situation, it is recommended that County specific research be conducted, and findings combined with the Nairobi's scenario to enable comprehensive decision-making regarding the procurement Act revisions. Further research should be conducted to measure whether the understanding of BIM has positively improved and whether software brand is a major contributor to this predicament. Further, case studies on BIM projects should be conducted to help review benefits and ROI. The education curriculum should be researched adequately and ways to equip Kenya in BIM research should be explored in all levels of education beginning with primary education, job market requirements should be probed, and gaps filled under well informed system.

REFERENCES

Abbas, A., Din, Z. U., & Farooqui, R. (2016). Integration of BIM in Construction Management Education: An Overview of Pakistani Engineering Universities. *Procedia Engineering, 145,* 151–157. https://doi.org/10.1016/j. proeng. 2016.04.034

Altaf, M. S., Hashisho, Z., & Al-Hussein, M. (2014). A method for integrating occupational indoor air quality with building information modeling for scheduling construction activities. *Canadian Journal of Civil Engineering*, *41*(3), 245–251. https://doi.org/10.1139/cjce-2013-0230

Anna, K. (2010). *Factor models The Foundations of Factor Analysis*. Published Master's Thesis, Central European University.

Arshad, M. F., Thaheem, M. J., Nasir, A. R., & Malik, M. S. A. (2019). Contractual Risks of Building Information Modeling : Toward a Standardized Legal Framework for Design-Bid-Build Projects. *Journal of Construction Engineering and Management*, *145*(4), 1–14. https://doi.org/10.1061/ (ASCE) CO.1943-7862.0001617

Asad, A. (2016). Building Information Modelling (BIM) and Project Management Implementation in Infrastructure and Civil Construction. *D31M1 - Construction Practice and IT,* 1–12.

Association of Construction Managers of Kenya. (2018). Registered Members – ACMK. Retrieved from https://acmk.co.ke/registered-members/

Autodesk. (2019). What Is BIM. Retrieved from https://www.autodesk.com/ solutions/ bim

Azhar, N., Kang, Y., & Ahmad, I. U. (2014). Factors Influencing Integrated Project Delivery In Publicly Owned Construction Projects : An Information Modelling Perspective. *Procedia Engineering*, *77*, 213–221. https://doi.org/10.1016/

j.proeng.2014.07.019

Azhar, S., Khalfan, M., & Maqsood, T. (2012). Building Information Modelling (BIM): Now and Beyond. *Australasian Journal of Construction Economics and Building, 12*(4), 15–28. https://doi.org/10.5130/ajceb.v12i4.3032

Aziz, N. D., Nawawi, A. H., & Ariff, N. R. M. (2016). Building Information Modelling (BIM) in Facilities Management: Opportunities to be Considered by Facility Managers. In Procedia - Social and Behavioral Sciences (Ed.), *AMER International Conference on Quality of Life* (Vol. 234, pp. 353–362). Medan, Indonesia: Elsevier. https://doi.org/10.1016/j.sbspro.2016.10.252

Bergin, M. S. (2012). History of BIM (Building Information Modelling). Retrieved from https://archinect.com/archlab/history-of-bim

Board of Registration of Architects and Quantity Surveyors. (2019). The Board of Registration of Architects and Quantity Surveyors (BORAQS). Retrieved from https://boraqs.or.ke/registered/architects-firm

Borjeghaleh, R. M., & Sardroud, J. M. (2016). Approaching Industrialization of Buildings and Integrated Construction Using Building Information Modeling. *Procedia Engineering, 164*, 534–541. https://doi.org/10.1016/j.proeng.2016.11.655

Bosch-sijtsema, P., & Gluch, P. (2019). Challenging construction project management institutions : the role and agency of BIM actors. *International Journal of Construction Management*, 1–11.https://doi.org/10.1080/15623599.2019.1602585

Bouška, R. (2016). Evaluation of maturity of BIM tools across different software platforms. *Procedia Engineering, 164*(June), 481–486. https://doi.org/10.1016/j.proeng.2016.11.648

Bui, N., Merschbrock, C., & Munkvold, B. E. (2016). A review of Building Information Modelling for construction in developing countries. *Procedia Engineering*,*164*(1877), 487–494.https://doi.org/10.1016/j.proeng.2016.11.649

Certo, S. C., & Certo, T. s. (2012). *Modern Management: Concepts and Skills*. (S. Yagan, Ed.) (12th ed.). New Jersey: Prentice Hall Pearson.

Chandra, H. P., Nugraha, P., & Putra, E. S. (2017). Building Information Modeling in the Architecture-engineering Construction Project in Surabaya. *Procedia Engineering*, *171*, 348–353. https://doi.org/10.1016/j.proeng.2017.01.343

Charehzehi, A., Chai, C., Yusof, A. M., Chong, H., & Loo, S. C. (2017). Building information modeling in construction conflict management. *International Journal of Engineering Business Management*, *9*, 1–18. https://doi.org/10.1177/1847979017746257

Chikere, C. C., & Nwoka, J. (2015). The Systems Theory of Management in Modern Day Organizations - A Study of Aldgate Congress Resort Limited Port Harcourt. *International Journal of Scientific and Research Publications*, *5*(9), 1–7. Retrieved from www.ijsrp.org

Child, D. (2006). *The essentials of factor analysis* (3rd ed.). New York: Continuum International.

Comrey, A. L., & Lee, H. B. (1992). *A First Course in Factor Analysis* (2nd ed.). New Jersey: Psychology Press Taylor & Francis.

Costin, A., Pradhananaga, N., & Teizer, J. M. (2012). Real-Time resource location tracking in building information models (BIM). In *Cooperative Design, Visualization, and Engineering 9th International Conference*. Osaka, Japan.

Creswell, J. w. (2014). *Research Design: Qualitative, Quantitative and Mixed Methods Approaches*. (V. Knight, Ed.) (4th ed.). California: SAGE publications. Inc.

Daniel, J. (2012). Choosing the Type of Probability Sampling. In V. Knight (Ed.), *Sampling Essentials: Practical Guidelines for Making Sampling Choices* (pp. 125–174). Los Angeles: SAGE. https://doi.org/https://dx.doi.org/10.4135/9781452272047.n5

Diathesopoulos, M. (2010). Relational contract theory and management contracts: A paradigm for the application of the Theory of Norms. *Lancaster University Law School Research Papers*, *July 15*, *2*(24028), 1–125. https://doi.org/http://dx.doi.org/10.2139/ssrn.1625348

Ding, L., & Xu, X. (2014). Application of Cloud Storage on BIM Life-cycle Management. *International Journal of Advanced Robotic Systems*, *11*(129), 1–10. https://doi.org/10.5772/58443

Dwivedi, Y. K., Rana, N. P., Jeyaraj, A., Clement, M., & Williams, M. D. (2017). Re-examining the Unified Theory of Acceptance and Use of Technology (UTAUT): Towards a Revised Theoretical Model. *Information Systems Frontiers*, *21*, 719–734. https://doi.org/10.1007/s10796-017-9774-y

Dworkin, S. L. (2012). Sample Size Policy for Qualitative Studies Using In-Depth Interviews. *Archives of Sexual Behaviour*, *41*, 1319–1320. https://doi.org/10.1007/s10508-012-0016-6

Eadie, R. (2014). The Impact of Building Information Modelling (BIM) on Public Sector Tender Documents for Civil Engineering Works. In *Education, Science and Innovations*. Pernik, Bulgaria: European Polytechnical University.

Eadie, R., McLernon, T., & Patton, A. (2015). An Investigation into the Legal issues relating to Building Information Modelling (BIM). In *RICS COBRA AUBEA 2015*. Sydney, Australia: RICS (Royal Institute of Chartered Surveyors).

Eastman, C., Teicholz, P., Sacks, R., & Liston, K. (2008). *BIM Handbook: A Guide to Building Information Modelling for Owners, Managers, Designers, Engineers and Contractors*. New Jersey & Canada: John Wiley & Sons, Inc.

Engineers Board of Kenya. (2019). Engineers Board of Kenya – Registered Engineers. Retrieved from https://ebk.or.ke/registered-consulting-engineers/

FIDIC. (2017). *FIDIC Conditions of Contract for Construction* (2nd Ed.). Geneva, Switzerland: International Federation of Consulting Engineers.

Foss, N. J., & Klein, P. G. (2016). Reflections on the 2016 Nobel Memorial Prize for contract theory (Oliver Hart and Bengt Holmström). *Erasmus Journal for Philosophy and Economics*, *9*(2), 167–180.

Friedman, M. (1937). The Use of Ranks to Avoid the Assumption of Normality Implicit in the Analysis of Variance. *Journal of the American Statistical Association*, *32*(200), 675–701.

Frydlinger, D., Cummins, T., Vitasek, K., & Bergman, J. (2016). *Unpacking Relational contracts*. Knoxville.

Gitee, P. W., & Yusuf, M. (2018). Effect of Building Information Modelling on Projects Implementation : A Case of Nairobi County. *International Journal of Civil and Structural Engineering Research*, *6*(1), 83–90.

Goubau, T. (2012). A History of BIM - APROPLAN. Retrieved from https://www.aproplan.com/blog/construction-collaboration/a-history-of-bim

Graphisoft. (2019). About BIM. Retrieved from https://www.graphisoft.com/archicad/open_bim/about_bim/

Grzyl, B., Miszewska-Urbańska, E., & Apollo, M. (2017). Building Information Modelling as an Opportunity and Risk for Stakeholders Involved in Construction Investment Process. In Procedia Engineering (Ed.), *Creative Construction Conference* (Vol. 196, pp. 1026–1033). Primosten, Croatia:

Elsevier. https://doi.org/10.1016/j.proeng.2017.08.045

Gwaya, A. O., Masu, S. M., & Wanyona, G. (2014). Development of Appropriate Project Management Factors for the Construction Industry in Kenya. *International Journal of Soft Computing and Engineering*, *4*(1), 70–76.

Hair, J. F. J., Black, W. C., Babin, B. J., & Anderson, R. E. (2014). *Multivariate Data Analysis* (7th ed.). England: Pearson.

Hasanzadeh, M. S., Hosseinalipour, M., & Hafezi, M. (2014). Collaborative Procurement in Construction Projects Performance Measures, Case Study: Partnering in Iranian Construction Industry. *Procedia - Social and Behavioral Sciences*, *119*, 811–818. https://doi.org/10.1016/j.sbspro.2014.03.091

Hennink, M. M., Kaiser, B. N., & Marconi, V. C. (2017). Code Saturation Versus Meaning Saturation : How Many Interviews Are Enough ? *Qualitative Health Research*, *27*(4), 591–608. https://doi.org/10.1177/1049732316665344

Hinton, P. R., Brownlow, C., McMurray, I., & Cozens, B. (2004). Cronbach Alpha. In *SPSS Explained* (pp. 363, 364). London, New York: Routledge Taylor & Francis.

Hosseini, M. R., Azari, E., Tivendale, L., Banihashemi, S., & Chileshe, N. (2016). Building Information Modeling (BIM) in Iran : An Exploratory Study. *Journal of Engineering, Project, and Production Management*, *6*(2), 78–89.

Hussin, A. A., & Omran, A. (2009). Roles of professionals in construction industry. In *The International Conference on Administration and Business* (pp. 248–256). Romania: University of Bucharest.

Kaiser, H. F. (1960). The application of Electronic Computers to Factor Analysis. *Education and Psychological Measurement*, *20*, 141–151.

Kalinichuk, S. (2015). Building information modeling Comprehensive Overview. *Journal of Systems Integration*, *3*, 25–34. https://doi.org/10.20470/jsi.v6i3.235

Kassem, M., Succar, B., & Dawood, N. (2014). *Building Information Modeling : Analyzing Noteworthy Publications of Eight Countries Using a Knowledge Content Taxonomy*. Alexander Bell Drive.

Kekana, T. G., Aigbavboa, C. O., & Thwala, W. D. (2014). Building Information Modelling (BIM): Barriers in Adoption and Implementation Strategies in the South Africa Construction Industry. In *International Conference on Emerging Trends in Computer and Image Processing* (pp. 109–111).

Kenya Institute for Public Policy Research and Analysis. (2016). *Kenya Economic Report 2016*. Nairobi.

Kenya National Bureau of Statistics. (2018). *Economic survey 2018*. Nairobi. Retrieved from https://africacheck.org/wp-content/uploads/2019/03/Economic-Survey-2018.pdf

Kenya National Bureau of Statistics. (2019a). *2019 Kenya Population and Housing Census Volume 1: Population by County and Sub-County*. *2019 Kenya Population and Housing Census* (Vol. I). Retrieved from https://www.knbs.or.ke/?wpdmpro=2019-kenya-population-and-housing-census-volume-i-population-by-county-and-sub-county

Kenya National Bureau of Statistics. (2019b). *Economic Survey 2019*. Nairobi, Kenya. Retrieved from https://open.africa/dataset/kenya-economic-survey-2019/resource/5b9357a4-6227-4fbf-9e10-ae7043a41ce3

Kenya Report. (2016a). HassConsult Real Estate, The Leading Private Property Developer in Kenya. Retrieved from https://marcopolis.net/hassconsult-real-estate-the-leading-private-property-developer-in-kenya.htm

Kenya Report. (2016b). Real Estate Sector in Kenya; Nairobi is a Regional Hub. Retrieved from https://marcopolis.net/real-estate-sector-in-kenya-nairobi-is-a-regional-hub-says-ben-woodhams.htm

Kenya Vision 2030. (2008). Kenya Vision 2030. Retrieved from http://vision2030.go.ke/

Khodeir, L. M., & Nessim, A. A. (2017). BIM2BEM integrated approach: Examining status of the adoption of building information modelling and building energy models in Egyptian architectural firms. *Ain Shams Engineering Journal*. https://doi.org/10.1016/j.asej.2017.01.004

Kiiru, H. W. (2015). *Public Procurement System and its Infuence on the Building Contract Performance During Project Implementation: The Case of Nairobi county*. Published Master's Thesis, Jomo Kenyatta University of Agriculture and Technology.

Kim, M., Ji, S., & Jun, H. (2018). BIM-based File Synchronization and Permission Management System for Architectural Design Collaboration. *Journal of Asian Architecture and Building Engineering*, *16*(3), 511–518. https://doi.org/10.3130/jaabe.16.511

Kimani, T. N., Jallow, H., Njuguna, M., & Alkizim, A. O. (2019). BIM Awareness : The Kenyan and UK Scenarios. In *The Sustainable and Innovation Conference* (pp. 157–161). Nairobi, Kenya.

Kimani, T. N., Njuguna, M., Alkizim, A. O., & Jallow, H. (2018). The Potential of BIM Models as Legal Construction Documents for Sustainable Growth in Kenyan Construction Industry. In *The 10 th International Conference on Construction in the 21st Century* (pp. 13–21). Colombo Sri Lanka.

Kogi, B. W., & Were, S. (2017). Factors Affecting Cost Overruns in Construction Projects a Case of Kenya National Highways Authority. *International Journal of Project Management*, *1*(10), 167–182.

Kong, A. T., & Gray, J. (2006). Problems with Traditional Procurement in the Malaysian Construction Industry-a survey. In *Australasian Universities Building Educators Association Annual Conference* (pp. 1–21). University of

Technology, Sydney.

Kothari, C. R., & Garg, G. (2019). *Research Methodology, Methods and Techniques* (4th ed.). New Delhi, Nairobi, London: New Age International Publishers.

Krejcie, R. V, & Morgan, D. W. (1970). Determining Sample Size for Research Activities. *Education and Psychological Measurements*, *30*, 607–610.

Kuiper, I., & Dominik, H. (2013). Rethinking the Contractual Context for Building Information Modelling (BIM) in the Australian Built Environment Industry. *Australasian Journal of Construction Economics and Building*, *13*(4), 1–17.

Kumar, B., & Hayne, G. (2016). A Framework for Developing a BIM Strategy. In *Information Technology in Construction*. Brisbane, Queensland: CIB innovation Journal.

Laerd statistics. (2018). Friedman Test in SPSS Statistics. Retrieved from https://statistics.laerd.com/spss-tutorials/friedman-test-using-spss-statistics.php

Latiffi, A. A., Brahim, J., & Fathi, M. S. (2014). The Development of Building Information Modeling (BIM) Definition. *Applied Mechanics and Materials*, *567*, 625–630. https://doi.org/10.4028/www.scientific.net/AMM.567.625

Liu, B., Wang, M., Zhang, Y., Liu, R., & Wang, A. (2017). Review and Prospect of BIM Policy in China. *IOP Conference Series: Materials Science and Engineering*, *245*(022021). https://doi.org/10.1088/1757-899X/245/2/022021

Lowry, R. (2012). Subchapter 15a: The Friedman Test for 3 or More Correlated Samples. Retrieved from http://vassarstats.net/textbook/ch15a.html

Manderson, A., Jefferies, M., & Brewer, G. (2015). Building Information Modelling and Standardised Construction Contracts: a Content Analysis of the GC21 Contract. *Construction Economics and Building*, *15*(3), 72–84. https://doi.org/http://dx.doi.org/10.5130/AJCEB.v15i3.4608

Manza, D. (2016). *Influence of Building Information Modelling Adoption on Completion of Construction Projects: A Case of Nairobi County, Kenya*. Published Master's Thesis, University of Nairobi.

Mason, M. (2010). Sample Size and Saturation in PhD Studies Using Qualitative Interviews. *Forum: Qualitative Social Research*, *11*(3). Retrieved from http://nbn-resolving.de/urn:nbn:de:0114-fqs100387

Mbaabu, P. P. (2012). *Factor Influencing Implementation of Road Construction Projects in Kenya: A Case of Isiolo County, Kenya.* Published Thesis, University of Nairobi.

McAuley, B., Hore, A., & West, R. (2017). *Global BIM Study - Lessons for Ireland's BIM Programme*. Dublin, Ireland: Construction IT Alliance (CitA). https://doi.org/10.21427/D7M049

Mouzas, S., & Blois, K. (2008). Relational Contract Theory: Confirmations and Contradictions. In Lancaster University Management School (Ed.), *24th IMP Conference*. Lancaster.

Mugenda, O. M., & Mugenda, A. G. (2003). *Research Methods Quantitative & Qualitative Approaches* (2nd ed.). Nairobi: African Centre for Technology Studies (ACTS) Press.

Munyoki, S. K. (2014). *Factors Influencing Completion of Construction Projects; A Case of Construction Projects in Nairobi*. Published Thesis, University of Nairobi.

Murray, J. E. J. (2002). Contract Theories and the Rise of Neoformalism. *Fordham Law Review*, *71*(3), 869–913. Retrieved from http://ir.lawnet.fordham.edu/flr/vol71/iss3/10

Musyimi, M. M. (2016). *Building Information Modelling Adoption in Construction Project Management in Kenya: A Case Study of Nairobi County*. Published

Master's Thesis, University of Nairobi.

Mutonyi, N., & Cloete, C. (2018). Adoption of Building Information Modelling in the construction industry in Kenya. *Navorsingsartikels • Research Articles*, *25*(2). https://doi.org/10.18820/24150487/as25i2.1

Mwangi Thiong'o, D., & Muchelule, Y. (2019). Effect of Building Information Modelling on Construction Projects Risks Management in Kenya. *American Based Research Journal*, *8*(10), 2304–7151. Retrieved from http://www.abrj.org

Nairobi City County. (2020). Nairobi City County eDevelopment Permit System. Retrieved from http://ccn-ecp.or.ke/

National Construction Authority. (2019). NCA Contractors. Retrieved from http://nca.go.ke/contractors/

National Institute of Building Science United States. (2019). Frequently asked questions about National BIM Standard - United States. Retrieved from https://www.nationalbimstandard.org/faqs

Ndemo, B. (2015, July 1). The Role of Youths in Fighting Corruption. *Business Daily*. Retrieved from https://www.businessdailyafrica.com/analysis/columnists/-The-role-of-ICT-in-fighting-corruption/4259356-2772112-5eabeg/index.html

Neill, J. (2008). Writing Up A Factor Analysis. *Creative Commons Attribution 2.5 Australia*, 1–15. Retrieved from http://creativecommons.org/licenses/by/2.5/au/ Table

Nicał, A. K., & Wodyński, W. (2016). Enhancing Facility Management through BIM 6D. *Procedia Engineering*, *164*(June), 299–306. https://doi.org/10.1016/j.proeng.2016.11.623

Nowak, P., Książek, M., Draps, M., & Zawistowski, J. (2016). Decision Making with Use of Building Information Modeling. *Procedia Engineering*, *153*, 519–526.

https://doi.org/10.1016/j.proeng.2016.08.177

Olatunji, A. O. (2011). A Preliminary Review on the Legal Implications of BIM and Model Ownership. *Journal of Information Technology in Construction*, *16*(December 2010), 687–696. Retrieved from http://www.itcon.org/2011/40

Olatunji, A. O. (2014). Views on Building Information Modelling, Procurement and Contract Management. *Management, Procurement and Law*, *167*(MP3), 117–126. https://doi.org/10.1680/mpal.13.00011

Oloo, A. O. (2013). *Influence of Procurement Procedures on Construction Project Performance: A Case of Power Plant Construction at Kenya Petroleum Refineries Limited, Mombasa*. Published Thesis, University of Nairobi.

Olsen, D., & Taylor, J. M. (2017). Quantity Take-Off Using Building Information Modeling (BIM), and Its Limiting Factors. *Procedia Engineering*, *196*(June), 1098–1105. https://doi.org/10.1016/j.proeng.2017.08.067

Olum, Y. (2004). Modern Management Theories and Practices. In *East African Central Banking Course* (pp. 0–24). Kampala.

Oxford Business Group. (2017). Infrastructure projects and private financing drive the construction sector in Kenya. Retrieved from https://oxfordbusinessgroup.com/overview/commitment-growth-large-scale-infrastructure-projects-and-private-financing-are-helping-drive-sector

Patil, V. H., Singh, S. N., Mishra, S., & Donovan, T. (2017). Parallel Analysis Engine. Retrieved from https://analytics.gonzaga.edu/parallelengine/.

Pring, A. (2019, February). Meet the man taking BIM to East Africa. Retrieved from https://www.bimplus.co.uk/analysis/meet-man-taking-bim-east-africa/

Procurement Management & Procurement Strategies. (2017). Contract Management Process – Key Points and Activities. Retrieved from https://www.purchasing-procurement-center.com/contract-management-process.html

Rogers, E. M. (1983). *Diffusion of Innovations* (3rd ed.). New York: The Free Press.

Rotich, J. C. (2014). *Contract Management Practice and Operational Performance of State Corporations in Kenya*. Published Master's Thesis, University of Nairobi.

Sahin, I. (2006). Detailed Review of Rogers' Diffusion of Innovation Theory and Educational Technology - Related Studies Based on rogers' Theory. *The Turkish Online Journal of Educational Technology*, *5*(2), 14–23.

Seboru, M. A. (2015). An Investigation into Factors Causing Delays in Road Construction Projects in Kenya. *American Journal of Civil Engineering*, *3*(3), 51–63. https://doi.org/10.11648/j.ajce.20150303.11

Smith, P. (2014a). BIM & the 5D Project Cost Manager. *Procedia - Social and Behavioral Sciences*, *119*, 475–484. https://doi.org/10.1016/j.sbspro.2016.06.179

Smith, P. (2014b). BIM implementation - global strategies. *Procedia Engineering*, *85*, 482–492. https://doi.org/10.1016/j.proeng.2014.10.575

Smith, S. A. (2004). Contract Theory. In *Contract Theory* (pp. 42–53; 101–163). Oxford, England.: Oxford University Press.

Succar, B. (2009). Building Information Modelling Framework: A Research and Delivery Foundation for Industry Stakeholders. *Automation in Construction*, *18*(3), 357–375. https://doi.org/10.1016/j.autcon.2008.10.003

Succar, B. (2010a). Building Information Modelling Maturity Matrix. In J. U. & U. Isikdag (Ed.), *Handbook of Research on Building Information Modelling and Construction Informatics: Concepts and Technologies* (pp. 65–103). IGI Publishing.

Succar, B. (2010b). The Five Components of BIM Performance Measurement. In *CIB World Congress* (pp. 287–300). Salford, United Kingdom: Academia.

Succar, B. (2013). *Building Information Modelling: conceptual constructs and performance improvement tools*. Published PhD Thesis, University of Newcastle.

Succar, B., & Kassem, M. (2015). Macro-BIM adoption: Conceptual structures. *Automation in Construction*, *57*, 64–79. https://doi.org/10.1016/j.autcon.2015.04.018

Succar, B., & Kassem, M. (2017). BIM adoption policies insights from across the world. In *CitA BIM gathering*. Dublin, Ireland: Academia.

Succar, B., Sher, W., Aranda-mena, G., & Williams, T. (2007). A Proposed Framework to Investigate Building Information Modelling Through Knowledge Elicitation and Visual Models. In *Australasian Universities Building Education*. Melbourne, Australia: Academia.

Tavakol, M., & Dennick, R. (2011). Making Sense of Cronbach's Alpha. *International Journal of Medical Education*, *2*, 53–55. https://doi.org/10.5116/ijme.4dfb.8dfd

The American Institute of Architects. (2007). *Integrated Project Delivery: A Guide*. California.

The Joint Building Council Kenya. (1999). *Agreement and Conditions for Building Works*. Nairobi: AAK.

The Republic of Kenya. Public Procurement and Asset Disposal Act 2015, Pub. L. No. No. 33 of 2015 (2016). Kenya: The National Council for Law Reporting.

The Republic of Kenya. The kenya gazette: The Estate Agent Act - The Estate Agent Registration Board, Registered Estate Agents (Cap 533), Pub. L. No. Cap 533 section 9, CXXI 1514 (2019). Kenya: EARB website.

The Republic of Kenya. (2020). Public Procurement Regulatory Authority. Retrieved from http://ppra.go.ke/about-us/

Thomas, S. (2015). BIM The Ten Workflows of Construction. Retrieved from https://conappguru.com/apps/bim-the-ten-workflows-of-construction-9/

Turina, N., Radujkovic, M., & Car-Pusic, D. (2008). “Design and Build” in Comparison with the Traditional Procurement Method and the Possibility of its Application in the Croatian Construction Industry. In *8th International Conference* (pp. 1–8).

Vasileiou, K., Barnett, J., Thorpe, S., & Young, T. (2018). Characterising and Justifying Sample Size Sufficiency in Interview-Based Studies: Systematic Analysis of Qualitative Health Research over a 15-year Period. *BMC Medical Research Methodology*, *18*(148), 1–18.

Wachira, N., Root, D., Bowen, P., & Olima, W. (2007). The Declining Role of the General Contractor in the Kenyan Construction Sector. In *CIB World Building Congress* (pp. 1883–1893).

Waigwa, W. (2016). waigwa 2016 BIM around the world-Kenya awakening to BIM benefits. Retrieved from https://www.bimplus.co.uk/people/ken4ya-awak3ening-bim-bene8fits/

Walliman, N. (2011). *Research Methods - The Basics*. London and Newyork: Routledge: Taylor & Francis Group.

Wambui, M. P. (2018). *An Investigation into the Role of Building Information Modelling in Reducing Cost and Time Overruns Experienced In 2-Dimensional Based Construction- A Survey of Construction Practitioners in Nairobi County*. Published Masters Thesis, University of Nairobi.

Weihrich, H. (2013). *Management: A Global, Innovative, and Entrepreneurial Perspective* (14th ed.). New Delhi, India: McGraw-Hill Education.

Williams, B., Onsman, A., & Brown, T. (2010). Exploratory Factor Analysis: A five-step guide for novices. *Journal of Emergency Primary Health Care*, *8*(3).

Retrieved from http://ro.ecu.edu.au/jephc/vol8/iss3/1%0D

Xu, X., Ma, L., & Ding, L. (2014). A Framework for BIM-enabled Life-cycle Information Management of Construction Project. *International Journal of Advanced Robotic Systems, 11*(126), 1–13. https://doi.org/10.5772/58445

Yalcinkaya, M., & Arditi, D. (2013). Building Information Modeling (BIM) and the Construction Managemnet Body of Knowledge. *International Federation for Information Processing*, 619–629.

Yong, A. G., & Pearce, S. (2013). A Beginner ' s Guide to Factor Analysis: Focusing on Exploratory Factor Analysis. *Tutorials in Quantitative Methods for Psychology*, *9*(2), 79–94.

APPENDICES

Appendix I: Respondents preferred BIM software

BIM Activities	Summary of BIM Software Number shown in brackets	Software their recorded number Shown in brackets
3D modelling	Autodesk (55) Graphisoft (23) Others (17)	Autodesk: Suites (3), Revit (32), AutoCAD (6), Civil 3D (5), 3D Max (3), BIM 360(2) InfraWorks (2); structural bridge design (1). Graphisoft: ArchiCAD (23) Others: Sketchup (7); Atlantis (2); Tekla (2); Rhino (2); Lumion (1); Solibri (1); Dalux (1); Dynamo (1)
2D documentation	Autodesk (30) Graphisoft (15) Others (5)	Autodesk: Suites (1), AutoCAD (20), Revit (8), InfraWorks (1). Graphisoft: ArchiCAD (13), Vectorworks (1), BIMX (1). Others: LOD Planner (1); Cost X (1); Procore (1); MS Excel (1); MS Office (1)
Costing	Autodesk (11) Graphisoft (1) Others (27)	Autodesk: Revit (5), Navisworks (3), BIM 360 (2), AutoCAD (1). Bluebeam (Nemestchek associated with Graphisoft) Others:Win-QS (7); MS Excel (6); Cost X (2); eTake-off Bridge (2); Vico office (1); Quick books (1); Esticom (1); Dimension X (1); Primus/FC (1); Causeway(1); MCQS (1); Procost-ESI (1); Planswift (1); QSCAD-master bill (1); Vico office (1)
Project planning & scheduling	MS project (19) Autodesk (12) Graphisoft (1) Others (12)	MS project (19). Autodesk: BIM 360 (5), Navisworks (2) InfraWorks (1), Plan grid (1), Assemble (1), AutoCAD (1), Revit (1). DROFUS (Nemestchek associated with Graphisoft) Others: Primavera (6). Gant Pro (1); LOD planner (1); Buildertrend (1); Causeway (1); MS word (1); iTWO (1)
Sustainability	Autodesk (9) Graphisoft (6) Others (6)	Autodesk: Revit (5), Navisworks (1), BIM 360 (1), Ecotect (1), Green building studio (1) Graphisoft: EcoDesigner (1), ArchiCAD (5)

BIM Activities	Summary of BIM Software Number shown in brackets	Software their recorded number Shown in brackets
		Others: Insight (2), Avail (1); MS word (1); MIDAS (1); MS Project (1)
Structural Design	Autodesk (38) Graphisoft (0) Prokon (7) Tekla (6) Others (5)	Autodesk: suites (1), Revit (17), AutoCAD (9), Robo (8), Structural bridge design (1), Civil 3D (1), Autodesk advanced steel (1) Prokon (7) Tekla (6) Others: MIDAS (1); Orion (1); Bentley-Staad (1); CSI Etabs (1) & CSI SAFE (1)
Mechanical Design	Autodesk (28) Graphisoft (1) Others (3)	Autodesk: Suites (1), Revit (12), AutoCAD (10), Fabrication (2), Civil 3D (1), CADmep (1), Inventor (1) Graphisoft: ArchiCAD (1) Bentley AECOsim building designer (1); MagiCAD (1); Insight (1)
Electrical Design	Autodesk (18) Graphisoft (3) Others (2)	Autodesk: Revit (10), AutoCAD (7), Fabrication (1) Graphisoft: ArchiCAD MEP (3) Bentley AECOsim building designer (1); MagiCAD (1)
Plumbing	Autodesk (24) Graphisoft (3) Others (2)	Autodesk: suites (1), Revit (13), AutoCAD (8) (Autodesk), Civil 3D (1), Fabrication (1) Graphisoft: ArchiCAD MEP (3); MagiCAD (2)
Total	Autodesk = 225 – 57.8% Graphisoft = 53 – 13.6% MS Project = 19 – 4.9% Prokon = 7 – 1.8% Tekla = 6 – 1.5% Others = 79 – 20.3% Total = 389 – 100%	Total = 389

Appendix II: Communalities for underlying factors of BIM adoption

Variables	Initial	Extraction
Intelligent 3D visualization	1.000	.628
Realtime capabilities	1.000	.748
Transparency	1.000	.749
Improved accuracy	1.000	.596
Buildability	1.000	.615
Collaboration	1.000	.669
Time saving	1.000	.567
Cost saving	1.000	.638
Quality improvement	1.000	.493
Return on Investment	1.000	.625
Better coordination	1.000	.747
improved communication	1.000	.636
Clash detection	1.000	.644
Consistent lifecycle information	1.000	.556
Better decision management	1.000	.613
Risk Management	1.000	.610
Safety Management	1.000	.659
Improved customer client relationship	1.000	.604
improved facility management	1.000	.631
Energy analysis	1.000	.680
Sustainability	1.000	.730
Top management support	1.000	.590
Financial Cost of adoption	1.000	.601
Technological capabilities	1.000	.683
pressure to remain competitive	1.000	.630
Size of a project	1.000	.679

Extraction Method: Principal Component Analysis.

Appendix III: Total Variance Explained - underlying factors of BIM adoption

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	11.079	42.612	42.612	11.079	42.612	42.612
2	1.919	7.381	49.992	1.919	7.381	49.992
3	1.415	5.443	55.435	1.415	5.443	55.435
4	1.202	4.624	60.059	1.202	4.624	60.059
5	1.008	3.877	63.936	1.008	3.877	63.936
6	.984	3.785	67.721			
7	.879	3.381	71.102			
8	.832	3.200	74.303			
9	.727	2.795	77.097			
10	.673	2.588	79.685			
11	.642	2.469	82.154			
12	.515	1.982	84.137			
13	.487	1.873	86.010			
14	.442	1.701	87.711			
15	.433	1.667	89.378			
16	.411	1.580	90.958			
17	.360	1.384	92.341			
18	.302	1.163	93.504			
19	.282	1.087	94.591			
20	.256	.986	95.576			
21	.237	.912	96.488			
22	.220	.845	97.333			
23	.212	.817	98.150			
24	.181	.698	98.848			
25	.164	.631	99.478			
26	.136	.522	100.000			

Extraction Method: Principal Component Analysis.

Appendix IV: Parallel analysis & Kaiser criteria comparison - BIM adoption

Component or Factor	Mean Eigenvalue	Percentile Eigenvalue	Calculated Eigenvalue (Kaiser Criteria)	Decision
1	1.803069	1.926773	11.079	Retain
2	1.672844	1.754450	1.919	Retain
3	1.568458	1.635770	1.415	Not retain
4	1.483207	1.555569	1.202	Not retain
5	1.406531	1.460730	1.008	Not retain
6	1.344156	1.389507	0.984	Not retain
7	1.287546	1.341335	0.879	Not retain
8	1.227845	1.276361	0.832	Not retain
9	1.175161	1.217223	0.727	Not retain
10	1.123391	1.160916	0.673	Not retain
11	1.074378	1.114239	0.642	Not retain
12	1.024859	1.059272	0.515	Not retain
13	0.977494	1.024012	0.487	Not retain
14	0.934361	0.970229	0.442	Not retain
15	0.889431	0.923922	0.433	Not retain
16	0.846810	0.879991	0.411	Not retain
17	0.804656	0.837338	0.360	Not retain
18	0.762905	0.795727	0.302	Not retain
19	0.719263	0.757485	0.282	Not retain
20	0.682185	0.716143	0.256	Not retain
21	0.644318	0.677514	0.237	Not retain
22	0.599126	0.638768	0.220	Not retain
23	0.558555	0.601919	0.212	Not retain
24	0.513872	0.558771	0.181	Not retain
25	0.464261	0.512491	0.164	Not retain
26	0.411350	0.464067	0.136	Not retain

Appendix V: Coefficient Matrix for underlying factors in BIM adoption

	Factors				
Variables	1	2	3	4	5
Intelligent 3D visualization	-.078	-.052	.004	**.405**	-.017
Realtime capabilities	-.151	-.001	-.054	**.481**	.042
Transparency	-.150	-.099	-.049	.136	**.518**
Improved accuracy	-.024	-.090	-.019	.136	**.255**
Buildability	**.061**	-.153	-.043	.074	.271
Collaboration	**.249**	-.136	-.044	.057	-.076
Time saving	**.168**	.039	-.113	-.051	.005
Cost saving	**.221**	.042	-.119	-.144	.004
Quality improvement	**.216**	-.038	-.044	-.178	.045
Return on Investment	-.144	.150	-.065	-.067	**.343**
Better coordination	**.238**	-.073	.023	.028	-.171
Improved communication	**.245**	-.037	.030	-.025	-.211
Clash detection	**.165**	.006	-.036	.144	-.212
Consistent lifecycle information	.045	-.057	**.173**	-.063	.040
Better decision management	**.180**	-.028	.027	-.112	-.013
Risk Management	.108	**.123**	.007	-.151	-.052
Safety Management	-.047	**.152**	-.063	-.156	.259
Improved customer client relationship	-.062	.071	**.177**	-.160	.109
Improved facility management	-.100	**.170**	.032	-.005	.088
Energy analysis	-.063	**.328**	-.169	.139	-.131
Sustainability	-.006	**.325**	-.126	.035	-.166
Top management support	-.062	.104	**.182**	-.035	-.056
Financial Cost of adoption	-.077	**.181**	.118	.023	-.121
Technological capabilities	-.107	.021	**.273**	.107	-.090
Pressure to remain competitive	-.121	-.027	**.346**	.135	-.157
Size of a project	.054	-.314	**.403**	-.146	.129

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.

Appendix VI: Communalities for BIM influence on ECM

Variables	Initial	Extraction
Definition of BIM	1.000	.542
My Organization has engaged a BIM consultant to help in BIM adoption	1.000	.826
My Organization has standards and guidelines on BIM adoption	1.000	.825
The government as the biggest construction client needs to lead in BIM adoption	1.000	.792
Government need to make BIM implementation compulsory	1.000	.659
Stakeholders are willing to pioneer in BIM adoption	1.000	.762
There are written materials to guide BIM implementation	1.000	.741
There are case studies done on BIM projects in Kenya	1.000	.686
BIM hardware must be recommended by the type of software in use	1.000	.786
Intelligent 3D visualization	1.000	.758
Realtime capabilities	1.000	.738
Transparency	1.000	.717
Improved accuracy	1.000	.661
Buildability	1.000	.712
Collaboration	1.000	.682
Time saving	1.000	.775
Cost saving	1.000	.791
Quality improvement	1.000	.685
Return on Investment	1.000	.682
Better coordination	1.000	.740
Improved communication	1.000	.691
Clash detection	1.000	.783
Consistent lifecycle information	1.000	.757
Better decision management	1.000	.737
Risk Management	1.000	.716
Safety Management	1.000	.737
Improved customer client relationship	1.000	.720
Improved facility management	1.000	.681
Energy analysis	1.000	.721
Sustainability	1.000	.722
Top management	1.000	.755
Financial Cost of adoption	1.000	.811
Technological capabilities	1.000	.764
pressure to remain competitive	1.000	.660
Size of a project	1.000	.675
BIM enables the construction team to work together effectively & efficiently	1.000	.807
BIM facilitates effective coordination	1.000	.800
BIM improves communication in the construction team	1.000	.829
BIM improves decision management process	1.000	.709

BIM aids in clash detection of construction element as designed by different professionals	1.000	.791
BIM makes real time correction of information easy at any stage of a project	1.000	.666
BIM enables faster execution of a project hence saving time	1.000	.629
BIM reduces cost of a project	1.000	.791
BIM reduces cost of operation and maintenance of a facility	1.000	.738
BIM facilitates positive ROI	1.000	.703
BIM improves quality	1.000	.745
BIM improved good working relationship	1.000	.733
BIM aids in early problem detection	1.000	.732
BIM helps to reduce variations	1.000	.790
BIM helps to reduce claims	1.000	.753
BIM makes dispute resolution easier	1.000	.805
Intellectual Property Rights is an important legal risk	1.000	.779
Sharing of copyright data is an important legal risk	1.000	.749
Professional liability is an important legal risk that comes with BIM	1.000	.803
Condition of contracts	1.000	.767
Data interoperability	1.000	.704
Processes and responsibilities	1.000	.730
Data security	1.000	.721
Cost compensation is an important legal risk that comes with BIM	1.000	.729
Lack of BIM standards is an important legal risk that comes with BIM	1.000	.739
Standard of care and professional negligence	1.000	.751
Model management	1.000	.727
Admissibility of electronic-based document	1.000	.710
Legislation and judicial precedence	1.000	.719
legal validation of design (NCC submissions)	1.000	.796
BIM has influenced/impacted engineering contract management	1.000	.719
It is necessary to have contractual guidelines to guide in BIM adoption	1.000	.660
Existing forms of contract should be modified to suit BIM	1.000	.788
BIM requires a new set of standard forms of contract	1.000	.690
The digital BIM model should be recognized as a contract document	1.000	.759
Construction contracts are competitively awarded to both local and international firms depending on BIM capabilities	1.000	.704
Government should adopt their procurement processes to suit collaborative BIM	1.000	.762
NCC submissions may require BIM model in future	1.000	.710
There is need for regulatory body mandated by the government	1.000	.725
The traditional procurement method has failed to meet client's expectations	1.000	.674

Extraction Method: Principal Component Analysis.

Appendix VII: Total variance explained - influence of BIM on ECM

	Initial Eigenvalues			Extraction Sums of Squared Loadings		
Component	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	22.703	30.271	30.271	22.703	30.271	30.271
2	4.626	6.168	36.439	4.626	6.168	36.439
3	3.830	5.106	41.545	3.830	5.106	41.545
4	3.314	4.419	45.964	3.314	4.419	45.964
5	2.545	3.393	49.357	2.545	3.393	49.357
6	2.075	2.766	52.123	2.075	2.766	52.123
7	1.887	2.516	54.639	1.887	2.516	54.639
8	1.618	2.157	56.796	1.618	2.157	56.796
9	1.510	2.013	58.809	1.510	2.013	58.809
10	1.462	1.949	60.759	1.462	1.949	60.759
11	1.404	1.871	62.630	1.404	1.871	62.630
12	1.310	1.746	64.377	1.310	1.746	64.377
13	1.301	1.734	66.111	1.301	1.734	66.111
14	1.240	1.653	67.763	1.240	1.653	67.763
15	1.133	1.510	69.274	1.133	1.510	69.274
16	1.091	1.455	70.729	1.091	1.455	70.729
17	1.058	1.410	72.139	1.058	1.410	72.139
18	1.024	1.365	73.504	1.024	1.365	73.504
19	.988	1.317	74.821			
20	.925	1.233	76.054			
21	.898	1.198	77.252			
22	.825	1.100	78.352			
23	.798	1.064	79.416			
24	.770	1.026	80.442			
25	.718	.957	81.399			
26	.690	.921	82.320			
27	.686	.914	83.235			
28	.643	.858	84.092			
29	.616	.822	84.914			
30	.589	.785	85.699			
31	.544	.725	86.424			
32	.517	.689	87.113			
33	.500	.667	87.780			
34	.493	.657	88.437			
35	.471	.628	89.065			
36	.433	.577	89.641			
37	.414	.552	90.194			
38	.401	.534	90.728			
39	.384	.512	91.240			
40	.369	.492	91.732			

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
41	.349	.465	92.198			
42	.330	.441	92.638			
43	.324	.432	93.070			
44	.317	.422	93.493			
45	.303	.404	93.896			
46	.290	.387	94.283			
47	.276	.369	94.652			
48	.264	.353	95.005			
49	.252	.335	95.340			
50	.242	.322	95.662			
51	.234	.312	95.974			
52	.224	.299	96.273			
53	.211	.281	96.554			
54	.202	.269	96.823			
55	.191	.255	97.078			
56	.182	.243	97.321			
57	.172	.229	97.550			
58	.162	.216	97.766			
59	.151	.201	97.967			
60	.146	.195	98.162			
61	.134	.178	98.340			
62	.133	.177	98.517			
63	.129	.172	98.689			
64	.125	.167	98.856			
65	.110	.147	99.003			
66	.102	.137	99.139			
67	.100	.133	99.272			
68	.095	.127	99.399			
69	.086	.114	99.513			
70	.081	.108	99.622			
71	.064	.085	99.707			
72	.062	.082	99.789			
73	.059	.079	99.868			
74	.050	.067	99.935			
75	.049	.065	100.000			

Extraction Method: Principal Component Analysis.

Appendix VIII: Parallel analysis/Kaiser criteria comparison BIM influence on ECM

Component or Factor	Mean Eigenvalue	Percentile Eigenvalue	Calculated Eigenvalue (Kaiser Criteria)	Decision
1	2.606120	2.745171	22.703	Retain
2	2.475397	2.586343	4.626	Retain
3	2.369192	2.464679	3.830	Retain
4	2.286348	2.363934	3.314	Retain
5	2.205150	2.270604	2.545	Retain
6	2.123873	2.197675	2.075	Retain
7	2.060206	2.124504	1.887	Retain
8	1.999861	2.061318	1.618	Not retain
9	1.934929	1.990621	1.510	Not retain
10	1.880150	1.925804	1.462	Not retain
11	1.825076	1.873714	1.404	Not retain
12	1.772448	1.825292	1.310	Not retain
13	1.723994	1.778357	1.301	Not retain
14	1.675764	1.718778	1.240	Not retain
15	1.629522	1.678879	1.133	Not retain
16	1.590385	1.644145	1.091	Not retain
17	1.544652	1.592289	1.058	Not retain
18	1.501957	1.538334	1.024	Not retain
19	1.463409	1.501321	.988	Not retain
20	1.422854	1.454627	.925	Not retain
21	1.386869	1.419438	.898	Not retain
22	1.348363	1.379641	.825	Not retain
23	1.313059	1.348478	.798	Not retain
24	1.276119	1.312400	.770	Not retain
25	1.243169	1.271998	.718	Not retain

Component or Factor	Mean Eigenvalue	Percentile Eigenvalue	Calculated Eigenvalue (Kaiser Criteria)	Decision
26	1.206460	1.241935	.690	Not retain
27	1.177747	1.210905	.686	Not retain
28	1.145196	1.178967	.643	Not retain
29	1.115340	1.145872	.616	Not retain
30	1.083892	1.112383	.589	Not retain
31	1.055317	1.087170	.544	Not retain
32	1.028207	1.056017	.517	Not retain
33	0.998324	1.027725	.500	Not retain
34	0.970207	1.001079	.493	Not retain
35	0.944057	0.973951	.471	Not retain
36	0.916337	0.947756	.433	Not retain
37	0.889704	0.917419	.414	Not retain
38	0.861852	0.888481	.401	Not retain
39	0.835955	0.863853	.384	Not retain
40	0.809658	0.834926	.369	Not retain
41	0.785176	0.808124	.349	Not retain
42	0.760082	0.783453	.330	Not retain
43	0.737745	0.765391	.324	Not retain
44	0.715183	0.739037	.317	Not retain
45	0.692134	0.715987	.303	Not retain
46	0.668950	0.691399	.290	Not retain
47	0.647051	0.667259	.276	Not retain
48	0.625203	0.651903	.264	Not retain
49	0.603887	0.624887	.252	Not retain
50	0.581439	0.601088	.242	Not retain
51	0.562146	0.584449	.234	Not retain
52	0.542628	0.564689	.224	Not retain

Component or Factor	Mean Eigenvalue	Percentile Eigenvalue	Calculated Eigenvalue (Kaiser Criteria)	Decision
53	0.523422	0.545441	.211	Not retain
54	0.502790	0.525580	.202	Not retain
55	0.482419	0.502912	.191	Not retain
56	0.462661	0.479993	.182	Not retain
57	0.445310	0.466881	.172	
58	0.424791	0.447231	.162	Not retain
59	0.407230	0.433420	.151	Not retain
60	0.389925	0.411405	.146	Not retain
61	0.373533	0.397676	.134	Not retain
62	0.356133	0.379222	.133	Not retain
63	0.339382	0.363480	.129	Not retain
64	0.320388	0.343825	.125	Not retain
65	0.301962	0.324868	.110	Not retain
66	0.286344	0.310989	.102	Not retain
67	0.269513	0.289430	.100	Not retain
68	0.252450	0.273728	.095	Not retain
69	0.235606	0.255080	.086	Not retain
70	0.217612	0.236845	.081	Not retain
71	0.198932	0.220725	.064	Not retain
72	0.180437	0.202411	.062	Not retain
73	0.161000	0.185428	.059	Not retain
74	0.137807	0.163401	.050	Not retain
75	0.111616	0.145353	.049	Not retain

Appendix IX: Component Score Coefficient Matrix - BIM influence on ECM

Variable	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6
BL1	-.038	-.038	.003	-.023	.057	**.203**
BL2	-.032	-.018	-.004	-.034	.002	**.271**
BL3 deleted	-.005	.024	.054	-.092	.074	-.039
BL4	-.042	.001	.002	-.039	**.161**	.022
BL5	-.046	-.015	.017	.018	**.111**	-.049
BL6	-.001	-.007	-.046	.069	**.082**	-.069
BL7	-.005	-.039	-.006	.040	**.138**	-.112
Tech	-.013	-.019	.013	.005	-.021	**.156**
BC1	-.007	-.023	**.116**	-.064	.015	.007
BC2	-.008	-.020	**.101**	-.031	-.014	.017
BC3	-.029	-.037	**.079**	.057	-.017	-.005
BC4	-.038	-.046	**.108**	.036	-.006	.002
BC5	.022	-.037	**.112**	-.037	.003	-.044
BC6	.016	-.062	**.144**	-.062	-.014	.032
BC7	-.041	-.039	**.107**	.044	.026	-.068
BC8	-.017	-.032	**.082**	.055	.015	-.084
BC9	-.008	-.018	**.077**	.022	-.002	-.051
BC10	-.033	-.017	-.020	**.155**	.025	-.046
BC11	-.018	-.033	**.128**	-.027	-.027	.062
BC12	-.018	-.026	**.097**	.001	-.017	.036
BC13	-.029	-.039	**.120**	-.001	-.030	.055
BC14	.018	.024	.007	.054	-.070	.033
BC15	.005	-.015	**.070**	.034	-.020	-.038
BC16	-.003	-.014	-.002	**.132**	-.013	-.049
BC17	-.002	-.008	-.024	**.160**	-.010	-.087
BC18	-.038	.000	-.028	**.145**	-.015	.029
BC19	-.015	-.026	-.009	**.143**	-.007	.000
BC20	-.051	-.047	.006	**.107**	.094	.020

Variable	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6
BC21	-.025	-.049	-.003	**.129**	.055	.005
BC22	.000	-.004	-.031	**.109**	-.023	.057
BC23	.008	-.030	-.026	**.124**	-.017	.043
BC24	-.011	.011	-.018	**.090**	-.067	.116
BC25	.009	.037	-.055	.054	-.113	**.216**
BC26	.015	.022	-.007	.012	-.077	**.123**
BECM1	-.025	**.086**	.092	-.127	.057	-.097
BECM2	-.008	**.086**	.053	-.084	-.003	-.009
BECM3	-.020	**.105**	.053	-.088	.019	-.062
BECM4	.000	**.111**	.038	-.072	-.021	-.070
BECM5	-.030	**.069**	.086	-.091	.017	-.034
BECM6	-.021	**.091**	.051	-.060	.009	-.063
BECM7	-.049	**.079**	-.019	.052	.058	-.098
BECM8	-.015	**.112**	-.080	.038	.025	-.045
BECM9	-.015	**.082**	-.056	.053	.003	.008
BECM10	-.017	**.104**	-.074	.053	.026	-.041
BECM11	-.013	**.120**	-.029	-.029	-.028	.025
BECM12	-.035	**.126**	-.051	.007	.003	-.002
BECM13	.000	**.090**	.047	-.085	-.052	.055
BECM14	.003	**.118**	-.066	.032	-.066	.028
BECM15	.002	**.100**	-.066	.050	-.062	.050
BECM16	-.015	**.123**	-.063	.014	-.040	.059
BLegalR1	**.118**	-.010	.007	-.079	-.063	.079
BLegalR2	**.116**	-.042	.019	-.052	-.053	.077
BLegalR3	**.121**	-.018	-.018	-.032	-.054	.065
BLegalR4	**.061**	-.006	-.032	.013	.046	-.021
BLegalR5	**.109**	-.006	-.014	-.026	-.038	.019
BLegalR6	**.113**	-.020	-.009	-.013	-.027	-.002
BLegalR7	**.122**	-.033	-.026	.026	-.045	-.013
BLegalR8	**.095**	-.033	-.039	.051	.020	-.074

Variable	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6
BLegalR9	**.113**	.022	-.031	-.026	-.056	-.036
BLegalR10	**.100**	-.018	-.009	-.020	.017	-.061
BLegalR11	**.094**	-.029	.040	-.041	-.041	.013
BLegalR12	**.093**	-.009	-.019	.011	-.006	-.046
BLegalR13	**.108**	-.004	-.037	.014	-.013	-.064
BLegalR14	**.075**	.005	-.042	.014	.048	-.079
BIMECM1	.001	.022	-.018	-.018	.022	**.136**
BIMECM2	**.041**	.008	.014	-.052	.065	-.015
BIMECM3	.046	-.009	-.015	-.052	**.116**	-.003
BIMECM4	.041	-.029	-.032	-.039	**.138**	.017
BIMECM5	.012	-.013	-.033	-.028	**.081**	.151
BIMECM6	.011	-.010	-.044	-.019	**.097**	.119
BIMECM7	-.007	-.010	.006	-.039	**.165**	-.012
BIMECM8	-.025	-.027	-.005	-.009	**.161**	.013
BIMECM9	.003	.024	-.024	-.043	**.116**	.000
BIMTPS	-.072	-.020	-.001	.045	**.141**	-.037
BA	-.029	.012	**.105**	-.065	.007	-.024

Extraction Method: Principal Component Analysis.

Rotation Method: Varimax with Kaiser Normalization.

Appendix X: Introductory letter

JKU/2/84

JOMO KENYATTA UNIVERSITY
OF
AGRICULTURE AND TECHNOLOGY
Sustainable Materials Research & Technology Centre
SMARTEC

P.O BOX 62000-00200, NAIROBI-KENYA. • Tel: (067)52181/2/3/4 • Fax: (067)52164 •E-mail: smartec@jkuat.ac.ke

DATE: 2nd May, 2019 **REF:** ENC331-2581/2017

TO WHOEVER IT MAY CONCERN

RE: DATA COLLECTION FOR MASTERS DEGREE THESIS

The above subject refers.

Hellen Nyaboke Mosse of Registration Number ENC331-2581/2017 is a student at Jomo Kenyatta University of Agriculture and Technology (JKUAT) currently undertaking her studies in Master of Science in Construction Engineering and Management.

She has successfully completed her course work (first year of study) and passed. She is currently undertaking her research work on **Influence of Building Information Modelling (BIM) on Contractual Relationships and Responsibilities: The Case Study of Nairobi County** and is collecting data to enable her achieve her objectives on this research topic, we therefore request that you give her the help she may need.

Any assistance accorded to her will be highly appreciated.

Yours Faithfully,

Dr. Eng. Charles Kabubo, Ph. D.
Director SMARTEC

SMARTEC SETTING TRENDS IN SUSTAINABLE CONSTRUCTION

Setting Trends in Higher Education, Research and Innovation

Appendix XI: Questionnaire

JOMO KENYATTA UNIVERSITY OF AGRICULTURE & TECHNOLOGY (JKUAT)

Sustainable Materials Research & Technology Centre (SMARTEC)

Strictly Confidential

My name is Hellen Mosse and I am a postgraduate student at JKUAT studying Msc. In Construction Engineering and Management. The survey forms part of my thesis whose research topic is INFLUENCE OF BUILDING INFORMATION MODELLING (BIM) ON ENGINEERING CONTRACT MANAGEMENT: The Case of Nairobi County.

Declaration: **You have been selected to take part in this study, your participation is of importance and is greatly appreciated. The study is governed by the ethics of Social Science Research. The information given is for academic purposes only, it will be treated in anonymity and it will be analysed together with that of other participants.**

SECTION A: BACKGROUND INFORMATION

1. What is your Profession

☐Civil Engineer ☐Construction Project Manager

☐Architect ☐Quantity Surveyor

☐Mechanical Engineer ☐Electrical Engineer

☐Contractor ☐Facility Manager

☐Other (Please specify)

2. Education: What is the highest degree or level of school you have completed?

☐certificate ☐Diploma

☐Bachelor’s degree ☐Master’s degree

☐Doctorate ☐Other (Please specify)

3. Who is your Employer?

☐Government ☐Private

☐Other (Please specify)

4. What is your Gender?

☐Female ☐Male

5. Number of years of experience:

☐0-5 ☐6-10

☐11-15 ☐Over 15

6. For how long have you used BIM? (years)

☐0-5 ☐6-10

☐11-15 ☐Other (Please specify)

7. How many technical staff (with construction qualifications) do you have within your organization?

☐0-5 ☐5-10

☐10-20 ☐20-30

☐Other (Please specify)

8. Which BIM role best describes you in your organization?

☐BIM Manager ☐BIM modeler/operator/user

☐BIM Coordinator ☐Other (Please specify)

9. What type of project do you handle?

☐Publicly financed ☐Privately financed

☐Both Publicly and Privately Financed ☐Other (Please elaborate)

SECTION B: BIM ADOPTION

1. Please select your most preferred choice for the following BIM definition:

BIM is a digital innovation and consists of a set of technologies, processes and policies based on an intelligent 3D model enabling Architecture, Engineering construction and operation stakeholders to effectively collaborate throughout the lifecycle of the facility

☐Strongly agree ☐Agree

☐Uncertain ☐Disagree

☐Strongly disagree

2. Have you adopted BIM in your organization?

☐Yes ☐No

☐Planning to adopt ☐Don’t plan to adopt

☐Other (please elaborate)

3. Have you ever used BIM in any construction projects?

☐Yes ☐No

☐Unsure ☐Other (please elaborate)

4. Do you have a BIM manager in your organization?

☐Yes ☐No

5. Which stage of BIM can you rate your organization to be in?

☐Stage 0 – Pre-BIM (Not on BIM platform)

☐Stage 1 – Object based modelling (Working with 3D modelling within the office)

☐Stage 2 – Model based collaboration (use same BIM model to Work with other professionals)

☐Stage 3 –Network based collaboration (use same BIM model to collaborate with other professionals)

6. In which stage of a project's lifecycle do you or your organization introduces BIM to projects

☐Preconstruction ☐Design stage

☐Construction ☐Operation

☐Maintenance ☐Preconstruction to demolition

7. Which dimensions (D) of BIM do you utilized (please tick as many as applies)?

☐3D Modelling ☐4D (Time)

☐5D (Cost) ☐6D (Operation)

☐7D (Maintenance) ☐8D (Safety)

8. How can you rate BIM adoption in your organization?

☐Improved client relations ☐Improved resource allocations

☐no tangible benefit ☐overall use of BIM was negative experience

☐Other (please state)

9. If you currently **do not** use BIM, please select the reasons for not doing so? (select as many as applicable)

☐Too expensive ☐Too complicated

☐Training is lacking ☐No client requirement to use it

☐Satisfied with existing system ☐I don't really understand BIM

☐Lack of standards and guidelines ☐Lack of government policy

☐Other (please specify)

10. In your opinion what are the challenges that affects BIM adoption in Kenya

BIM Leadership

Please select your most preferred choice for the following statements

	1	2	3	4	5
	Strongly agree	Agree	Uncertain	Disagree	Strongly disagree
1. My organization has engaged a BIM consultant to help in BIM adoption					
2. My organization has standards and guidelines on BIM adoption					
3. The government as the biggest construction client need to lead in BIM adoption					
4. The government need to make BIM implementation compulsory					
5. Stakeholders are willing to pioneer in BIM adoption, (no 'wait and see' attitude)					
6. There are written materials to guide BIM implementation in Kenya					
7. There are case studies done on BIM projects in Kenya					

BIM Technology

1. In your opinion is BIM a software?

☐Yes ☐No

☐I don't know ☐Other (please specify)

2. Please indicate BIM software preference with regard to activity (Please indicate as many as apply to your type of activity)

BIM ACTIVITIES	**PREFERRED BIM SOFTWARE**
3D modelling	
2D documentation	
Costing	
Project planning& scheduling	
Sustainability	
Structural Design	
Mechanical Design	
Electrical Design	
Plumbing	

3. Please select your most preferred choice for the following statement on BIM Hardware:

Hardware must be as recommended by the type of software in use

☐Strongly agree ☐Agree

☐Uncertain ☐Disagree

☐Strongly disagree

BIM Education and Training

1. Did you get **Educated** on BIM from University/College

   ☐Yes ☐No

2. Who gave you your Primary initial BIM **Training**?

   ☐Software companies ☐Software sellers

   ☐BIM champion ☐My employer

   ☐I trained myself ☐Other (please specify)

SECTION C: Important Components of BIM

Please rate the importance of components in BIM adoption

	1	2	3	4	5
	Very important	Important	Uncertain	Less important	Not important
Benefit based					
1. Intelligent 3D model for visualization					
2. Real time capabilities					
3. Transparency (Information is accessible)					
4. Improved Accuracy					
5. Buildability (ease and efficiency with which structures can be built)					
6. Collaboration (two or more people working together to achieve something)					
7. Time saving					
8. Cost saving					
9. Quality improvement					
10. Return on investment (the profit from an activity for a particular period compared with the amount invested in it)					
11. Better coordination					
12. Improves Communication					
13. Clash detection (Identifying if two parts of a structure are interfering with one another)					
14. Consistent information (Lifecycle information management)					

	1	2	3	4	5
15. Better Decision management					
16. Risk management (Plan, monitor and control those measures needed to prevent exposure to risk)					
17. Safety management					
18. Improved customer-client relationships					
19. Improved facility management					
20. Improved facility management					
21. Energy analysis (assessing the way energy is used and the transfer and/ or conversion of energy)					
22. Sustainability analysis (the environment pressure and impacts, society users' comfort & social benefits and economics related to lifecycle costs)					
External factors					
23. Top management support					
24. Financial cost of adoption					
25. Technological capabilities					
26. Pressure to remain competitive					
27. Size of a project					

SECTION D: Engineering Contract Management

1. Which standard form of contract do you use in your construction projects?

☐FIDIC (International Federation of Consulting Engineers)

☐JBC (The joint Building Council) ☐Other (Please specify)

2. Please select your most preferred choice for the following statements:

The traditional procurement method has failed to meet client's expectations

☐Strongly agree ☐Agree

☐Uncertain ☐Disagree

☐Strongly disagree

3. Which method of procurement do you use or prefer?

☐Design-Bid-Build ☐Design-Build

☐Management contracting ☐Joint venture

☐Public-private partnerships

4. In your opinion how has the traditional procurement methods failed the client

SECTION E: BIM and Engineering Contract Management

Please select your most preferred choice for the following statements

	1	2	3	4	5
Collaboration, Time Saving, Cost saving, improved quality and ROI	Strongly agree	Agree	Uncertain	Disagree	Strongly disagree
1. BIM enables the construction team to work together effectively and efficiently					
2. BIM facilitates effective coordination					
3. BIM improves communication in the construction team					
4. BIM improves decision management process					
5. BIM aids in clash detection of construction elements as designed by different professionals					
6. BIM makes real-time correction of information easy at any stage of a project					
7. BIM enable faster execution of a project hence saving time					
8. BIM reduces cost of a project					
9. BIM reduces cost of operation and maintenance of a facility					
10. BIM facilitates positive return on investment (ROI)					
11. BIM improves quality					
12. BIM improved good working relationship					
13. BIM aids in early problem detection					
14. BIM helps to reduce variations					
15. BIM helps to reduced claims					
16. BIM makes dispute resolution easier					

Please rate the legal risks that come with BIM

	1	2	3	4	5
	Very important	Important	Uncertain	Less important	Not important
1. Intellectual property rights					
2. Sharing of copyright data					
3. Professional liability					
4. Condition of contracts (e.g. Fidic)					
5. Data interoperability					
6. Processes and responsibilities					
7. Data security					
8. Cost compensation					
9. lack of BIM standards					
10. Standard of care and professional negligence					
11. Model management					
12. Admissibility of electronic-based documents					
13. Legislation and judicial precedence					
14. Legal validation of design (NCC submissions)					

Please select your most preferred choice for the following statements

	1	2	3	4	5
	Strongly agree	Agree	Uncertain	Disagree	Strongly disagree
1. BIM has influenced/impacted engineering contract management					
2. It is necessary to have contractual guidelines to guide BIM adoption					
3. Existing forms of contract (FIDIC, JBC) should be modified to suit BIM					
4. BIM requires new set of standards forms of contracts (e.g. FIDIC, JBC)					
5. The digital BIM model should be recognized as a contract document					
6. Construction contracts are competitively awarded to both local and internationals firms depending on BIM capabilities					
7. Governments should adopt their procurement processes to suit collaborative BIM					

	1	2	3	4	5
8. Nairobi City County (NCC) submissions may require BIM model in future					
9. There is need for a regulatory body mandated by the government					

10. BIM brings in new roles (Select as many as applies)

☐BIM manager ☐BIM coordinator

☐BIM modeler ☐BIM consultant

☐Other (please specify)

THANK YOU

Appendix XII: Interview guide (Knowledgeable persons)

JOMO KENYATTA UNIVERSITY OF AGRICULTURE & TECHNOLOGY (JKUAT)

Sustainable Materials Research & Technology Centre (SMARTEC)

Strictly Confidential

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Declaration: **You have been selected to take part in this study, your participation is of importance and is greatly appreciated. The study is governed by the ethics of Social Science Research. The information given is for academic purposes only, it will be treated in anonymity and it will be analysed together with that of other participants.**

Date:

1. What is your opinion on BIM and its adoption?
2. What would you say is the biggest hindrance to BIM adoption?
3. How has BIM influenced contract management?
   (quality, Time, Cost, Business benefit, return on investment, decision making, Early problem detection, variations, claims, Risk management, Dispute resolution, relationships, responsibilities)
4. Has BIM made it easier or harder to manage contracts?
5. How does BIM affect the current standard forms of contract (e.g. JBC, FIDIC) and the public procurement and asset disposal Act?
6. Do you think the Government needs to develop a BIM policy?
7. Should there be a BIM policy regulatory body?
8. How is data management in BIM?
9. BIM requires the contractor to join the team early, what is your take on this?
10. The facility management role is given great importance by BIM, how do you see this important role in the Kenyan context and in relation to BIM?
11. Have you come across any Noteworthy BIM Publications (literature on guide, protocol and mandate selected and organized by a country) in Kenya? How important are they towards BIM implementation?

Thank you.

Appendix XIII: Research permit

REPUBLIC OF KENYA

NATIONAL COMMISSION FOR SCIENCE, TECHNOLOGY & INNOVATION

Ref No: **747517**

Date of Issue: **15/October/2019**

RESEARCH LICENSE

This is to Certify that Ms.. Hellen Mosse of Jomo Kenyatta University of Agriculture and Technology, has been licensed to conduct research in Nairobi on the topic: Influence of Building Information Modelling (BIM) on Contractual Relationships and Responsibilities: The Case Study of Nairobi County for the period ending : 15/October/2020.

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Appendix XIV: Research Output

Journal Publication: Influence of Building Information Modelling (BIM) on Engineering Contract Management in Nairobi, Kenya. Publisher: Scientific Research Publishing (SCIRP). Journal: World Journal of Engineering and Technology (WJET). Volume 8, No.3 August 2020.Website:https://www.scirp.org/journal/paper information .aspx?paperid=101723.

Journal Publication: Underlying factors guiding Building Information Modelling (BIM) adoption in Nairobi, Kenya. Publisher: Jomo Kenyatta University of Agriculture and Technology (JKUAT). Journal: Journal of Sustainable Research in Engineering (JSRE). Volume 6, No.2 12th December 2020. Website: https://jsre.jkuat.ac.ke/index.php/jsre/article/view/103/106.

Conference Presentation: Factors Affecting Building Information Modelling (BIM) Adoption in Nairobi Kenya. 6th October 2020- JKUAT online platform. Sustainable Research and Innovation (SRI) conference.

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ISSN Online: 2331-4249
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Influence of Building Information Modelling (BIM) on Engineering Contract Management in Nairobi, Kenya

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Abstract

Building Information Modelling (BIM) is a technology and a process that has brought changes in the construction's traditional procurement system. Kenya lacks contractual guidelines on implementation of BIM; this makes the adoption of BIM slow and difficult. Previous research has identified a gap in contractual relationships, roles and resulting risks. The objectives of this study were to investigate BIM adoption in Nairobi and to investigate the influence of BIM on Engineering Contract Management (ECM) in Nairobi Kenya. The survey research was a descriptive study with 175 responsive questionnaires. Respondents comprised of Civil Engineers, Construction Project Managers, Architects, Quantity Surveyors, Contractors and Facility Managers. Data was collected through self-administered questionnaire and in-depth interview. Descriptive analytics, correlation and Exploratory factor analysis methods were used to analyse quantitative data. Qualitative data was analysed thematically. It emerged that adoption level was at 56.6% and shallow understanding of BIM capabilities remains to be a barrier to its adoption and implementation. It also emerged that BIM improves ECM; when time, cost, quality, collaboration and return on investment improve, ECM becomes easier. Latent factors found in BIM and ECM relationship were Legal Implications, awareness and knowledge, efficiency, versatility, mandate and leadership, and competitiveness. Further, the study found out that BIM influence on ECM demands for establishment of standards, guidelines, policy, legal framework, and regulations, which can be achieved by amending the public procurement act which dictates the operation of all the other standard forms of contract. Further research should be conducted to measure whether the understanding of BIM had positively improved.

Keywords

Building Information Modelling, BIM, Adoption, Implementation, Collaboration, BIM Contractual Roles and Responsibilities, Contract Management

1. Introduction

One of the challenges in the construction industry is lack of effective collaboration which has contributed to poor quality delivery, time, and cost overruns in the lifecycle of a project. The BIM system gives the solution to these challenges caused by the Traditional procurement system. However, Kenya lacks a legal framework for BIM implementation, more so due to its collaborative nature that is changing relationships, roles, and responsibilities. The Kenyan industry lacks a formula, on how to handle these changes, how to use BIM, how to handle legal issues and how to handle contract management issues. The objectives of the study were to investigate BIM adoption, and to investigate the influence of BIM on engineering contract management (ECM) in Nairobi, Kenya.

The purpose of this survey study was to investigate how contract management has been affected by BIM which is relatively a new technology and whose adoption is ongoing, and whether it requires new systems and structures to be formed for maximum effectiveness and efficiency. The study facilitated understanding of the current standing of legal and contractual maturity of BIM. It was hoped the findings will stimulate the technological and legal fraternities to sufficiently deliberate the contractual uncertainties to facilitate a smoother uptake of BIM in the industry.

Research on BIM adoption, BIM's legal implications and contractual context for BIM has extensively been carried out in developed countries, the findings can be applied to most country scenarios. However, Bui *et al.*, (2016) recommend comprehensive country specific research to be carried out in developing countries to address challenges being faced from the point of view of those countries.

2. Literature Review

2.1. What BIM Is

BIM is defined as a digital representation of the physical and functional characteristics of a facility, BIM is a shared knowledge resource for information about a facility, forming a reliable basis for decisions during its (facility) life-cycle; defined as existing from earliest conception to demolition [1]. Having several collaborators in the lifecycle of a project, makes management of information paramount [2]. BIM is not a software as has been the common misconception, rather, a Software supporting BIM should provide openness, interoperability, functionality, accuracy of data, expandability, time management, clash detection, cost estimation and facility management [3].

Building Information Modelling (BIM) is considered as a major paradigm shift after computer-aided design (CAD) by majority professionals and academic researchers [4]. Being a new technology, BIM system is a potential legal risk [5], that require contractual guidelines because new technologies affect the existing systems and structures, hence demanding for new laws and policy [6] to consolidate interrelationships and holistically, contract management [2].

According to [7] there are three BIM stages: stage 1 (object-based modelling), stage 2 (model-based collaboration), and stage 3 (network-based integration). Additionally, BIM is a collaboration tool with subsets referred to as dimensions (D): 3D (object modelling), 4D (time), 5D (cost), 6D (operations), 7D (sustainability) and even safety for 8D [8].

2.2. Factors Guiding Adoption of BIM

BIM is a tool used for lifecycle management of information [9], with the advantage of digital storing [10]. It promotes process cooperation, collaborative efforts with lifecycle seamless flow of information [11] [12]. It provides 3D visualization [13], with real-time characteristics that allow revision of drawings at any stage of construction [14]. Ability to cooperate with the entire team, including the contractor and facility manager who traditionally were late entrants [15]. Return on investment (ROI) has guided companies to implement BIM after studying projects done with BIM [16].

Benefits of BIM towards an effective ECM include, reduced delivery time, reduced project cost [16] [17] [18], resource saving, better coordination, detection of clashes, better time management [16] [18], improved profitability and customer-client relationship [2]. BIM makes decision management easier [19] and better project management [4]. It further enables effective risk management [15], conflict management [20], sustainability management and energy analysis which are all addressed collaboratively with interactive feedback on design decisions and consequences [9] [10].

Some professionals are more inclined to BIM more than others, for instance, Architects are taking the lead in BIM, but, Civil Engineers to have a lot to benefit from it, by using it on civil and infrastructure projects [14]. In Kenya, the private industry is leading in adoption, but it is also limited by the Public procurement Act which mainly favours the traditional procurement system.

2.3. Conflict of the BIM System with the Traditional Procurement System

Before Deficiencies of the traditional procurement methods include, time overrun, material wastage, cost overrun and quality compromise [21]. There is a conflict between BIM system and traditional system [13]; lifecycle collaborative BIM remains hindered by the adversarial nature of the traditional procurement system [5].

Legal issues brought by BIM include: Sharing of copyright data; model management and ownership; BIM standards; processes and responsibilities; standard of care and professional negligence; Intellectual Property Rights; professional liability; claims and disputes; BIM cost compensation; additional project insurance; collaborative working and new roles; software, data security and interoperability; admissibility of electronic-based documents; legal validation of design; legislation and judicial precedence [22] [23] [24].

Developing countries such as Kenya are generally struggling with lack of BIM awareness, lack of standard, little or no government support, unclear legal status of BIM, lack of skills, limited financial, unclear benefits of BIM [25], software, hardware and internet issues [26]. In Kenya, the private sector is leading adoption, though at a slow pace [27] [28].

The Kenyan Procurement Act may be a major legal impediment. The Public Procurement and Asset Disposal Act 2016 outlines that in case of conflict and inconsistencies with other standard documents, the Act is set to prevail, the only exception being where procurement of professional services is governed by an Act of Parliament.

3. Methodology

This was a descriptive study, through questionnaire survey and in-depth interview. Self-administered questionnaires with both structured and unstructured questions were used to collect data. In-depth interviews with knowledgeable persons were carried out using a pre-drafted interview guide. The research was done in Nairobi Kenya and the respondents were drawn from consultants in the construction industry, they included Civil Engineers, Construction Project Managers, Architects, Quantity Surveyors, Mechanical Engineers, Electrical Engineers, Contractors, and Facility Managers.

Respondents' selection was through stratified random sampling, but with a prerequisite of, awareness of BIM regardless of whether they had used it or adopted it. This measure was to help avoid training respondents who had never heard of BIM. Out of the 252 questionnaires distributed, 175 were completed and returned which accounted for 69% return rate. Considering that follow-up reminders were made resulting in improved return rate, there however, were respondents who still did not return their questionnaires, some cited that though they had heard of BIM, their competency could not afford them confidence to complete the questionnaire.

Knowledgeable persons on BIM subject were required for the in-depth interview, and therefore, Snowball sampling was used; 8 interviews were successfully conducted. The interview stopped at 8 respondents because saturation point had been reached [29]. Both the quantitative and qualitative data was cleaned, coded and analysed quantitatively and thematically respectively.

4. Results

The primary target of respondents comprised of eight groups but during data collection a third group emerged of 2 combined areas of practice namely, 0.6%

Architect & Contractor, 0.6% Electrical Engineer & Facility Manager, 1.1% Construction Project Manager & Contractor, 1.1% Civil Engineer & Construction Project Manager, 0.6% Quantity Surveyor & Facility Manager, 0.6% Quantity Surveyor & Contractor, 1.1% Quantity Surveyor & Construction Project Manager making a total of 6.3%. See Table 1 for the profile of the respondents.

Respondents years of experience were: 36% had 0 - 5 years, 33.1% had 6 - 10 years, 16.6% had 11 - 15 years, and 14.3% had over 15 years of experience. Number of years that the respondents had used BIM were: 67.4% for 0 - 5 years, 17.1% for 6 - 10 years, and 5.7% for 11 - 15 years and 9.7% had never used BIM. Respondents indicated their BIM roles as: 52% were BIM user/modeler, 12% were BIM managers, 11.4% were BIM coordinators while 24.6% had no BIM roles.

The definition of BIM was provided, 96% agreed that it represented the definition of BIM. However, a contradiction arose on being asked if BIM is a software, 65.1% thought that BIM was a software, and only 32.6% thought BIM was not a software, whereas 2.3% did not know what to think. On adoption, 56.6% had adopted BIM, and 18.9% had not and 23.4% were planning to adopt, 1.1% were on ongoing adoption. 68% had a BIM manager, while 32% did not have a BIM manager. On the respondents who had used BIM on construction projects the study established that 68.6% had, 30.0% had not and 1.1% were unsure.

Respondents were also asked the stages of BIM they were in. 29.1% were in stage 0, 28.6% were in stage 1, 29.7% were in stage 2, and 12.6% were in stage 3. On BIM dimension the majority 71.4% mainly use BIM for 3D (modelling), 22.3% for 5D (cost), 16.6% 4D (time), 10.3% 6D (operation), 9.7% 7D (maintenance), and 8% used 8D (safety). Majority of respondents introduced BIM at 41.1% at design stage, 28.6% at preconstruction, 2.9% construction, 1.1% maintenance, 4.6% introduce BIM in all stages while 21.7% do not use BIM in any stage.

Table 1. Respondents profile, adoption rate per profession and overall adoption rate.

	Frequency	%	Cumulative %	Adoption per profession %	Overall adoption %
Civil Engineer	32	18.3	18.3	46.9	8.6
Construction Project Manager	37	21.1	39.4	59.5	12
Architect	37	21.1	60.6	70.3	14.9
Quantity Surveyor	31	17.7	78.3	38.7	6.9
Mechanical Engineer	6	3.4	81.7	66.7	2.3
Electrical Engineer	14	8.0	89.7	64.3	5.1
Contractor	3	1.7	91.4	100	1.7
Facility Manager	4	2.3	93.7	75	1.7
Other (2 combinations)	11	6.3	100	45.5	2.9
Total	175	100.0			56.6

Adoption of BIM within each profession showed that Architects had the highest adoption rate at 70.3% while Quantity surveyors had the least at 38.7%. In overall adoption rate Architects were leading at 14.9% followed by Construction Project Managers at 12% and Civil engineers at 8.6% the bottom adopters were Facility Managers and Contractors who were both at 1.7%. Refer to Table 1.

There were 29.1% with college BIM education though there lacks curriculum, those who had not received a BIM educated were 78.6%. At the job market, 48% were self-trained and 20.6% were trained by the employer, some of whom were already self-trained. 14.3% were trained by software companies, 13.1% by software sellers, 9.1% by BIM champion, 2.9% by online tutorials, 1.1% in seminars and conferences, 1.7% were still on training while 8% were not trained.

Those who had not adopted BIM were asked what the reasons were, 17.7% reported that training was lacking, 12% said there was no client requirement, 9.7% lack of standards & guidelines, 9.1% said that BIM implementation process was too expensive, 8% cited lack of policy, 4.6% were satisfied with existing system, 4.6% did not understand BIM, 4% reported that BIM was too complicated and 0.6% cited that top management did not understand BIM.

The respondents were asked if traditional procurement system had failed the client. Majority agreed that it had failed the client; 54% agreed, 29% disagreed and 17% were uncertain. The preferred method of procurement were: Design-Bid-Build (DBB) was preferred by 39% followed by 26% Design-Build (DB), 22% Management Contracting, 6% Public-Private-Partnerships (PPP), 4% Joint venture (JV) and 3% did not have a preferred method of procurement. Respondents cited the following standard forms of contract commonly used in the Kenyan construction industry: The Joint Building Council (JBC) at 68.6%, International Federation of Consulting Engineers (FIDIC) at 50.9%, 4% Public Procurement Regulatory Authority (PPRA formerly PPOA), 1.1% Engineering Procurement and Construction Contract (EPC), 1.1% The New Engineering Contract (NEC) and 0.6% The Joint Contract Tribunal (JCT).

The question of whether BIM has influenced ECM, 72% of respondents stated it had, 5%, disagreed while 23% were uncertain. BIM being a new technology had brought new roles, respondents identified them as BIM manager, BIM coordinator, BIM modeler/user, BIM consultant, and BIM champion.

4.1. Reliability Test of the Likert Scale Items

A reliability analysis to check internal consistency of the questionnaire's 75 Likert scale items was carried out; it was found to be excellent at a Cronbach's alpha of 0.963.

4.2. Correlation for BIM and ECM

A correlation analysis was carried out using Pearson correlation (r) to examine the relationship between the independent variable BIM and dependent variable

ECM. The characteristics of BIM measured were collaboration, time saving, cost reduction, quality improvement, and ROI. Collaboration was found to be significant and positively correlated to ECM, $r(173) = 0.453$, $p < 0.01$. Time saving was positively correlated to ECM, $r(173) = 0.439$, $p < 0.01$. A complete list of correlations is shown in **Table 2**. **Table 3** shows the correlation when BIM variables were combined to form one variable, BIM is significant and positively correlated to ECM, $r(173) = 0.493$, $p < 0.01$; When BIM improves ECM also improves in terms of time saving, cost reduction, quality improvement, better collaboration hence a positive ROI.

4.3. Underlying Factors of Influence of BIM on ECM

Exploratory factor analysis (EFA) was carried out with principal component analysis as the extraction method the primary purpose being to compute the latent factors of influence of BIM on ECM. This analysis used EFA because the number and nature of expected factors were unknown [30]. 5-point Likert scale was used to measure the 75 variables. The variables had a significant positive correlation at $p < 0.01$ and $p < 0.05$.

Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy was found to be okay, at KMO = 0.872, Bartlett's test of sphericity was significant at χ^2 = 9575.289, $p < 0.001$. The diagonals of the anti-image correlation matrix were also over 0.5. Communalities were above 0.5 hence confirming that each item shared some common variance with other items. This proved that Factor analysis was a suitable method of analysis.

Table 2. Correlation for influence of BIM on ECM (N = 175).

		ECM	C	TS	CR	QI	ROI
ECM	r	1					
Collaboration (C)	r	0.453**	1				
Time saving (TS)	r	0.439**	0.800**	1			
Cost reduction (CR)	r	0.431**	0.691**	0.661**	1		
Quality improvement (QI)	r	0.376**	0.690**	0.659**	0.667**	1	
ROI	r	0.411**	0.620**	0.550**	0.701**	0.614**	1

**. Correlation is significant at the 0.01 level (2-tailed).

Table 3. Correlation for influence of BIM adoption on ECM (N = 175).

		ECM	BIM
ECM	r	1	
BIM	r	0.493**	1

**. Correlation is significant at the 0.01 level (2-tailed).

A total of 75 variables were computed, 73.504% cumulative variance accounted for the 18 components with Eigenvalue greater than 1, as shown in Table 4. A parallel analysis was then conducted, resulting in 7 factors retainment. The web engine parallel analysis calculates Eigenvalues based on parameters provided by the researcher, the result is compared with eigenvalue from computer generated data set, factors retained have a higher eigenvalue than that provided by corresponding eigenvalues from the engine [31]. See Table 5 for the summary.

The decision was made to conduct the test again with a preset fixed number of 7 factors. This resulted in 54.4% cumulative variance being accounted for by preset factors. By Oblimin rotation the correlation of the 7 factors was below 0.5 implying they were not highly correlated, hence the need to change from oblique rotation to orthogonal rotation by varimax. The factor analysis was conducted again under varimax rotation.

Table 4. Total variance explained.

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	22.703	30.271	30.271	22.703	30.271	30.271
2	4.626	6.168	36.439	4.626	6.168	36.439
3	3.830	5.106	41.545	3.830	5.106	41.545
4	3.314	4.419	45.964	3.314	4.419	45.964
5	2.545	3.393	49.357	2.545	3.393	49.357
6	2.075	2.766	52.123	2.075	2.766	52.123
7	1.887	2.516	54.639	1.887	2.516	54.639
8	1.618	2.157	56.796	1.618	2.157	56.796
9	1.510	2.013	58.809	1.510	2.013	58.809
10	1.462	1.949	60.759	1.462	1.949	60.759
11	1.404	1.871	62.630	1.404	1.871	62.630
12	1.310	1.746	64.377	1.310	1.746	64.377
13	1.301	1.734	66.111	1.301	1.734	66.111
14	1.240	1.653	67.763	1.240	1.653	67.763
15	1.133	1.510	69.274	1.133	1.510	69.274
16	1.091	1.455	70.729	1.091	1.455	70.729
17	1.058	1.410	72.139	1.058	1.410	72.139
18	1.024	1.365	73.504	1.024	1.365	73.504
19	.988	1.317	74.821			
20	.925	1.233	76.054			
21 - 75	Omitted	by author				

Extraction Method: Principal Component Analysis.

Table 5. Parallel analysis tabulation with Calculated Eigenvalues.

Component/ factor	Parallel Eigenvalue	Percentile Eigenvalue	Calculated Eigenvalue	% of variance	Decision
1	2.027918	2.109525	22.703	30.271	Retain
2	1.944076	2.005931	4.626	6.168	Retain
3	1.880338	1.925693	3.830	5.106	Retain
4	1.827315	1.867672	3.314	4.419	Retain
5	1.784450	1.826314	2.545	3.393	Retain
6	1.740780	1.789314	2.075	2.766	Retain
7	1.699345	1.736520	1.877	2.516	Not retained
8	1.662571	1.694751	1.618	2.157	Not retained
9	1.626509	1.655897	1.510	1.013	Not retained
10	1.592867	1.630366	1.462	1.949	Not retained
11 - 75 Omitted by author	1.559097 - 0.317981	1.594474 - 0.342128	1.104 - 0.049	1.871 - 0.281	Not retained

The internal consistency for the seventh factor was very poor but upon deleting two variables it improved to 0.592. But having two variables in a factor did not seem to communicate a clear latent factor, this prompted another factor analysis to be run with fixed numbers of 6 factors instead of 7.

The 6 factors retained were given umbrella names as follows. More details are tabulated in **Appendix 1**. Factor 1—Legal implications: Had 30.271% variance explained, an Eigen value of 22.703, and it had 15 variables loading in it with a Cronbach Alpha of 0.933 inferring excellent reliability.

Factor 2—Awareness and Knowledge: Had 6.168% variance explained, an Eigenvalue of 4.626, had 16 variables loading in it with a Cronbach Alpha of 0.939 inferring excellent reliability.

Factor 3—Efficiency: It had 5.106% variance explained, an Eigenvalue of 3.830, 14 variables loaded in it with a Cronbach Alpha of 0.915 inferring excellent reliability.

Factor 4—Versatility: Had 4.419% variance explained, an Eigenvalue of 3.314, 11 variables loaded in it with a Cronbach Alpha of 0.889 inferring high reliability.

Factor 5—Mandate and leadership: Had 3.393% variance explained, an Eigenvalue of 2.546, with 12 variables, Cronbach Alpha of 0.831 inferring high reliability.

Factor 6—Competitiveness: 2.766% variance explained, an Eigenvalue of 2.075, loaded 6 variables with a Cronbach Alpha of 0.671 inferring moderate reliability.

4.4. Situation of BIM Adoption in Nairobi, Kenya

The in-depth interview showed that BIM adoption in Kenya is still low, due to shallow understanding of BIM, this argument was based on observations made by the respondents from their interactions in the construction industry. The descriptive statistics showed the adoption rate of 56.6%, it also showed that though 96% of the respondents knew what BIM is, only 33% rightfully stated it is not a software, 65% believed that BIM is a software and the remaining 2% did not know whether it is a software or not. A cross-tabulation of this contradiction is shown in Table 6, where 62.6% of those who have adopted BIM believed BIM is a software the trend is similar for the non-adopters, those planning to adopt and those who had partially adopted. The low level of adoption was because of high cost of implementation, lack of proper training, lack of awareness and knowledge, lack of contractual guidance, lack of necessary skills, change resistant attitude, and lack of understanding. Other factors include, Education curriculum failure to include BIM, complexity of BIM, lack of leadership, inadequate sensitization, size of projects dictating adoption, lack of case studies and lack of BIM champions. Further, Contractors unwillingness to adopt, client's failure to require BIM, inflexible employers, unfavourable procurement rules, rigid traditional procurement system and lack of government mandate are other reasons for low adoption level. These low numbers contribute to difficulty in collaboration.

Respondents opined that BIM complements professional work, other benefits include, time and cost saving, generative designs, and real-life simulation. Complex projects design can be handled without having to expand the workforce. Additionally, lifecycle information storage and management make operation and maintenance easier and cost effective.

According to the respondents, BIM has influenced contract management by making it easier. Additionally, BIM facilitates, collaboration, improved quality, business benefit, positive ROI, easier decision making, clash detection, early problem detection in professional relationships. It also makes it easier for parties to appreciate design components, reduces adversarial relationships, it eliminates inconsistencies and abortive works. Bills of quantities are more accurately done, it gives transparency, empowers clients to appreciate real-time 3D visualization. It thus enables risk management through early identification and mitigation. There is emergence of new roles such as BIM manager, BIM coordinator and BIM Consultant.

Table 6. Cross-tabulation of BIM adoption and whether BIM is a software.

		Is BIM a software			
		Yes	No	I do not know	Total
Have you adopted BIM in your organization	Yes	62.6%	36.4%	1.0%	100% - 99 No.
	No	63.6%	27.3%	9.1%	100% - 33 No.
	Planning to Adopt	70.7%	29.3%	0.0%	100% - 41 No.
	Partially/ongoing adoption	100%	0%	0%	100% - 2 No.
	Total	65.1% 114 No.	32.6% 57 No.	2.3% 4 No.	100% - 175 No.

5. Discussion

From the results of the research, the BIM adoption level in Nairobi was established as 56.6%, with Architects, Construction project managers and Civil engineers in that order leading in adoption, designers such as Engineers and architects are more receptive of BIM as compared to other groups. Lack of understanding is the biggest impediment to BIM adoption and even though 96% of the respondents seemingly knew what BIM was, 65.1% thought that BIM is a software which is not the case; only 32.6% knew that it is not a software. Despite BIM having many dimensions, 3D modelling was largely utilized, other dimensions remained unexplored. Kenyan research and educational centres are failing by not including BIM in the curriculum, this affects the technical capacity that could be used to advance skills in the job market.

When BIM and ECM were correlated, the correlation was significant and positive. That means that, when BIM adoption improves, ECM also improves hence project's success. When the adoption increases, the effect on ECM becomes more pronounced. This influence could be interpreted through the six underlying factors on the relationship between BIM and ECM, namely: Legal implications, awareness and knowledge, efficiency, versatility, mandate and leadership, and competitiveness. Refer to **Appendix 1**. The factors have been interpreted as below.

Legal risks: 15 variables loaded under this factor, data security loaded highest and contractual guidelines loaded the least. BIM operates in a digital environment unlike the traditional system that operates with hardcopy documentation, security of data thus becomes an immediate concern as people implement BIM. Processes need to be revised, responsibility and liability should be assigned to the right professionals, which should include the new skills brought by BIM. Legislation and legal precedence rated the fourth highest; being a new system in Kenya, BIM lacks judicial precedence, hence the need for laws to enable effective ECM. Data interoperability was an implication because consultants use different types of software and require collaborating digitally. Sharing of copyright data and intellectual property rights have a very thin line in the digital BIM. The implementation process comes with a cost implication, ways of recovering the cost incurred were unclear. Further, BIM environment is transparent with each design component meaning something to a professional, so standard of care becomes a collective responsibility, professional negligence is reduced, and admissibility of electronic-based document is managed by the BIM manager. Currently, there lacks standards to oversee this, but with formulation of standards it will make model management easier. Legal validation of design by the local authority needs to consider using the digital model unlike the traditional system that uses hardcopies and, in some cases, 2D digital drawings. Condition of contracts needs revision from traditional hardcopy system to digital BIM system.

Awareness and knowledge: 16 variables loaded under this factor, dispute resolution loaded highest and clash detection loaded the least. Being aware and having knowledge of BIM through education and training, followed by proper use of the BIM system makes ECM easier. Dispute resolution loaded highest, then, improved workmanship, reduced variations and claims, improved quality, decision management and communication are made easier through its collaborative nature. BIM also facilitates positive ROI, reduced cost of the project, early problem detection, real-time correction of information at any stage, effective coordination, reduced cost of operation and maintenance, faster execution of a project and clash detection.

Efficiency: 14 variables loaded under efficiency with better coordination loading the highest and BIM definition the least. The benefits of BIM make ECM easier and enable efficiency in projects through, better coordination, collaboration, clash detection, improved accuracy, time saving, improved communication, buildability, intelligent 3D visualization, cost saving, real-time capabilities, better decision management, transparency and quality improvement. BIM definition variable defines BIM and depicts the influence of efficiency on ECM.

Versatility: 11 variables loaded under versatility, safety management loaded highest and consistent lifecycle information loaded the least. BIM brings versatility to ECM, coordination of those aspects of a construction project that were traditionally separate from design, are centrally managed. For instance, Safety management is a major concern in construction sites, BIM real-time monitoring, evaluation and analysis ensures mitigation measures are put in place in time, this applies to risk management in general. Further, positive ROI realized by professionals and clients, leads to, improved customer client relationship. Other aspects are improved facility management, sustainability, and energy analysis. Ensuring consistent lifecycle information hence making ECM easier.

Mandate and leadership: 12 variables loaded under this factor, the government should adopt their procurement process to suit collaborative BIM loaded highest and written materials to guide BIM implementation loaded the least. When it comes to new technologies the authorities become vital in enabling countrywide implementation. Legal validation of the digital model to the Nairobi County Council can only function through a mandate. The government may need to make BIM implementation compulsory, hence requiring revised or new sets of standard forms of contract. The mandate will ensure Kenyan consultants are equally competitive as their international counterparts towards winning construction contracts. A regulatory body mandated by the government is important to help with standardization of BIM within the country. The government should also mandate the digital BIM model to be recognized as a contract document. Case studies on BIM projects and noteworthy BIM publications in Kenya, will be important in guiding stakeholders in BIM adoption hence abandon the traditional procurement system which is not receptive to technological advancement.

Competitiveness: 6 variables loaded under competitiveness with my organization needing standards and guidelines loading the highest and size of the project loading the least. An organization having standards and guidelines on BIM and engaging a BIM consultant is a good indicator of international competitiveness in ECM. Pressure to remain competitive shows that progressive trends are themselves full of pressure to stay at the top. Additionally, the necessary technological tools must be put in place. The bigger the project the more the need to implement BIM, smaller projects seem not to be presenting contract management challenges.

6. Conclusions

Definition of influence in the context of this paper is to have an effect or change on how something develops or behaves. BIM adoption and implementation have an effect on the development of ECM in response. Legal implications call for a legal framework purposely for the BIM system. There is a need for increased awareness and knowledge whereby perception and understanding of BIM and its benefits make contract management easier, reducing risks, improving relationships, saving resources, and giving business benefits. Components of BIM regarded to be important for its adoption are increasing efficiency in ECM. Versatility of BIM capabilities bring more advantages beyond the primary ones depicted by efficiency factor. Further, new relationships will be created such as contractor's and facility manager's early involvement in the project, inevitably, novel risks ensue, that require a BIM system solution and not a solution from the traditional system.

The government and its agencies have a responsibility to revise the Kenyan procurement ACT to suit collaborative BIM. International competitiveness requires that professionals use the most efficient tools to sell their engineering creativity, this competitiveness package enables projects success. BIM is slowly but aggressively demanding for standards, guidelines, policy, legal framework, and regulations, this will improve contractual relationships and give contractual guidelines on roles, relationships, and risks. Ultimately this will enable effective ECM.

Adoption and implementation of BIM requires awareness of what BIM is, leadership to give guidance, education to build technical capacity, training to advance the skills and necessary technology to execute the BIM process. There is generally low understanding of BIM in Nairobi; therefore, the players in the construction industry should make understanding of BIM an urgent pull factor towards efficient and effective ECM. Future studies should find out if this state is changing.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

[1] National Institute of Building Science United States (2019) Frequently Asked Questions about National BIM Standard—United States.

https://www.nationalbimstandard.org/faqs

[2] Azhar, S., Khalfan, M. and Maqsood, T. (2012) Status of BIM Adoption and the BIM Experience of Cost Consultants in Australia. *Australasian Journal of Construction Economics and Building*, **12**, 15-28. https://doi.org/10.5130/AJCEB.v12i4.3032

[3] Bouška, R. (2016) Evaluation of Maturity of BIM Tools across Different Software Platforms. *Procedia Engineering*, **164**, 481-486. https://doi.org/10.1016/j.proeng.2016.11.648

[4] Kalinichuk, S. (2015) Building Information Modeling. *Journal of Systems Integration*, **3**, 25-34. https://doi.org/10.20470/jsi.v6i3.235

[5] Kuiper, I. and Dominik, H. (2013) Rethinking the Contractual Context for Building Information Modelling (BIM) in the Australian Built Environment Industry. *Australasian Journal of Construction Economics and Building*, **13**, 1-17. https://doi.org/10.5130/AJCEB.v13i4.3630

[6] Mouzas, S. and Blois, K. (2007) Relational Contract Theory: Confirmations and Contradictions.

[7] Succar, B. (2009) Building Information Modelling Framework: A Research and Delivery Foundation for Industry Stakeholders. *Automation in Construction*, **18**, 357-375. https://doi.org/10.1016/j.autcon.2008.10.003

[8] Smith, P. (2014) Project Cost Management with 5D BIM. *Procedia Social and Behavioral Sciences*, **119**, 475-484. https://doi.org/10.1016/j.sbspro.2014.03.053

[9] Xu, X., Ma, L. and Ding, L. (2014) A Framework for BIM-Enabled Life-Cycle Information Management of Construction Project. *International Journal of Advanced Robotic Systems*, **11**, 1-13. https://doi.org/10.5772/58445

[10] Nowak, P., Książek, M., Draps, M. and Zawistowski, J. (2016) Decision Making with Use of Building Information Modeling. *Procedia Engineering*, **153**, 519-526. https://doi.org/10.1016/j.proeng.2016.08.177

[11] Grzyl, B., Miszewska-Urbańska, E. and Apollo, M. (2017) Building Information Modelling as an Opportunity and Risk for Stakeholders Involved in Construction Investment Process. *Procedia Engineering*, **196**, 1026-1033. https://doi.org/10.1016/j.proeng.2017.08.045

[12] Nicał, A.K. and Wodyński, W. (2016) Enhancing Facility Management through BIM 6D. *Procedia Engineering*, **164**, 299-306. https://doi.org/10.1016/j.proeng.2016.11.623

[13] Bosch-Sijtsema, P. and Gluch, P. (2019) Challenging Construction Project Management Institutions: The Role and Agency of BIM Actors. *International Journal of Construction Management*, 1-11. https://doi.org/10.1080/15623599.2019.1602585

[14] Ali, A. (2016) Building Information Modelling (BIM) and Project Management Implementation in Infrastructure and Civil Construction.

[15] Olsen, D. and Taylor, J.M. (2017) Quantity Take-Off Using Building Information Modeling (BIM), and Its Limiting Factors. *Procedia Engineering*, **196**, 1098-1105. https://doi.org/10.1016/j.proeng.2017.08.067

[16] Khodeir, L.M. and Nessim, A.A. (2016) BIM2BEM Integrated Approach: Examining Status of the Adoption of Building Information Modelling and Building Energy Models in Egyptian Architectural Firms. *Ain Shams Engineering Journal*, 1-10.

[17] Aziz, N.D., Nawawi, A.H. and Ariff, N.R.M. (2016) Building Information Modelling (BIM) in Facilities Management: Opportunities to Be Considered by Facility Managers. *Procedia—Social and Behavioral Sciences*, **234**, 353-362. https://doi.org/10.1016/j.sbspro.2016.10.252

[18] Azhar, N., Kang, Y. and Ahmad, I.U. (2014) Factors Influencing Integrated Project Delivery in Publicly Owned Construction Projects: An Information Modelling Perspective. *Procedia Engineering*, **77**, 213-221. https://doi.org/10.1016/j.proeng.2014.07.019

[19] Yalcinkaya, M. and Arditi, D. (2013) Building Information Modeling (BIM) and the Construction Management Body of Knowledge. 10*th Product Lifecycle Management for Society* (*PLM*), Nantes, 6-10 July 2013, 619-629. https://doi.org/10.1007/978-3-642-41501-2_61

[20] Charehzehi, A., Chai, C., Yusof, A.M., Chong, H. and Loo, S.C. (2017) Building Information Modeling in Construction Conflict Management. *International Journal of Engineering Business Management*, **9**, 1-18. https://doi.org/10.1177/1847979017746257

[21] Borjeghaleh, R.M. and Sardrou, J.M. (2016) Approaching Industrialization of Buildings and Integrated Construction Using Building Information Modeling. *Procedia Engineering*, **164**, 534-541. https://doi.org/10.1016/j.proeng.2016.11.655

[22] Arshad, M.F., Thaheem, M.J., Nasir, A.R. and Malik, M.S.A. (2019) Contractual Risks of Building Information Modeling: Toward a Standardized Legal Framework for Design-Bid-Build Projects Standardized Legal Framework for Design-Bid-Build Projects. *Journal of Construction Engineering and Management*, **145**, 1-14. https://doi.org/10.1061/(ASCE)CO.1943-7862.0001617

[23] Manderson, A., Jefferies, M. and Brewer, G. (2015) Building Information Modelling and Standardised Construction Contracts: A Content Analysis of the GC21 Contract. *Construction Economics and Building*, **15**, 72-84. https://doi.org/10.5130/AJCEB.v15i3.4608

[24] Eadie, R., McLernon, T. and Patton, A. (2015) An Investigation into the Legal Issues Relating to Building Information Modelling (BIM). *RICS COBRA AUBEA* 2015, Sydney, 8-10 July 2015, p. 8.

[25] Bui, N., Merschbrock, C. and Munkvold, B.E. (2016) A Review of Building Information Modelling for Construction in Developing Countries. *Procedia Engineering*, **164**, 487-494. https://doi.org/10.1016/j.proeng.2016.11.649

[26] Hosseini, M.R., Azari, E., Tivendale, L., Banihashemi, S. and Chileshe, N. (2016) Building Information Modeling (BIM) in Iran: An Exploratory Study. *Journal of Engineering, Project, and Production Management*, **6**, 78-89. https://doi.org/10.32738/JEPPM.201607.0002

[27] Manza, D. (2016) Influence of Building Information Modelling Adoption on Completion of Construction Projects: A Case of Nairobi County, Kenya. Published Master's Thesis, University of Nairobi, Nairobi.

[28] Musyimi, M.M. (2016) Building Information Modelling Adoption in Construction Project Management in Kenya: A Case Study of Nairobi County. Published Master's Thesis, University of Nairobi, Nairobi.

[29] Hennink, M.M., Kaiser, B.N. and Marconi, V.C. (2017) Code Saturation versus Meaning Saturation: How Many Interviews Are Enough. *Qualitative Health Research*, **27**, 591-608. https://doi.org/10.1177/1049732316665344

[30] Williams, B., Onsman, A. and Brown, T. (2010) Exploratory Factor Analysis: A Five-Step Guide for Novices. *Journal of Emergency Primary Health Care*, **8**, 1-13. https://doi.org/10.33151/ajp.8.3.93

[31] Patil, V.H., Singh, S.N., Mishra, S. and Donovan, T. (2017) Parallel Analysis Engine. Patil 2017 Parallel Analysis. https://analytics.gonzaga.edu/parallelengine

Appendix 1. Influence of BIM on ECM Summary Table

Factor	Variable	Loading factor
Factor 1: Legal implications variance explained = 30.271% Eigenvalue = 22.703 Cronbach's Alpha = 0.933 N = 15	Data security	0.759
	Processes and responsibilities	0.743
	Professional liability	0.731
	Legislation and judicial precedence	0.695
	Data interoperability	0.694
	Sharing of copyright data	0.691
	Intellectual Property Rights	0.672
	Cost compensation	0.663
	Standard of care and professional negligence	0.660
	Admissibility of electronic-based document	0.654
	Lack of BIM standards	0.632
	Model management	0.632
	legal validation of design (NCC submissions)	0.582
	Condition of contracts (e.g. FIDIC)	0.532
	It is necessary to have contractual guidelines to guide in BIM adoption	0.448
Factor 2: Awareness and knowledge variance explained = 6.168% Eigen value = 4.626 Cronbach's Alpha = 0.939 N = 16	BIM makes dispute resolution easier	0.736
	BIM improved good working relationship	0.724
	BIM helps to reduce variations	0.701
	BIM improves quality	0.687
	BIM improves decision management process	0.686
	BIM improves communication in the construction team	0.680
	BIM facilitates positive ROI	0.663
	BIM helps to reduce claims	0.654
	BIM reduces cost of a project	0.646
	BIM aids in early problem detection	0.626
	BIM makes real time correction of information easy at any stage of a project	0.620
	BIM facilitates effective coordination	0.615
	BIM reduces cost of operation and maintenance of a facility	0.592
	BIM enables the construction Team to work together effectively and efficiently	0.584
	BIM enables faster execution of a project hence saving time	0.560
	BIM aids in clash detection of construction element as designed by different professionals	0.520

Continued

Factor 3: Efficiency variance explained = 5.106% Eigenvalue = 3.830 Cronbach's Alpha = 0.915 N = 14	Better coordination - BIM component	0.731
	Collaboration - BIM component	0.705
	Clash detection - BIM component	0.675
	Improved accuracy - BIM component	0.630
	Time saving - BIM component	0.628
	improved communication - BIM component	0.609
	Buildability - BIM component	0.609
	Intelligent 3D visualization - BIM component	0.578
	Cost saving - BIM component	0.557
	Realtime capabilities - BIM component	0.554
	Better decision management - BIM component	0.547
	Transparency - BIM component	0.529
	Quality improvement - BIM component	0.499
	BIM definition	0.484
Factor 4: Versatility variance explained = 4.419% Eigenvalue = 3.314 Cronbach's Alpha = 0.889 N = 11	Safety management	0.644
	Improved facility management	0.617
	Return on investment	0.609
	Risk management	0.593
	Improved customer client relationship	0.582
	Sustainability	0.572
	Financial cost	0.544
	Top management support	0.507
	Energy analysis	0.498
	Technological capabilities	0.459
	Consistent lifecycle information	0.390
Factor 5: Mandate and leadership variance explained = 3.393% Eigenvalue = 2.546 Cronbach's Alpha = 0.831 N = 12	Government should adopt their procurement processes to suit collaborative BIM	0.671
	NCC submissions may require BIM model in future	0.623
	Government need to make BIM implementation compulsory	0.609
	BIM requires a new set of standards forms of contract	0.587
	Existing forms of contract should be modified to suit BIM	0.533
	Construction contracts are competitively awarded to both local and international firms depending on BIM capabilities	0.513
	There is need for regulatory body mandated by the government	0.492
	The digital BIM model should be recognized as a contract document	0.487
	There are case studies done on BIM projects in Kenya	0.450
	The traditional procurement has failed to meet client's expectations	0.445
	Stakeholders are willing to pioneer in BIM adoption	0.361
	There are written materials to guide BIM implementation	0.307

Continued

Factor 6: Competitiveness variance explained = 2.766% Eigen value = 2.075 Cronbach's Alpha = 0.671 N = 6	My organization has standards and guidelines on BIM adoption	0.675
	My organization has engaged a BIM consultant to help in BIM adoption	0.539
	Pressure to remain competitive - BIM component	0.528
	BIM has influenced/impacted engineering contract management	0.421
	BIM hardware must be recommended by the type of software in use	0.409
	Size of a project - BIM component	0.313

KMO = 0.872, Bartlett's χ^2 = 9575.289, $p < 0.001$, Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization. a. Rotation converged in 8 iterations.

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Underlying factors guiding Building Information Modelling (BIM) adoption in Nairobi, Kenya

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Abstract. Aspects that are distinct and are primarily beneficial are considered the initial impetus to adoption of new technologies. Building information Modelling (BIM) is one such technology, whereby consultants in the construction industry consider important components of BIM as a deciding factor to its adoption. The objectives of this study were to investigate BIM adoption in Nairobi and to identify significant components in its adoption. This was a descriptive study with a sample of 175 respondents comprising of Civil Engineers, Construction Project Managers, Architects, Mechanical Engineers, Electrical Engineers, Quantity surveyors, Contractors, and Facility Managers. The data was collected through self-administered questionnaires. Descriptive analysis and Exploratory Factor Analysis methods were used to analyse data. It emerged that 56.6% have adopted BIM and lack of understanding of BIM capabilities seems to be a hindrance to BIM adoption. Efficiency, Versatility, Competitiveness, Intelligence and Transparency were the five underlying factors that were extracted and found to be important to BIM adoption. It is recommended that BIM adoption will take place quicker through raising awareness, giving leadership, education, and training to stakeholders in the construction industry. Further research should be done on how software contributes to lack of understanding of BIM.

Keywords: Adoption; BIM; BIM component, BIM factors; Building information Modelling; Collaboration

1. Introduction

One of the challenges in the construction industry is lack of effective collaboration which has contributed to poor quality delivery, time, and cost overruns in the lifecycle of a project. The BIM system gives the solution to these challenges caused by the Traditional Procurement System (TPS). The TPS has been blamed for resource wasting for instance, in Kenya time is wasted to a magnitude of 50% for over 70% of projects [1]. Thika superhighway cost escalated by 30% and time exceeded by 2 years [2]. Another challenge is missing contract documents and politician involvement in construction projects [3].

Kenya is geared towards being a newly-industrialized middle income country by 2030 [4]; this can be achieved by putting in place systems and structures that support trends that save on resources and are sustainable. Information and Communication Technology (ICT) advancement in Kenya encourages transparency that helps to fight corruption; unfortunately corrupt cartels are against such systems [5]. The government organizations are slow in ICT uptake for instance the Nairobi City County (NCC), though they moved to 2D drawings digital approvals approval [6] they still have not adopted BIM.

This survey research was carried out with an aim of uncovering the underlying factors in BIM adoption in Nairobi. The objectives of this study were to investigate BIM adoption and to identify significant components in its adoption in Nairobi, Kenya. Even though BIM adoption research has been carried out in several countries, country specific research is advised in developing countries [7]. BIM acceptance is expected to be gradual and will affect the existing systems and structures hence the stakeholders' cooperation becomes paramount.

1.1. What is BIM

Building Information Modelling (BIM) is considered to be a major paradigm shift after Computer Aided Design (CAD) by professionals and academic researchers [8]. BIM is defined as a digital representation of the physical and functional characteristics of a facility, BIM is a shared knowledge resource for information about a facility, forming a reliable basis for decisions during its (facility) life-cycle; defined as existing from earliest conception to demolition [9]. Having several collaborators in the lifecycle of a project, makes management of information paramount [10]. BIM is not a software as has been the common misconception, rather, a Software supporting BIM should provide, transparency, interoperability, simplicity, functionality, accuracy, expandability, time management, clash detection, cost estimation and facility management [11]. BIM is a system with policy, process and technology fields [12].

According to [13] the BIM stages are: stage 0 (pre-BIM), stage 1 (object-based modelling), stage 2 (model-based collaboration), and stage 3 (network-based integration). BIM is a collaboration tool with subsets commonly described as dimensions (D): 3D (object modelling), 4D (time), 5D (cost), 6D (operations), 7D (sustainability) and even safety for 8D [14].

1.2. BIM Adoption globally and in Kenya

When adopting and implementing BIM, the government leadership and mandates are essential towards achieving mutual standards and protocols and to facilitate avoidance of effort duplication. This has proven to be the critical factor for successful BIM implementation in leading countries such as USA, UK and Singapore [15]. However some countries such as Canada, Australia, Brazil, China and Mexico have followed a different model where private organizations have lead in adoption efforts [16].

In Kenya, the private sector is leading in BIM adoption, though at a slow pace. in addition the challenges stated here are the same ones that affect the Kenyan industry [17][18]. There is limited knowledge and the leaders in the construction industry do not have an implementation formula [19], the adoption process is led by software sellers such as Autodesk and Graphisoft [18] and the TPS derails adoption efforts [17][18].

Research done by [20] in 2018 found that majority of Kenyan professionals were in BIM stage 1, followed by BIM stage 2 and the minority were in stage 3. Whereas [18] who did a research in 2016 found out majority of professionals to be in stage 2. BIM was reported to be mainly in use during design stage, and it was minimally used in preconstruction, construction and post construction [18].

1.3. Factors guiding adoption of BIM

BIM is an information management tool [21], with the advantage of digital storing of all data in the project's lifecycle [22]. It promotes process cooperation and collaborative efforts [23], [24]. It further provides a platform for 3D visualization, automation, integration and communication between the different stakeholders [25]. It presents the ability to easily make changes in real-time at any stage of construction [26]. BIM reduces the industry's fragmentation and improves on efficiency and effectiveness, [27], parties such as the contractor and facility manager can have an early entrance into the project, to give input on buildability and operation requirements respectively [28], [29]. Globally, BIM gives competitive advantage to international job bidding [15].

Benefits of BIM include reduced project cost [30], [31], [32], better coordination, clash detection, better time management, resource saving [31], [32], improved profitability, improved customer-client relationship [10], and ability to handle large and complex projects easily [33]. BIM allows easier decision management [34] and easier project management [8]. Further, it helps in risk management, [28], construction conflict management [35], sustainability management and energy analysis, all of which can be addressed collaboratively with interactive feedbacks on design decision consequences [22], [21]. During operation and maintenance, BIM enables the facility management to be more efficient hence realizing positive return on investment (ROI) [35], [24].

1.4. Challenges of BIM in Construction

There is a conflict between BIM system and the TPS [25]. TPS allows use of BIM for visualization only [18] whereas BIM demands lifecycle utilization. Lack of government efforts to mandate BIM [36], lack of contractual guidelines for the BIM system [37] and lack of BIM standards [7] are impediments towards BIM adoption. The fragmented nature of the construction industry [38] and the inability to cooperate [24], [31] makes it harder on how to implement BIM mainly because of unclear consensus [10].

There is generally a change resistant attitude in the industry [24] and stakeholders do not want to pioneer [14]. Further, BIM is not understood well, because adoption has remained at 3D Modelling for visualization and clash detection, while other areas have remained unexploited [39]. Type of software, data interoperability and emerging new skills that lack adequate training are challenges [24]. Unclear benefits of BIM is another barrier [7], and this could also be alluded to lack of sufficient studies on ROI on project executed by BIM; however for those firms that conducted a ROI study, it guided them to adopt [31].

2. Methodology

This descriptive study method utilized self-administered questionnaires with both structured and unstructured questions. The location was Nairobi Kenya and the respondents were drawn from eight strata made up of consultants in the construction industry namely, Civil Engineers, Construction Project Managers, Architects, Quantity Surveyors, Mechanical Engineers, Electrical Engineers, Contractors, and Facility Managers.

The sample size was arrived at using the following Cochran formula which was simplified by Yamane's studies [40]. The study adopted the calculated samples size of 371.

$$n = \frac{z^2_{\alpha/2} \cdot p \cdot q \cdot N}{e^2(N-1) + z^2_{\alpha/2} \cdot p \cdot q} \quad (1)$$

therefore,

$$n = \frac{1.96^2 \cdot (0.5) \cdot (1-0.5) \cdot 10597}{0.05^2(10597-1) + 1.96^2 \cdot 0.5 \cdot (1-0.5)} \quad (2)$$

Sample size = 370.76 =371

Where: -

n = Size of sample

N = Study population

e = Acceptable error (±5%)

p = Sample proportion (0.5)

q = 1- p

$z^2_{\alpha/2}$= the standard normal deviation set at 95% with a confidence level (=1.96)

The sample size was determined in two steps. Step one was through stratified sampling and step two was through purposive sampling. The sample size selection was based on a prerequisite of awareness of BIM regardless of whether they had used it or adopted it, this measure was to help avoid training respondents who had never heard of BIM. 371 potential respondents were contacted through equal distribution, 252 questionnaires were distributed, out of which 175 were completed and returned, this accounted for 69% return rate. Though the follow-up reminders contributed to improved return rate, some respondents still failed to return their questionnaires.

The quantitative and qualitative data was cleaned, coded and analyzed quantitatively and thematically respectively.

3. Results

The profile of the respondents was as per Table I.

Table I: Respondents profile, adoption rate per profession and overall adoption rate

Frequency		Percent	Cumulative Percent	Adoption per profession %	Overall adoption %
Civil Engineer	32	18.3	18.3	46.9	8.6
Construction Project Manager	37	21.1	39.4	59.5	12
Architect	37	21.1	60.6	70.3	14.9
Quantity Surveyor	31	17.7	78.3	38.7	6.9
Mechanical Engineer	6	3.4	81.7	66.7	2.3
Electrical Engineer	14	8.0	89.7	64.3	5.1
Contractor	3	1.7	91.4	100	1.7
Facility Manager	4	2.3	93.7	75	1.7
Other (2 combinations)	11	6.3	100	45.5	2.9
Total	175	100.0			56.6

There were respondents who had 2 combined areas of practice namely, Architect & Contractor, Electrical Engineer & Facility Manager, Construction Project Manager & Contractor, Civil Engineer & Construction Project Manager, Quantity Surveyor & Facility Manager, Quantity Surveyor & Contractor, Quantity Surveyor & Construction Project Manager, totaling 6.3%.

The work experience of the majority was between 6 to 10 and 0 to 5 years at 33.1% and 36% respectively, 11 to 15 year accounted for 16.6% and over 15 years were 14.3%. Most of the respondents were in the 0 to 5 and 6 to10 years brackets of experience, implying younger population exposure to BIM hence their availability for the survey. Most respondents had used BIM in the last 0 to 5 years at 67.5%, 17.1% for 6 to10 years and 5.7% for 11 to15 years and those who had never used BIM were 9.7%. This shows that BIM was relatively new in Nairobi. BIM roles played by the respondents included, 52% BIM users/modelers, 12% BIM managers and 11.4% BIM coordinators and the remaining 24.6% said they had no BIM roles.

3.1. Adoption of BIM

56.6% of the respondents had adopted BIM, 18.9% had not adopted, 23.4% were planning to adopt, 1.1% were in the processes of adopting. It was noted that the Architects, Construction Project Managers and Civil Engineers were in the front line of BIM adoption at 14.9%, 12% and 8.6% respectively (Table 1). Having a BIM manager is an indication that adoption has taken place, the study showed that, 32% respondents had a BIM manager, while 68% did not have. 68.6% of adopters reported to have used BIM on a construction project while 30.3% hade not used BIM on any construction project.

The definition of BIM given resulted to 96% agreeing to it, suggesting that respondents knew what BIM is. However, this knowledge was contradicted when 65.1% of the respondents thought that BIM is a software, and only 32.6% thought BIM is not a software, whereas 2.3% did not know what to think. The study also found out that in terms of software preference, Autodesk ranked highest at 57.8% followed by Graphisoft at 13.6%.

BIM stages from respondent's organizations showed that stage 0 representation was - 29.1%, stage 1 - 28.6%, stage 2 - 29.7% and stage 3 - 12.6%. On BIM dimension the majority 71.4% mainly used BIM for 3D modelling, 16.6% used 4D, 22.3% used 5D, 10.3% used 6D, 9.7% used 7D and 8% used 8D. Majority 41.1% introduced BIM at design stage, 2.9% at construction, 1.1% at maintenance, 4.6% introduced BIM in all stages, and 21.7% did not introduce BIM at all.

Respondents who got BIM education in college were 29.1% though there lacks a curriculum, those who did not receive a BIM educated were 78.6%. At the job market, 48% were self-trained and 20.6% were trained by the employer, though some of them were already self-trained.

Those who had not adopted BIM were asked what the reasons were, 17.7% reported that training was lacking, 12% there was no client requirement, 9.7% lack of standards & guidelines, 9.1% BIM was too expensive, 8% reported lack of policy, 4.6% were satisfied with existing system, 4.6% did not understand BIM whereas 4% reported that BIM was too complicated.

3.2. Ranking of the important Components of BIM adoption

The variable depicting the important components of BIM adoption were ranked to find out their importance as per respondents' preference. The ratings were from 1=very important, 2=important, 3=uncertain, 4=less important, and 5=not important. The Friedman Ranking test was used to rank them from the most important to the least important. This test compares the mean ranks between the related variables [41][42][43], the results are tabulated in Table II. It appeared that collaboration component was very important to most professionals adopting BIM followed by intelligent 3D visualization, improved accuracy, and clash detection in that order.

The results from Table II indicates that BIM components that come with BIM adoption were significant χ^2 (25) = 421.019, p=0.000, w=0.097.

Table II: Significant component in BIM adoption ranking

Rank	Important component in BIM adoption	Mean Rank
1.	Collaboration	10.84
2.	Intelligent 3D visualization	11.17
3.	Improved accuracy	11.17
4.	Clash detection	11.28
5.	Better coordination	11.56
6.	Time saving	11.98
7.	Buildability	12.10
8.	Quality Improvement	12.10
9.	Improved communication	12.22
10.	Transparency	12.61
11.	Cost saving	12.62
12.	Real time capabilities	13.05
13.	Better decision Management	13.06
14.	Consistent lifecycle information	13.19
15.	Risk Management	13.67
16.	Sustainability	15.05
17.	Improved Customer client relationship	15.27
18.	Improved facility management	15.37

19.	Energy analysis	15.39
20.	Safety Management	15.50
21.	Return on investment	15.90
	External factors	
1.	Size of a project	13.65
2.	Technological capabilities	14.83
3.	Pressure to remain competitive	15.62
4.	Financial cost of adoption	15.83
5.	Top management support	15.95

Test Statistics[a]	
N	175
Chi-Square	423.019
Df (degree of freedom)	25
Asymptotic Sig.	.000

a. Friedman Test

3.3. Underlying factors of the important components of BIM adoption

To find out the important components driving BIM adoption, the respondents were required to rate the importance using a 5-point Likert scale range from; 1=Very important, 2=important, 3=Uncertain, 4=less important, 5=Not important. The 26 variables under study were based on characteristic benefits of BIM and other external factors. The internal consistency of the 26 Likert scale items was checked and an excellent Cronbach alpha of 0.942 was found.

The primary purpose of the study was to compute the latent factors for BIM adoption. This analysis uses Exploratory Factor Analysis (EFA) because the number and nature of expected factors was unknown [44]. The extraction method used was Principal Component Analysis (PCA) and the rotation method was varimax with Kaiser Normalization.

The correlation matrix displaying the relationships between individual variables showed a correlation coefficient above 0.30 [44] hence the suitability of EFA for data analysis. Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy was KMO = 0.907; a KMO above 0.5 is satisfactory [45]. Bartlett's test of sphericity was significant at $\chi^2 = 2743.280$, $p < 0.001$ meaning that the correlation matrix of the variables in the dataset diverges significantly from the identity matrix [46]. The diagonals of the anti-image correlation matrix were also over 0.8 proving measure of sampling adequacy [45]. Communalities were above 0.4 hence variables were explaining the variance through the common factors [47] hence confirming that each item shared some common variance with other items. This proved that EFA was a suitable method of analysis.

The 26 variables computed, 63.9% cumulative variance accounted for 5 components each with Eigenvalue over 1, and each accounting for 42.6%, 7.4%, 5.4%, 4.6% and 3.9% of the variance, respectively (Table III).

The test was done again with a preset fixed number of the five factors based on Table III results. Factor labels proposed were efficiency for factor 1, versatility for factor 2, Competitiveness for factor 3, intelligence for factor 4 and transparency for factor 5. Internal consistency was examined for items under each factor, Cronbach's Alpha values were excellent for Factor 1, high for factors 2, 3, 4 & 5. These findings are shown on Table IV.

3.4. Challenges affecting BIM adoption in Nairobi, Kenya.

Concerns affecting BIM adoption as per the respondents were found to be cost of implementation, inadequate training, lack of awareness and knowledge, lack of contractual guidance, lack of BIM skills, change resistant attitude, lack of understanding and education curriculum failure to include BIM. Others include, complexity of BIM, rigidity in leadership, lack of sensitization, fear of corrupt hidden interest being exposed by transparent BIM, size of projects, lack of case studies, lack of BIM champion, contractors unwillingness to adopt until they are forced to adopt, and clients failure to require BIM in their projects. The traditional procurement system was also reported as a major hindrance to the BIM system.

Table III: Total Variance Explained

	Initial Eigenvalues			Extraction Sums of Squared Loadings		
Component	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	11.079	42.612	42.612	11.079	42.612	42.612
2	1.919	7.381	49.992	1.919	7.381	49.992
3	1.415	5.443	55.435	1.415	5.443	55.435
4	1.202	4.624	60.059	1.202	4.624	60.059
5	1.008	3.877	63.936	1.008	3.877	63.936
6	0.984	3.785	67.721			
7	0.879	3.381	71.102			
8-26	Omitted	by author				

Extraction Method: Principal Component Analysis.

Table IV: Underlying factors of BIM adoption

	Factors				
Variables	Efficiency	Versatility	Competitiveness	Intelligence	Transparency
Better coordination	**0.734**			0.311	
Collaboration	**0.724**			0.336	
Improved communication	**0.686**				
Cost saving	**0.670**	0.348			
Better decision management	**0.626**				
Time saving	**0.610**	0.331			
Quality improvement	**0.608**				
Clash detection	**0.607**			0.428	
Buildability	**0.510**			0.320	0.490
Sustainability	0.321	**0.759**			
Energy analysis		**0.722**		0.312	
Improved facility management		**0.594**	0.345		
Financial Cost of adoption		**0.576**	0.457		
Safety Management		**0.556**			0.484
Risk Management	0.484	**0.512**			
Size of a project			**0.714**		
pressure to remain competitive			**0.713**		
Technological capabilities		0.353	**0.669**		
Top management support		0.481	**0.543**		
Improved customer client relationship		0.448	**0.524**		
Consistent lifecycle information	0.409		**0.502**		
Realtime capabilities				**0.795**	
Intelligent 3D visualization				**0.706**	
Transparency				0.351	**0.728**
Return on Investment		0.529			**0.545**
Improved accuracy	0.410			0.387	**0.472**
% variance explained	42.612	7.381	5.443	4.624	3.877
Eigenvalue	11.079	1.919	1.415	1.202	1.008
Cronbach's Alpha	0.902	0.864	0.816	0.741	0.717

KMO = 0.907, Bartlett's $\chi^2 = 2743.280$, $p < 0.001$. Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.

BIM Regression models based on the coefficient matric shown on Appendix 1 are produced are as follows.

Efficiency = .238 Better coordination + .249 Collaboration + .245 Improved communication + .221 Cost saving + .180 Better decision management + .168 Time saving + .216 Quality improvement+ .165 Clash detection+ .061 Buildability

Versatility = .325 Sustainability + .328 Energy analysis + .170 Improved Facility management + .181 Financial cost of adoption + .152 Safety management + .123 Risk management

Competitiveness = .403 Size of a project + .346 Pressure to remain competitive + .273 Technological capabilities + .182 Top management support + .177 Improved customer client relationship + .173 Consistent lifecycle information

Intelligence = .481 Realtime capabilities + .405 Intelligent 3D visualization

Transparency = .518 Transparency + .343 Return on investment + .255 Improved accuracy

All coefficients were positive; implying when the variables improve then the factors also improve in performance. These factors are suitable for further analysis which is beyond the scope of this study.

4. Discussion

It was easier to find willing Architects, Civil Engineers, Construction Project Managers, and quantity surveyors to participate in the survey as compared to Electrical Engineers, Mechanical Engineers, Facility Managers and Contractors. Lack of awareness of BIM in the latter group was noticeably bigger as compared to the former group.

BIM adoption level was at 56.6%, Architects, Construction project managers and Civil engineers in that order lead in adoption. Lack of understanding and the TPS were a big challenge to BIM adoption; BIM was being confused for being a software. Even though 96% of the respondents seemingly knew what BIM is,

65.1% thought that BIM is a software which is not the case and only 32.6% knew that it is not a software. Inadequate training and education, lack of awareness and knowledge are the main reasons behind lack of BIM understanding and affecting adoption of BIM in favour of TPS.

On BIM stages, 29.1% of the respondents were at stage 0, 28.6% were in stage 1, 29.7% were in stage 2 and 12.6% were in stage 3. This shows progressive growth in BIM adoption in Nairobi from year 2016 till 2020. This was after comparing this results to findings in 2016 that showed pre-BIM had 40%, stage 1 had 60%, stage 2 and 3 had 0% each [18], and in 2018 that showed that stage 1 had 50%, stage 2 had 45.56%, stage 3 had 4.44% [20].

Despite BIM having many dimensions, 3D modelling was largely utilized, other dimensions are largely unexplored this corroborates [39]. The TPS which separates construction stages and encourages adversarial relationships does not support collaborative BIM it hinders utilization of the BIM system in totality.

Kenyan research and educational centres are not including BIM in the curriculum, this affects the technical capacity that could be used to advance skills in the job market. The type of skills needed should be outlined by the construction industry to enable universities and colleges to develop a BIM curriculum. At the job market, proper training lacks due to either employers' lack of interest or lack of skilled trainers. Though the younger respondents were comfortable to participate in this survey, it however emerged that the number of years of experience does not really affect adoption, rather the employer is likely to influence adoption hence the private sector is leading adoption. On the other hand, having a larger number of younger respondents showed to some extent, that the older generation was not comfortable to adopting to new trends and technologies. The study established that on job BIM training seemed to be the way most professionals were gaining knowledge and awareness on BIM.

Software companies and sellers whose main aim is to sell their products seemed to have created a gap that had led some professionals to think that BIM is a software, which is not the case. Autodesk suit was found to be the most popular in software preference; this was due to intensive marketing by the group.

Collaboration was ranked as the number one significant component in BIM adoption followed by, intelligent 3D visualization, improved accuracy, clash detection, better coordination, time saving, buildability, quality improvement, improved communication, transparency, cost savings real time capabilities and better decision management. This shows other aspects of BIM are largely unexplored beyond immediate ones like the 3D visualization. The highly ranked variables fell under efficiency and intelligence factors. All factors were interpreted as below.

Factor 1 – Efficiency: This factor was made up of the following 9 variables in order of loading: better coordination, collaboration, improved communication, cost saving, better decision management, time saving, quality improvement, clash detection, and buildability. Professionals in the industry are interested in how to efficiently carry out their responsibilities while saving on resources this are the immediate advantages of adopting BIM.

Factor 2 – Versatility: Versatility comprises of the following 6 variables in order of loading: sustainability, energy analysis, improved facility management, financial cost of adoption, safety management, and risk management. Other than the primary benefits, there are added benefits captured in these variables that come with improved technical know-how of BIM use and they come as a secondary requirement for making the decision to adopt. Sustainability and energy analysis loaded highest, notably, the green construction is an important topic globally and BIM enables simulation analysis prior to construction.

Factor 3 – Competitiveness: Competitiveness comprises of the following 6 variables in order of loading: size of a project, pressure to remain competitive, technological capabilities, top management support, improved customer client relationship, and consistent lifecycle information. Size of a project was found to be dictating use of BIM, however all sizes of projects at an international scale demand competitiveness, hence professionals led by their top management should foster technological capabilities to boost consistent lifecycle information, ultimately ensuring improved customer client relationship.

Factor 4 – Intelligence: The intelligence factor was made up of two variables as follows in order of their loading: Real-time capabilities, and intelligent 3D visualization. Information is shared in real-time and there is no danger of working on superseded drawings. BIM offers intelligent 3D visualization with simulation capabilities in real-time; this helps the team to appreciate their product prior to construction, and through all stages of a project's lifecycle.

Factor 5 – Transparency: This factor constitutes of the following three variables in order of their loading: transparency, return on investment and improved accuracy. BIM enables transparency because real-time data is accessible to relevant parties, there is no room for ambiguity or loopholes that facilitate over pricing and chances for corrupt deals are greatly reduced by transparent BIM. This plus other BIM benefits ensure positive ROI. Improved accuracy in the transparent environment cuts down on waste.

5. Conclusion

This research was designed as a survey in Nairobi Kenya, though other studies have studied BIM's adoption benefits and challenges this study targeted looking for underlying factors in BIM adoption. The respondents were parties that were aware of BIM. The objectives were to investigate BIM adoption in Nairobi and to identify the significant components of BIM adoption in Nairobi. BIM as a new technology is affected by the existing systems and structures hence demanding for the industry cooperation for the optimal benefits to be reaped. The underlying factors extracted tries to explain this phenomenon beyond the obvious attitude.

Adoption was found to be progressive, whereby 56.6% had adopted BIM, and with most of the industry players planning to adopt. Majority of the respondents were in BIM stages 1 and 2 while 3D was widely used as compared to the other dimensions. The main hindrance found to BIM adoption was lack of understanding of what BIM is; respondents were still confusing BIM for software; however, BIM is a system. The TPS conflicts with the BIM system. Proper training is recommended to elevate BIM understanding levels, this will ensure that BIM adoption goes beyond the custom of utilizing 3D visualization and clash detection.

Hindrances to BIM adoption were found to be: Cost of implementation, traditional procurement system, rigidity in leadership, fear of corrupt and hidden interest being exposed by transparent BIM, change resistant attitude, training and education challenges, complexity of BIM and size of projects. In addition, lack of the following impeded adoption: knowledge and awareness, understanding, contractual guidance, BIM skills, case studies, BIM champion and client's initiative.

The significant components found were efficiency, versatility, competitiveness, intelligence and transparency. They are the latent factors and they elicit the decision for the industry to adopt BIM.

Efficiency supports BIM adoption; it reflects immediate benefits that are easily communicated to users and understood. The factor is also geared towards effective collaboration which is a big challenge in the Kenyan fragmented construction industry. If collaboration is effective it in turn enables resource saving this corroborates [18]. These benefits make contract management process easier and effective. In this regard, awareness needs to be increased to enable adoption for the benefits to be useful to the industry.

Versatility factor supports adoption; this is about secondary benefits of BIM that players are likely to seek for after the primary needs have been addressed. Processes such as sustainability, energy and risk management analysis which have been traditionally difficult to conduct are easily executed through computer simulation. Energy analysis and sustainability which are green construction factors are catered for using simulation to reduce waste. Risk management especially safety risk which is a big challenge in the construction industry is well analyzed and mitigated early enough. It is up to the stakeholders to move from the outdated techniques of executing projects and embrace the versatility in BIM this corroborates [23]. Consequently, training of skills is key to bring understanding into the industry of how BIM brings versatility in the industry.

Competitiveness factor supports BIM adoption. Stakeholders who are used to carrying out small sized projects argue that BIM could be too expensive and complex to adopt in their situation. However, the global view shows that clients and trends are moving towards complex projects regardless of the size, therefore players must aim at remaining competitive or risk losing out on jobs. Competition has become borderless and the Kenyan professionals and contractors can become competitive enough to compete with international ones this corroborates [15], for BIM has become the global benchmark for competitiveness. The forward looking client seeks better ways of addressing the dynamics in the industry and the technological advancements eliminates methods that are detrimental to future trends this supports [48][49]. BIM helps the client understand their projects better, consultants who have adopted BIM are chosen to execute such client's projects, the non-adopters loose-out on such projects. Consequently, the top management input is important. There is need to invest in education and proper training to aid optimal BIM usage. Policy, process, and technology must work together to enable competitiveness.

Intelligence factor is in support of BIM adoption. Through the computer simulation all the planning and analysis is done before construction. Further any revisions made on the model are updated in real time. This is consistently maintained in the lifecycle of the project hence the cost of a project at operation and maintenance stage is greatly reduced as compared to how it is with TPS. Though TPS has attempted to incorporate BIM mainly for visualization, as has been practiced in Nairobi Kenya it however is important to note that the benefits of BIM are reaped when BIM system is adopted in totality, this corroborates [18].

Transparency supports and hinders BIM adoption at the same time. Ambiguity, errors, and misunderstanding are reduced because everyone is reading from the same model. Overquoting is not feasible and the client can follow through all steps with ease. Records and drawings sometimes get lost, BIM mitigates this because it is an information management tool in the lifecycle of a project. Transparency in ICT is good at curbing corruption but it is not supported by cartels this corroborates [5]; auditing can efficiently be carried out. Transparency leads to positive ROI.

Achievement of all the benefits of collaborative BIM is hindered by TPS and its adversarial nature that favours corrupt cartels. Unfortunately, there is no clear formula of adopting BIM in Nairobi, or in other counties in Kenya and in most countries because of lack of standards and guidelines this finding supports [19][17][18][10]. Where BIM has worked well the government has been involved this corroborates [36]. Though in Nairobi, some private organizations have taken the initiative to adopt BIM ahead of government directives, it should be noted that this group prepares procurement contracts, standards, and guidelines on an ad-hoc basis. These pioneering initiatives are likely to influence other reluctant observers where competitiveness is a factor determining winning of tenders. This was depicted by [16] as one of the models used across the world to aid adoption.

The recurring themes that need action here are awareness, procurement system, government mandate, standards, guidelines, education, training and technology; this corroborates [36]. Ultimately, adoption and implementation require awareness of what BIM is, leadership to give guidance, education to build technical capacity, training to advance the skills and necessary technology to execute the BIM process.

This study is applicable to other counties in Kenya and to most developing countries' scenarios, however situation specific research is recommended. The factors found could be analyzed further under Confirmatory Factor Analysis (CFA). Further research should be done on how software contributes to lack of understanding of BIM. It is also recommended that case studies on BIM projects be carried out in Nairobi to study ROI.

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References

[1] M. A. Seboru, "An Investigation into Factors Causing Delays in Road Construction Projects in Kenya," *Am. J. Civ. Eng.*, vol. 3, no. 3, pp. 51–63, 2015.

[2] B. W. Kogi and S. Were, "Factors Affecting Cost Overruns in

Construction Projects a Case of Kenya National Highways Authority," *Int. J. Proj. Manag.*, vol. 1, no. 10, pp. 167–182, 2017.

[3] P. P. Mbaabu, "Factor Influencing Implementation of Road Construction Projects in Kenya: A Case of Isiolo County, Kenya.," University of Nairobi, 2012.

[4] Kenya Vision 2030, "Kenya Vision 2030 _ Kenya Vision 2030," *Government of Kenya*, 2008. [Online]. Available: http://vision2030.go.ke/. [Accessed: 25-Nov-2018].

[5] B. Ndemo, "The Role of Youths in Fighting Corruption," *Business Daily*, Nairobi, Kenya, 01-Jul-2015.

[6] Nairobi City County, "Nairobi City County eDevelopment Permit System," *e Development Permit System*, 2020. [Online]. Available: http://ccn-ecp.or.ke/. [Accessed: 11-Jul-2020].

[7] N. Bui, C. Merschbrock, and B. E. Munkvold, "A review of Building Information Modelling for construction in developing countries," *procedia Eng.*, vol. 164, no. 1877, pp. 487–494, 2016.

[8] S. Kalinichuk, "Building information modeling," *J. Syst. Integr.*, vol. 3, pp. 25–34, 2015.

[9] National Institute of Building Science United States, "Frequently asked questions about National BIM Standard - United States," *National Institute of Building Science: National BIM Standard - United States*, 2019. [Online]. Available: https://www.nationalbimstandard.org/faqs. [Accessed: 26-Jun-2019].

[10] S. Azhar, M. Khalfan, and T. Maqsood, "Building Information Modelling (BIM): Now and Beyond," *Australas. J. Constr. Econ. Build.*, vol. 12, pp. 15–28, 2012.

[11] R. Bouška, "Evaluation of maturity of BIM tools across different software platforms," in *Procedia Engineering*, 2016, vol. 164, no. June, pp. 481–486.

[12] B. Succar, "Building information modelling framework: A research and delivery foundation for industry stakeholders," *Autom. Constr.*, vol. 18, no. 3, pp. 357–375, 2009.

[13] B. Succar, "The Five Components of BIM Performance Measurement," 2009.

[14] P. Smith, "Project Cost Management with 5D BIM," *Procedia - Soc. Behav. Sci.*, vol. 119, pp. 475–484, 2014.

[15] P. Smith, "BIM implementation - global strategies," *Procedia Eng.*, vol. 85, pp. 482–492, 2014.

[16] B. Succar and M. Kassem, "BIM adoption policies insights from across the world," in *CitA BIM gathering*, 2017.

[17] D. Manza, "Influence of Building Information Modelling Adoption on Completion of Construction Projects: A Case of Nairobi County, Kenya," Published Master's Thesis, University of Nairobi, 2016.

[18] M. M. Musyimi, "Building Information Modelling Adoption in COnstruction Project Management in Kenya: A Case Study of Nairobi County," Published Master's Thesis, University of Nairobi, 2016.

[19] T. N. Kimani, H. Jallow, B. M. Njuguna, and A. O. Alkizim, "BIM Awareness: The Kenyan and UK Scenarios," in *The Sustainable and Innovation Conference*, 2019, pp. 157–161.

[20] M. P. Wambui, "An Investigation into the Role of Building Information Modelling in Reducing Cost and Time Overruns Experienced In 2-Dimensional based construction- a Survey of construction practitioners in Nairobi County.," University of Nairobi, 2018.

[21] X. Xu, L. Ma, and L. Ding, "A Framework for BIM-enabled Life-cycle Information Management of Construction Project," *Int. J. Adv. Robot. Syst.*, pp. 1–13, 2014.

[22] P. Nowak, M. Książek, M. Draps, and J. Zawistowski, "Decision Making with Use of Building Information Modeling," *Procedia Eng.*, vol. 153, pp. 519–526, 2016.

[23] B. Grzyl, E. Miszewska-Urbańska, and M. Apollo, "Building Information Modelling as an Opportunity and Risk for Stakeholders Involved in Construction Investment Process," in *Procedia Engineering*, 2017, vol. 196, no. June, pp. 1026–1033.

[24] A. K. Nicał and W. Wodyński, "Enhancing Facility Management through BIM 6D," in *Procedia Engineering*, 2016, vol. 164, no. June, pp. 299–306.

[25] P. Bosch-sijtsema and P. Gluch, "Challenging construction project management institutions: the role and agency of BIM actors," *Int. J. Constr. Manag.*, pp. 1–11, 2019.

[26] A. Ali, "Building Information Modelling (BIM) and Project Management Implementation in Infrastructure and Civil Construction," 2016.

[27] B. Succar, "Building Information Modelling: conceptual constructs and performance improvement tools," University of Newcastle, 2013.

[28] D. Olsen and J. M. Taylor, "Quantity Take-Off Using Building Information Modeling (BIM), and Its Limiting Factors," *Procedia Eng.*, vol. 196, no. June, pp. 1098–1105, 2017.

[29] E. Papadonikolaki, A. Verbraeck, and H. Wamelink, "Formal and informal relations within BIM-enabled supply chain partnerships," *Constr. Manag. Econ.*, vol. 35, no. 8–9, pp. 531–552, 2017.

[30] N. D. Aziz, A. H. Nawawi, and N. R. M. Ariff, "Building Information Modelling (BIM) in Facilities Management: Opportunities to be Considered by Facility Managers," in *Procedia - Social and Behavioral Sciences*, 2016, vol. 234, pp. 353–362.

[31] L. M. Khodeir and A. A. Nessim, "BIM2BEM integrated approach: Examining status of the adoption of building information modelling and building energy models in Egyptian architectural firms," *Ain Shams Eng. J.*, pp. 1–10, 2016.

[32] N. Azhar, Y. Kang, and I. U. Ahmad, "Factors Influencing Integrated Project Delivery In Publicly Owned Construction Projects: An Information Modelling Perspective," *Procedia Eng.*, vol. 77, pp. 213–221, 2014.

[33] R. M. Borjeghaleh and J. M. Sardroud, "Approaching Industrialization of Buildings and Integrated Construction Using Building Information Modeling," in *Procedia Engineering*, 2016, vol. 164, pp. 534–541.

[34] M. Yalcinkaya and D. Arditi, "Building Information Modeling (BIM)," *Int. Fed. Inf. Process.*, pp. 619–629, 2013.

[35] A. Charehzehi, C. Chai, A. M. Yusof, H. Chong, and S. C. Loo, "Building information modeling in construction conflict management," *Int. J. Eng. Bus. Manag.*, vol. 9, pp. 1–18, 2017.

[36] B. McAuley, A. Hore, and R. West, "Global BIM Study - Lessons for Ireland ' s BIM Programme Global BIM Study," Dublin, Ireland, 2017.

[37] M. F. Arshad, M. J. Thaheem, A. R. Nasir, and M. S. A. Malik, "Contractual Risks of Building Information Modeling: Toward a Standardized Legal Framework for Design-Bid-Build Projects Standardized Legal Framework for Design-Bid-Build Projects," *J. Constr. Eng. Manag.*, vol. 145, no. 4, pp. 1–14, 2019.

[38] B. Kumar and G. Hayne, "A Framework for Developing a BIM Strategy," in *Information Technology in Construction*, 2016.

[39] M. R. Hosseini, E. Azari, L. Tivendale, S. Banihashemi, and N. Chileshe, "Building Information Modeling (BIM) in Iran: An Exploratory Study," *J. Eng. Proj. Prod. Manag.*, vol. 6, no. 2, pp. 78–89, 2016.

[40] V. Kasiulevičius, V. Šapoka, and R. Filipavičiūtė, "Sample size calculation in epidemiological studies," *Gerontologija*, vol. 7, no. 4, pp. 225–231, 2006.

[41] R. Lowry, "The Friedman Test for 3 or More Correlated Samples," *Friedman Ranking Test*. pp. 1–5, 2012.

[42] M. Friedman, "The Use of Ranks to Avoid the Assumption of

Normality Implicit in the Analysis of Variance," *J. Am. Stat. Assoc.*, vol. 32, no. 200, pp. 675–701, 1937.
[43] Laerd statistics, "Friedman Test in SPSS - How to run the procedure, understand the output and run post-hoc tests using a relevant example in SPSS." Laerd statistics, 2013.
[44] B. Williams, A. Onsman, and T. Brown, "Exploratory factor analysis: A five-step guide for novices," *J. Emerg. Prim. Heal. Care*, vol. 8, no. 3, pp. 1–13, 2010.
[45] J. F. J. Hair, W. C. Black, B. J. Babin, and R. E. Anderson, *Multivariate Data Analysis*, 7th ed. England: Pearson, 2014.
[46] C. R. Kothari and G. Garg, *Research Methodology, Methods and Techniques*, 4th multi. New Delhi, Nairobi, London: New Age International Publishers, 2019.
[47] D. Child, *The essentials of factor analysis*, 3rd Ed. Ney York: Continuum International, 2006.
[48] N. Turina, M. Radujkovic, and D. Car-Pusic, "Design and build" in comparison with the traditional procurement method and the possibility of its application in the Croatian construction industry," in *8th International Conference*, 2008, pp. 1–8.
[49] N. Wachira, D. Root, P. Bowen, and W. Olima, "The Declining Role of the General Contractor in the Kenyan Construction Sector," in *CIB World Building Congress*, 2007, pp. 1883–1893.

Appendix 1: Component Score Coefficient Matrix for underlying factors of BIM adoption

	Factors				
Variables	1	2	3	4	5
Intelligent 3D visualization	-.078	-.052	.004	**.405**	-.017
Realtime capabilities	-.151	-.001	-.054	**.481**	.042
Transparency	-.150	-.099	-.049	.136	**.518**
Improved accuracy	-.024	-.090	-.019	.136	**.255**
Buildability	**.061**	-.153	-.043	.074	.271
Collaboration	**.249**	-.136	-.044	.057	-.076
Time saving	**.168**	.039	-.113	-.051	.005
Cost saving	**.221**	.042	-.119	-.144	.004
Quality improvement	**.216**	-.038	-.044	-.178	.045
Return on Investment	-.144	.150	-.065	-.067	**.343**
Better coordination	**.238**	-.073	.023	.028	-.171
Improved communication	**.245**	-.037	.030	-.025	-.211
Clash detection	**.165**	.006	-.036	.144	-.212
Consistent lifecycle information	.045	-.057	**.173**	-.063	.040
Better decision management	**.180**	-.028	.027	-.112	-.013
Risk Management	.108	**.123**	.007	-.151	-.052
Safety Management	-.047	**.152**	-.063	-.156	.259
Improved customer client relationship	-.062	.071	**.177**	-.160	.109
Improved facility management	-.100	**.170**	.032	-.005	.088
Energy analysis	-.063	**.328**	-.169	.139	-.131
Sustainability	-.006	**.325**	-.126	.035	-.166
Top management support	-.062	.104	**.182**	-.035	-.056
Financial Cost of adoption	-.077	**.181**	.118	.023	-.121
Technological capabilities	-.107	.021	**.273**	.107	-.090
Pressure to remain competitive	-.121	-.027	**.346**	.135	-.157
Size of a project	.054	-.314	**.403**	-.146	.129

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.

Factors Affecting Building Information Modelling (BIM) Adoption in Nairobi Kenya

Hellen Nyaboke Mosse[1], Charles Kabubo[2] and Mugwima Njuguna[3]

Abstract**—**Building Information Modelling (BIM) is a digital innovation that consists of a set of technologies, processes and policies and is based on an intelligent 3D model that enables Architecture, Engineering, Construction and Operation (AECO) team members to effectively collaborate, throughout the lifecycle of a facility. One of the challenges in the construction industry is lack of effective collaboration, which has contributed to poor quality, time and cost overruns in the lifecycle of a project. BIM is part of the solution to these challenges. However, Kenya lacks standards and guidelines to guide the implementation of BIM, making the adoption of BIM slow and difficult. The study sought to investigate level of BIM adoption in Nairobi and to identify the factors that influence its adoption. The study is exploratory with a sample of 18 respondents comprising Civil Engineers, Construction Project Managers, Architects, Mechanical Engineers, Electrical Engineers, Quantity surveyors, contractors and Facility Managers. The data was collected through a self-administered questionnaire and in-depth interview. It emerged that 93.8% know what BIM is and 62.2% have adopted BIM. Lack of understanding of BIM seems to be a key hindrance factor towards BIM adoption. 56.3% of the respondents understand that BIM is a not a software the rest do not understand BIM, since 25.1% think BIM is a software while 18.8 are uncertain. Cost, lack of knowledge, change resistant attitude, slow return on investment, and lack of government involvement are factors found affecting BIM adoption and implementation. It is recommended that BIM adoption will take place quicker through raising awareness, leadership, education and training regarding stakeholders in the construction industry. Further research is necessary to find out software contribution to lack of understanding of BIM.

Keywords**—**Adoption, BIM, Building information Modelling, Collaboration, Implementation.

I. INTRODUCTION

Building Information Modelling (BIM) is considered as a major paradigm shift after computer aided design (CAD) by the majority of industrial professionals and academic researchers [1]. It was first described by Charles Eastman in 1975, who published a paper of a prototype called Building Description Systems (BDS), that experimented on design applications [2]. Presently, BIM has been developed to allow the client, contractors and other professionals to access data through mobile devices, from wherever they are [3]. BIM is defined as a digital representation of the physical and functional characteristics of a facility, BIM is a shared knowledge resource for information about a facility, forming a reliable basis for decisions during its (facility) life-cycle; defined as existing from earliest conception to demolition [4]. Having this several collaborators in the life-cycle of a project makes management of information paramount [5]. BIM is not a software as has been the common misconception, rather, a Software supporting BIM should provide openness, interoperability and compatibility; simplicity and functionality, accuracy of data, expandability (3rd party plug-in), time management and clash detection, cost estimation and facility management [6].

According to [7] there are three BIM stages: BIM stage 0 (pre-BIM), BIM stage 1 (object based modelling), BIM stage 2 (model based collaboration), BIM stage 3 (network-based integration) and the last stage leads to Integrated Project delivery. BIM is a collaboration tool with various subsets commonly described in terms of dimensions: 3D (object modelling), 4D (time), 5D (cost), 6D (operations), 7D (sustainability) and even safety for 8D [8].

II. FACTORS GUIDING ADOPTION OF BIM

BIM is an information management tool [9], it promotes process cooperation, collaborative efforts and presents a chance for seamless flow of information in the life-cycle of a project [10], [11]. BIM enables coordination, clash detection, resource saving during construction, return on investment (ROI) [12] reduced project cost [13], [12], [14], better time management[12], [14] improved profitability and customer-client relationship [5]. It also enables facility management to be more efficient hence ROI is realized [11]. BIM also caters for risk management and safety evaluation [15], [9]. BIM provides a platform for visualization, collaboration, automation, integration and communication between the different stakeholders [16].

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Successful adoption of BIM relies on the power of the stakeholder, whereby the client is the most powerful and will attain more benefits as compared to the Project Manager followed by the Architect and the Engineer [17]. Government leadership and mandates that lead to achieve mutual standards and protocols and avoid duplication of efforts have proven to be a critical factor for successful BIM implementation in leading countries such as USA, UK and Singapore [18].

III. CHALLENGES OF BIM IN CONSTRUCTION

There is a conflict between BIM system and traditional procurement system [16]. The traditional procurement allows use of BIM for visualization only [19] whereas BIM demands life-cycle utilization. There is unclear consensus on how to implement BIM [5] and the fragmented nature of the industry makes it harder [20]. Lack of government efforts to mandate BIM [21], lack of contractual guidelines [22], and lack of standards [23] are impediments towards BIM adoption. There is generally a change resistant attitude in the industry [11] and stakeholders do not want to pioneer, but prefer to watch, from a distant, on the situation to evolve [8]. Furthermore, there is a challenge with the new skills that have emerged and that lack adequate training [11].

Whereas there are issues on type of software to use, there equally seem to be a challenge on data interoperability [11]. How well BIM is understood is a major concern, because adoption of BIM has remained at 3D Modelling for visualization and clash detection, while other areas have remained unexploited [24].

Research on BIM adoption has been carried out extensively in developed countries and findings can apply to most countries scenarios, though, Bui et al. [23] recommend comprehensive country specific research to be carried out in developing countries to address specific challenges within those countries. This exploratory study was carried out to find out factors affecting BIM adoption in Nairobi, Kenya.

IV. METHODOLOGY

This research was exploratory, the survey research was done through self-administered questionnaires and in-depth interviews that generated both quantitative and qualitative data. Snowball sampling was used to carry out this exploratory research, since BIM is relatively new in Kenya. The research focused on Nairobi and the respondents were drawn from Civil Engineers, Architects, Construction Project Managers, Quantity Surveyors, Contractors and Facility Managers. The in-depth interview was targeting knowledgeable persons in BIM, while the self-administered questionnaire method was targeting professionals with some knowledge of BIM. Sample size was 16 for self-administered questionnaires and 2 for in-depth interview.

V. RESULTS AND DISCUSSION

Respondents' profile was as per Fig. 1, they have been exposed to publicly financed and privately financed projects (Fig. 2). 81% of the respondents have used BIM between 0 to 5 years (Table I), their work experience was spread out from 0 to 30 years. This work experience did not necessarily contribute to BIM adoption, experience in the group of 0 to 5 have only used BIM between 0 to 5 years, this is a similar case to those with experience of between 15 to 30 years. The group of 5 to 15 years of experience, however, shows 73% have used BIM in 0 to 5 years, 18% in 5 to 10 years and 9% in 10 to 15 years.

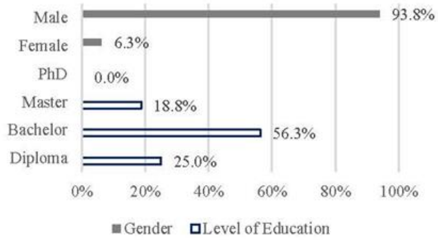

Fig. 1 Respondents profile

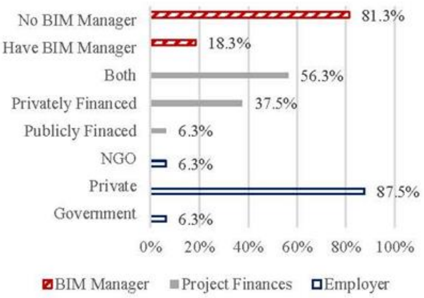

Fig. 2 Respondents Employer, Project finances and BIM Manager

Table I
Work experience in relation to BIM experience

Number of years of experience	How many years have you used BIM 0-5	5-10	10-15	Total
0-5	100%	0%	0%	100%
5-15	73%	18%	9%	100%
15-30	100%	0%	0%	100%
Total	81%	13%	6%	100%

A. Adoption of BIM

As shown in Fig. 3 BIM adoption was found to be at 62.2% and 93.8% of respondents claim to know what BIM is. However, when asked if BIM was a software, only 56.3% were able to say it is not a software, hence confirming that BIM is not well understood this corroborates [24]. Most respondents 62.4% reported to be at 3D modelling, this show that BIM adoption in Nairobi is either at stage 1 or at stage 0 moving to stage 1.

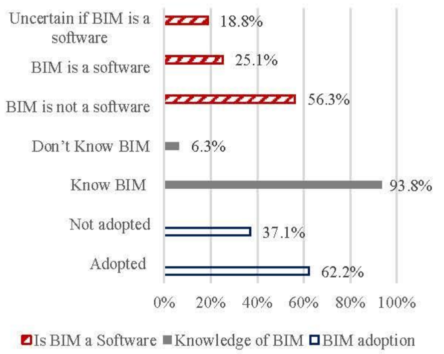

Fig. 3 BIM knowledge and adoption

B. Factors in BIM adoption

Personal Motivation and attitude: It were found that a person's motivation combined with the input of the organization they worked for contributed to BIM adoption. Fig. 4 shows BIM self-trained make up 75% of the total respondent, whereas 43.8% were trained by the employer. Some of the self-trained also benefitted from employers' training. College BIM Education contributes to 12.5%, the remaining 87.5% never got educated on BIM. Change resistant attitude was qualitatively recorded to be a major obstacle, professionals tend to be rigid towards new technologies mainly due to lack of information on BIM. It was also noted that professionals are not willing to explore, research and adopt new concepts that could improve workflow.

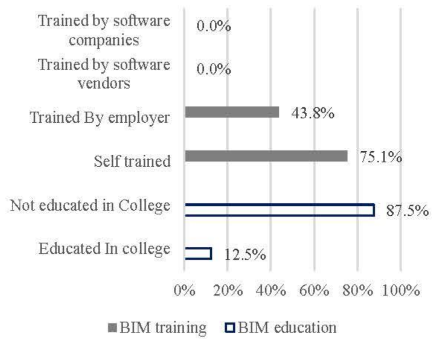

Fig. 4 Education and Training

Readiness to adopt BIM: Presence of a BIM manager in an organization is a strong indicator that the organization is planning to, or it has already adopted BIM, the results showed that only 18.3% of the organizations had a BIM manager while 81.3% did not have (Fig. 2). However, there were respondents who had adopted BIM at an individual's capacity, and they recorded they did not have a BIM manager. A BIM consultant is another adoption indicator 56.2% reported to have engaged a consultant in their organization, while 37.6% did not have. An organization with standard and guidelines is on the right path to adoption, 31.3% reported to be having guidelines, 43.8% had standards (Table II).

Awareness: There was insufficient knowledge of BIM, for 93.7% could identify definition of BIM but only 56.1% knew that BIM is not a software, 18.8% did not know whereas 25% thought it is a software. Respondents were relating BIM to 3D modelling, visualization and clash detection, they either refuse to exploit or were unaware of the 4D, 5D, 6D, 7D and 8D.

Collaboration, time saving, cost and Return on Investment (ROI) were some of the key components important in BIM adoption and the respondents agreed at a mean of 1.31, 2.13, 1.69 and 2.91 respectively, as shown in Table II. Though ROI is a component that needs case studying over a period, already there is a general agreement of 68.7% that BIM facilitates a positive ROI, this however, seems to be slow on small projects.

Education and training: In terms of education only 12.5% had received BIM education in college, though there lacks a formal curriculum for it. While at the job market 75.1% were self-trained in BIM, some reported that employers do not prioritize on BIM training. Fig. 4 and Table II illustrate this. There lacks well-rounded BIM training by experienced and skilled trainers this could also be attributed to inadequate BIM skills and BIM experts.

Technology: 81.3% and 62.6% reported to be having capable network and software, respectively. Some employers, however, did not readily invest in new technologies and did not allocate time for their learning.

High cost of implementation: 75% of the respondents believed that the cost of BIM implementation was high in terms of hardware, software & training.

BIM Government Policy and regulations: Having established that there lacks clear consensus on how to implement BIM from literature review [5], the study established that this was also the case for Nairobi. It was found that 67.2% respondents thought that a BIM guide is needed and 87.5% felt the need for the regulations to be backed up with a regulatory body (Fig. 5 and Table II).

Leadership: 93.7% of the respondents felt that government should lead in BIM adoption, being that it is the biggest construction client. On whether BIM should be made compulsory, the results were at a mean of 2.56 where 42.8% agreed, 31.3% were uncertain and 24.9% did not agree. The following were other observations on Leadership:

- Clients are not demanding BIM on their project because they do not understand it.
- Employers do not invest in new technologies and, they do not allocate time for learning BIM and new technologies
- Lack of facilities that can support BIM besides lack of government's will to fund research and actual implementation is a gap in BIM leadership. Consequently, the implementation process requires the initiative of the private sector.

Table II
Factors in BIM adoption

Symbol	MEAN	Agree %	Uncertain %	Disagree %
BIM Definition	1.25	93.8	6.3	0
BIM is not a software	2.31	56.3	18.8	25.1
BIM handles large and complex projects effectively	1.19	100	0	0
Improved decision making	1.56	93.7	6.3	0
Improved communication	1.56	93.7	6.3	0
BIM's real time	1.94	87.4	6.3	6.3
Consistent data management	1.88	75	25	0
3D visualization	1.50	93.7	6.3	0
Clash detection	1.63	87.5	12.5	0
Computer simulation	1.69	87.5	12.5	0
BIM saves time	2.13	81.2	18.8	0
BIM saves cost	1.69	81.3	18.8	0
BIM aids collaboration	1.31	93.8	0	6.3
BIM facilitates ROI	2.19	68.7	25	6.3
Have Software	2.19	62.6	31.3	6.1
Have capable Hardware	1.81	81.3	6.3	12.4
Education	3.88	12.5	6.2	81.3
Training	2.31	75	12.5	75
3D (modelling)	2.50	62.4	0	37.6
4D (Time)	3.50	31.3	6.1	62.6
5D (Cost)	3.56	17.9	18.8	63.3
6D (Operation)	3.50	24.9	12.5	62.6
7D (Maintenance)	3.63	18.8	12.5	68.8
8D (Safety)	3.94	6.3	18.7	75.0
Organizations with guidelines	3.0	43.8	18.7	37.5
Organizations with standards	2.88	31.3	31.2	37.5
Organization with BIM consultant	2.75	56.2	6.2	37.6
Government should lead in adoption	1.56	93.7	0	6.3
BIM should be made compulsory by the government	2.56	43.8	31.3	24.9

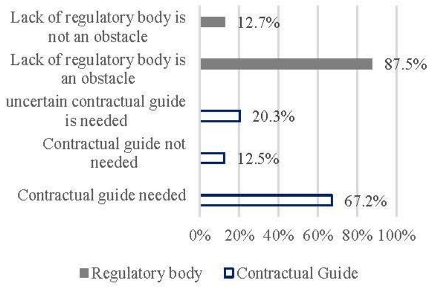

Fig. 5 BIM Regulations and Guide

- Transparency in construction projects is a disadvantage to some stakeholders who may be against curbing graft, BIM ensures seamless, sustainable and logistic flow of information, this corroborates [11].
- Inadequate benchmarking against more BIM advanced countries.
- Fragmentation in the construction industry contributes to coordination and hesitancy of the stakeholders towards BIM adoption and implementation.
- There is a scarcity of BIM champions, individuals or organizations pushing for BIM.

Other Qualities favouring BIM adoption included the real time characteristics, improved, decision management, communication, data management, coordination, and computer simulation (Table 11).

VI. CONCLUSION

Understanding of BIM is an enormous challenge in BIM adoption in Nairobi Kenya, because even for those who have adopted BIM and claim to be knowing BIM still confuse it for being a software; they use specific software's name - especially REVIT - interchangeably with the term BIM. Though the respondents named cost of implementation as a major impediment, others think it is a misconception which can be eliminated by having full knowledge and understanding of BIM workflow. This will eliminate flawed processes, where a small percentage of benefits from the available tools is used, hence reaping low in efficiency.

Further studies should use bigger sample size on the topic, in addition, there is need to find out if software companies, sellers and marketers contribute to low understanding of BIM.

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REFERENCES

[1] S. Kalinichuk, "Building information modeling," *J. Syst. Integr.*, vol. 3, pp. 25–34, 2015.

[2] T. Goubau, "A History of BIM - APROPLAN," *A History of BIM*, 2012. [Online]. Available: https://www.aproplan.com/blog/construction-collaboration/a-history-of-bim. [Accessed: 10-Oct-2018].

[3] Graphisoft, "About BIM," *Graphisoft a Nemetschek Company*, 2019. [Online]. Available: https://www.graphisoft.com/archicad/open_bim/about_bim/. [Accessed: 26-May-2019].

[4] National Institute of Building Science United States, "Frequently asked questions about National BIM Standard - United States," *National Institute of Building Science: National BIM Standard -United States*, 2019. [Online]. Available: https://www.nationalbimstandard.org/faqs. [Accessed: 26-Jun-2019].

[5] S. Azhar, M. Khalfan, and T. Maqsood, "(asce)ei.1943-5541.0000193 Status of BIM Adoption and the BIM Experience of Cost Consultants in Australia," *Australas. J. Constr. Econ. Build.*, vol. 12, pp. 15–28, 2012.

[6] R. Bouška, "Evaluation of maturity of BIM tools across different software platforms," in *Procedia Engineering*, 2016, vol. 164, no. June, pp. 481–486.

[7] B. Succar, "The Five Components of BIM Performance Measurement," 2009.

[8] P. Smith, "Project Cost Management with 5D BIM," *Procedia - Soc. Behav. Sci.*, vol. 119, pp. 475–484, 2014.

[9] X. Xu, L. Ma, and L. Ding, "A Framework for BIM-enabled Life-cycle Information Management of Construction Project," *Int. J. Adv. Robot. Syst.*, pp. 1–13, 2014.

[10] B. Grzyl, E. Miszewska-Urbańska, and M. Apollo, "Building Information Modelling as an Opportunity and Risk for Stakeholders Involved in Construction Investment Process," in *Procedia Engineering*, 2017, vol. 196, no. June, pp. 1026–1033.

[11] A. K. Nicał and W. Wodyński, "Enhancing Facility Management through BIM 6D," in *Procedia Engineering*, 2016, vol. 164, no. June, pp. 299–306.

[12] L. M. Khodeir and A. A. Nessim, "BIM2BEM integrated approach: Examining status of the adoption of building information modelling and building energy models in Egyptian architectural firms," *Ain Shams Eng. J.*, pp. 1–10, 2016.

[13] N. D. Aziz, A. H. Nawawi, and N. R. M. Ariff, "Building Information Modelling (BIM) in Facilities Management: Opportunities to be Considered by Facility Managers," in *Procedia - Social and Behavioral Sciences*, 2016, vol. 234, pp. 353–362.

[14] N. Azhar, Y. Kang, and I. U. Ahmad, "Factors Influencing Integrated Project Delivery In Publicly Owned Construction Projects: An Information Modelling Perspective," *Procedia Eng.*, vol. 77, pp. 213–221, 2014.

[15] D. Olsen and J. M. Taylor, "Quantity Take-Off Using Building Information Modeling (BIM), and Its Limiting Factors," *Procedia Eng.*, vol. 196, no. June, pp. 1098–1105, 2017.

[16] P. Bosch-sijtsema and P. Gluch, "Challenging construction project management institutions : the role and agency of BIM actors," *Int. J. Constr. Manag.*, pp. 1–11, 2019.

[17] A. Ali, "Building Information Modelling (BIM) and Project Management Implementation in Infrastructure and Civil Construction," 2016.

[18] P. Smith, "BIM implementation - global strategies," *Procedia Eng.*, vol. 85, pp. 482–492, 2014.

[19] M. M. Musyimi, "Building Information Modelling Adoption in COnstruction Project Management in Kenya: A Case Study of Nairobi County," Published Master's Thesis, University of Nairobi, 2016.

[20] B. Kumar and G. Hayne, "A Framework for Developing a BIM Strategy," in *Information Technology in Construction*, 2016.

[21] B. McAuley, A. Hore, and R. West, "Global BIM Study - Lessons for Ireland ' s BIM Programme Global BIM Study," Dublin, Ireland, 2017.

[22] M. F. Arshad, M. J. Thaheem, A. R. Nasir, and M. S. A. Malik, "Contractual Risks of Building Information Modeling : Toward a Standardized Legal Framework for Design-Bid-Build Projects Standardized Legal Framework for Design-Bid-Build Projects," *J. Constr. Eng. Manag.*, vol. 145, no. 4, pp. 1–14, 2019.

[23] N. Bui, C. Merschbrock, and B. E. Munkvold, "A review of Building Information Modelling for construction in developing countries," *procedia Eng.*, vol. 164, no. 1877, pp. 487–494, 2016.

[24] M. R. Hosseini, E. Azari, L. Tivendale, S. Banihashemi, and N. Chileshe, "Building Information Modeling (BIM) in Iran : An Exploratory Study," *J. Eng. Proj. Prod. Manag.*, vol. 6, no. 2, pp. 78–89, 2016.