INVESTIGATION OF THE CURRENT LEVEL OF BUILDING INFORMATION MODELLING (BIM) ADOPTION BY BUILDING CONTRACTORS IN KENYA

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Investigation of the Current Level of Building Information Modelling (BIM) Adoption by Building Contractors in Kenya

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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 15.05.2024

Joel Odhiambo Oyuga

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

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DEDICATION.

To my wife, Faith, for her patience and support during my period of studies.

To my mother, Mrs Oyuga, without your strong foundation, this would have not been possible.

To my children, Angel, baby Odhiambo and Angelo, for being patient with their dad

.

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Though several people have contributed in one way or the other to enable me to finish this research, I am solely responsible for any shortcomings in this thesis.

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ACRONYMS AND ABBREVIATIONS

2D	Two Dimension
3D	Three Dimension
4D	Fourth Dimension
5D	Fifth Dimension
AIA	American Institute of Architects
ANOVA	Analysis of Variance
AGC	Association of General Contractors
AOT	Accessibility, Observability and Trialability
BDT	BIM Demonstration and Training
BIM	Building Information Modelling
BIMIF	BIM Implementation Framework
BIMIBK	Building Information Modelling Implementation Board of Kenya
BORAQS	Board of Registration of Architects and Quantity Surveyors
BQ	Bills of Quantities
BSA	BuildingSMART Alliance
BSI	British Standards Institute
CAD	Computer Aided Drafting
CBD	Central Business District

CBET	Competency Based Education and Training
CD	Compact Disc
CDACC	TVET Curriculum Development Assessment and Certification Centre
CDM	Construction Delivery Method
CICRP	Computer Integrated Construction Research Program
CI/SFB	Construction Index/Samarbetskommitten for Byggnadsfragor
COBie	Construction Operations Building Exchange
CNC	Computer Numerical Control
CPD	Continuous Professional Development
CPM	Construction Project Management
CSE	Civil Structural Engineer
CUE	Commission of University Education
DBB	Design-Bid-Build
DVD	Digital Versatile Disc
EBK	Engineer's Board of Kenya
EU-BIM	European Union BIM Task Group
EU	European Union
FWCI	Foundation of the Wall and Ceiling Industry
GSA	Government Service Administration

ICT	Information Communication and Technology
ICD	Interoperability and Clash Detection
IDCC	Integrated Design, Coordination and Collaboration
IFC	Industry Foundation Class
IPD	Integrated Project Delivery
IT	Information Technology
JKUAT	Jomo Kenyatta University of Agriculture and Technology
KABCEC	Kenya Association of Building and Civil Engineering Contractors
KBRC	Kenya Building Research Centre
KNBS	Kenya National Bureau of Statistics
K-S	Kolmogorov-Smirnov Test
M	Mean
MEP	Mechanical, Electrical and Plumbing
MEPAM	MEP Analysis and Modelling
MS	Microsoft
NACOSTI	National Commission of Science, Technology, and Innovations
NBIMS	National BIM Standards
NBS	National Building Specifications
NBTG	National BIM Training Guide

NCA	National Construction Authority
NCLR	National Council of Law Reporting
NIBS	National Institute of Building Sciences
NIST	National Institute of Standards and Technology
PAS	Publicly Available Specifications
P&D	Plumbing and Drainage
QTO	Quantity Take Off
R&D	Research and Development
RFI	Request for Information
RIBA	Royal Institute of British Architects
RICS	Royal Institute of Chartered Surveyors
ROI	Return on Investment
SAM	Structural Analysis and Modelling
SD	Standard Deviation
SE	Standard Error
SNK	Student-Newman-Keuls Post Hoc Test
SPSS	Statistical Package for Social Sciences
TVETA	Technical and Vocational Education and Training Authority
UK	United Kingdom

USA United States of America

USACE United States Army Corps of Engineers

XML Extensible Markup Language

ABSTRACT

Construction is a key industry in any economy. It is made up of many actors, delivery methods, deliverables, workflow processes and tools. Building Contractors are one of the main actors within this industry since they execute physical construction to match the virtual output by design actors. BIM has come out as one of the versatile tools that Building Contractors employ in their construction processes to achieve an ideal Iron Triangle metrics of Time, Cost and Quality. These new, disruptive methodologies and approaches have resulted in higher levels of BIM Adoption by Building Contractors around the world. This is not the case for Building Contractors in Kenya. This study investigated the current status of BIM Adoption by Building Contractors in Kenya, established the status of BIM Essentials, BIM Maturity and BIM Risk Tolerance amongst Building Contractors in Kenya, and established the relationship between these three factors and BIM Adoption. This study used the survey method. For questionnaires, data collection through random sampling was domiciled in active construction sites within Nairobi County, within specific planning zones that had met the threshold of BIM deployment. Interviews were also administered to NCA, KABCEC, BIM Resellers and Insurance Agents to corroborate and clarify certain findings identified during analysis of questionnaires. Data was processed using Ms Excel 2016, SPSS 22 and PSPP. Inferential analysis was deployed using tools like Shapiro-Wilk test, sample t tests, one-way ANOVA tests, regression models and Pearson Correlation. Using one sample t test with a universal mean of 2 representing low, BIM Essentials, $t(61) = -0.109$, $\alpha > 0.05$, $SD = 1.15$ indicated that BIM Essentials amongst Building Contractors was low. BIM Maturity, $t(61) = 1.214$, $\alpha > 0.05$, $SD = 1.49$ indicated that BIM Maturity amongst Building Contractors was low. BIM Risk Tolerance, $t(61) = 0.492$, $\alpha > 0.05$, $SD = 1.15$ indicated that BIM Risk Tolerance amongst Building Contractors was low. Overally, BIM Adoption, $t(61) = -0.118$, $\alpha > 0.05$, $SD = 1.47$ indicated that BIM Adoption amongst Building Contractors was low. A primary multivariate regression model indicated that BIM Essentials positively influenced BIM Adoption while BIM Maturity and BIM Risk Tolerance were not strong enough to influence BIM Adoption. This study found out that BIM Adoption by Building Contractors in Kenya was lower compared to global trends. At a macro level, the main reasons for this were the predominant Design-Bid-Build method of construction delivery, high costs of BIM licences, low or no government involvement on issues relating to BIM, low levels of professional BIM training and poor enforcement of copyright laws in Kenya. At a micro level, Building Contractors adopted 2DCAD, 3DBIM and 5DBIM tools that are related to their scope of works more than the 4DBIM, SAMBIM and MEPAMBIM tools. For BIM to thrive amongst Building Contractors in Kenya, this study recommends that the National Government be greatly involved by creating relevant mandates and regulations, by funding BIM related research, by enforcing copyright laws, and by creating specific time defined taskgroups to advance this cause. This study proposes a BIM Implementation Framework to assist in improving BIM adoption amongst Building Contractors in Kenya.

KEYWORDS: BIM Adoption, BIM Essentials, BIM Maturity, BIM Risk Tolerance, Diffusion of Innovation, Hype Cycle.

CHAPTER ONE

INTRODUCTION

1.1 Background of the Study

Construction has been synonymous with human development and therefore, several attributes associated with this industry have been defined and refined over time. These attributes include actors, delivery methods, deliverables, workflow processes and tools. The Construction Industry is made up of various actors, broadly categorised under client, design actors, government agencies, building contractors and manufacturers (Graphisoft, 2015) who are further subdivided into various specialities. For the Building Contractors to effectively communicate and execute their mandate, they use pre-established construction delivery methods (CDMs) which broadly fall under the Design-Bid-Build (DBB) or the Integrated Project Delivery (IPD) method (Chien et al., 2014). Regardless of the CDM, the building contractors must work within pre-established workflow processes whose stages include conceptual, detail design, analysis, documentation, construction, operation and maintenance stage (Cheng & Lu, 2015). Tools used by Building Contractors in any of CDM's to achieve the workflow have improved over time giving rise to various periods such as the traditional, the Computer Aided Drafting (CAD) and the Building Information Modelling (BIM) periods (Azhar et al., 2011). The deliverables have remained the same over this period of time, comprising of graphical documentation like orthographic, parallel and perspective projections and non-graphical documentation like specifications, calculations, quantity take-offs, cost estimation and construction schedules (Graphisoft, 2015). BIM breaks away from this form of workflow process and offers a virtual model based documentation that consolidates both graphical and non-graphical into one parametric model (NBS, 2017).

BIM is the use of Information Technology (IT) based interfaces (Enynon, 2016; Walasek & Barszcz, 2017) to create a virtual model of a building, and in the process, make the said virtual building a seamless depository of all information relating to the building, including physical and functional characteristics, and life cycle information

(Azhar et al., 2011) during the whole lifetime of the said building. BIM brings in several capabilities which cannot be achieved in the traditional or CAD method. Besides Two Dimension (2D) drafting and Three Dimension (3D) modelling, new capabilities include 3D parametric modelling, Fourth Dimension (4D) parametric scheduling, Fifth Dimension (5D) parametric costing, Integrated Design Coordination and Collaboration (IDCC), Interoperability and Clash detection (ICD), Structural Analysis and Modelling (SAM), MEP Analysis and Modelling (MEPAM).

BIM is regarded as the most prominent, radical and transformative technology to have been experienced(Steinert & Leifer, 2010) in the construction industry. Its adoption follows a predictable pattern with regards to adoption of new technologies and several theories and models have been generated to explain this phenomenon.

Levels of BIM adoption at a global level are varied, with the notable factors influencing it being time, geographical location, size of economy and government policies towards BIM (Oyuga et al., 2022). With regards to time, for example, BIM usage in the UK has grown from 13% in 2011 to 73% in 2020 (NBS, 2020) while the USA experienced an equivalent growth from 28% in 2008 (MHC, 2012) to 79% in 2015 (Gerges et al., 2017). With regards to geographical location, Europe, North America and Asia (Liao et al., 2020) have higher level levels of BIM adoption compared to South America (Loyola & López, 2018), Africa (Babatunde et al., 2020), Middle East and Oceania. With regards to size of economy, growth of BIM was notable in developed economies, a pattern that is not replicated in developing economies with cost of BIM tools coming out as a major barrier to BIM adoption. With regards to government policies towards BIM, studies have shown that countries with higher BIM adoption levels have had direct government interventions, or subtle policies that guide towards improved BIM adoption (Oyuga et al., 2021). While the UK government directly intervened through introducing and enforcing BIM mandates, generating and enforcing BIM related policies, consistently funding BIM related activities and has heavily in BIM research (NBS, 2019), the USA government took a subtle approach by using Government Service Administration (GSA) and United States Army Corps of Engineers (USACE) to influence adoption by generating and enforcing BIM related policies for example making it compulsory for all government contracts to be handled in BIM, establishing minimum thresholds for new projects that must be implemented using BIM, consistently funding BIM related activities and has heavily in BIM research (Cheng & Lu, 2015).

Available studies with regards to BIM adoption in Kenya inferred that the adoption rate was low. Various Kenyan researcher have tried to quantify BIM adoption rate over time. Manza, in his 2016 study of BIM adoption levels concluded that BIM was still at it's infancy stage in Kenya (Manza, 2016). Mosse *et al,* when doing a similar study in 2020 found out that there were improvements of BIM adoption levels to highs of 70% amongst architects and lows of 37% amongst Quantity Surveyor, with the average adoption rate being 57% (Mosse et al., 2020) This pattern is consistent with other global patterns showing that time had a positive influence on BIM adoption in a country. This study therefore strived to give an updated status with regards to BIM adoption levels in Kenya. With regards to geographical location and size of economy, studies have shown that Kenya is not different from its geographical neighbours at a global level, countries like South Africa, Nigeria or Ethiopia in terms of structure, CDMs and cultural perceptions towards construction (Oyuga et al., 2022) and as such low level of adoption are consistent to the levels in the mentioned countries.

This study shall limit itself to the Diffusion of Innovation Theory (Sarkar, 1998) and the Hype Cycle Theory (Steinert & Leifer, 2010). Study of these two theories show that adoption of BIM is influenced by several factors which are broadly classified as BIM Essentials associated factors (which include Availability, Observability and Trialability, Contagion, Hyping and Social Organisation), BIM Maturity associated factors (which include Simplicity and Complexity, Interoperability and Compatibility, Demonstration and Training, Collaboration, Experience and Government Policies) and BIM Risk Tolerance associated factors (which include Relative Advantage, Protection of Intellectual Property, Professional Liability, Confidentiality and User Fatigue) amongst other factors.

1.2 Problem Statement

Use of BIM has resulted into better results with regards to the Iron Triangle metrics of Construction which constitute of time, cost and quality. 3D parametric modelling has improved how Building Contractors understand a building before starting the actual construction. 4D parametric scheduling has improved how the Building Contractor organises the project duration based on parametric activities and sub activities. 5D parametric costing has helped the Building Contractors understand in real time, effect on project cost that certain decisions create. The other capabilities complement these three chief metrics to improve the overall construction process.

While these benefits might be considered small and meaningless when dealing with a Building Contractor at a micro level, when considering all Building Contractors, the benefit at a national level is substantial to any economy with institutions like NBS publicly stating that BIM adoption has resulted in cost savings and efficiency in delivering public projects (NBS, 2020). Most governments especially in America, Europe and Asia have taken note of these benefits and come up with deliberate policies and mandates (McAuley et al., 2017) that enhance BIM adoption amongst Building Contractors within their respective jurisdictions.

Within the frontiers of Information Technology, Kenya has been known as a leader on innovation and adoption of ICT related technologies like M-PESA (Nippon Koei Co Ltd et al., 2014) and USHAHIDI (Ajao, 2017). However, with regards to BIM adoption in Kenya, there seems to be a disconnect to this trend. Detailed studies have not been done to clearly show how BIM adoption by Building Contractors in Kenya compare globally which can be interpreted to mean that there is a low level of BIM adoption amongst Building Contractors in Kenya. With studies showing this BIM adoption increases with time, this study strives to investigate this and possible give the current status of BIM Adoption by Building Contractors, a position that can be used in future studies to establish if the adoption is improving. Several catalysts and barriers might be causing the current state of adoption, that this study also strives to investigate.

1.3 Purpose of the Study

To establish reasons behind the low levels of BIM Adoption amongst Building Contractors in Kenya, the study shall carry out a survey to investigate the level of BIM adoption amongst Building Contractors besides looking at catalysts and barriers that are causing the mentioned status of BIM adoption amongst Building Contractors.

1.4 Study Objectives

1.4.1 Ultimate Objective.

To create an appropriate framework that will improve BIM adoption levels amongst Building Contractors considering the catalysts and barriers that influence adoption.

1.4.2 Specific Objectives.

1) To establish the current level of BIM adoption amongst Building Contractors in Kenya.
2) To investigate the relationship between BIM Essentials and BIM Adoption amongst Building Contractors in Kenya.
3) To investigate the relationship between BIM Maturity and BIM Adoption amongst Building Contractors in Kenya.
4) To investigate the relationship between BIM Risk Tolerance and BIM Adoption amongst Building Contractors in Kenya.

1.5 Study Assumptions

This thesis has made assumptions based on theories associated with this study.

1) All stakeholders in the Building Construction Industry are rational beings who have given preferences, pursue self-interest and seek to get the best value possible at the minimal cost possible (Vriend, 1995).
2) The results of the Construction Delivery Methods (CDMs) used to deliver construction projects in Kenya are consistent with the global standards in terms of cost, duration, and quality.
3) Governance networks and policies towards Building Contractors have been consistent and long term in nature. Though specifics of these policies may vary, their effect cuts across all cadres of Building Contractors equally.
4) Cost and exposure of all Building Contractors to ICT related technologies is equal and consistent throughout all the NCA cadres and influences the Building Contractors in the same way.

1.6 Study Significance

This research picks up from the works of Kassem (2015) on macro-BIM adoption and applies concepts of BIM adoption to Building Contractors in Kenya. Various indicators were tested to give measurements on Availability, Observability and Trialability (AOT) of BIM to know the level of BIM adoption (Kassem & Succar, 2015). This research also picks up from the works of Succar (2009) on BIM maturity and applies it to Building Contractors in Kenya. Various indicators to give measurements on government policies, BIM training, BIM simplicity, BIM interoperability and BIM capabilities to know the level of BIM Maturity (Succar, 2009). This research further picked up from the works of Sung (1996) on Financial Risk Tolerance and applies concepts of BIM Risk Tolerance where various indicators were tested to give measurements of BIM experience, BIM awareness on benefits and challenges, Intellectual Property and Construction Liability Cover (Sung & Hanna, 1996).

Research work on BIM adoption in Kenya is less compared with other jurisdictions at a global level. As of December 2016, works of Mumbua (2016) on BIM adoption amongst CPM in Kenya and Manza (2016) on BIM influence on completion of construction projects were the notable publications on BIM in Kenya. This study fills a research gap by investigating levels of BIM adoption specifically amongst Building Contractors in Kenya thereby enhancing our understanding of how this critical stakeholder in construction views BIM.

1.7 Study Justification

Since Industrial Revolution, most industries like automobile and manufacturing have refined their processes resulting in superior products at affordable costs. This cannot be said about the construction industry which is said to have lagged behind in refining its processes. BIM is regarded as a new, good, disruptive technology in the construction industry since it overhauls all traditional systems and methodologies that have been used in this sector. For Building Contractors, BIM minimises several inefficiencies (Alhusban et al., 2017) ranging from design documentation, information inaccuracies and incompatibility.

Benefits accrued from BIM adoption have been documented by many researchers for a period of about 20 years. This continuous documentation has catalysed BIM adoption either naturally through contagion, or through government interventions as shown in the table 116 in appendix 5. This study is relevant since it investigates why Building Contractors in Kenya are lagging on issues relating to BIM adoption, yet Kenya is a global leader on ICT related technologies.

1.8 Study Scope

Geographically, this study focuses on Nairobi County and specifically, the planning zones established in 2004 (Nippon Koei Co Ltd et al., 2014) that ensures that Building Contractors appointed for projects within these jurisdictions are certified NCA level 4 and above. As indicated in figure 1 in Appendix 6, these zones are CBD, Upper Hill, Westlands, Spring Valley and Kileleshwa, Main Industrial Area, Light Industries and Baba Dogo Industrial Area.

Theoretically, this study focuses heavily on situational facets of BIM adoption and use and lightly on various perceptive facets of BIM capabilities. The study looks at the current status of the construction sector and how this affects decisions of Building Contractors on BIM adoption for example how trialability of a BIM tool would influence a Building Contractor to adopt it, how level of complexity of a BIM tool would make a Building Contractor prefer one BIM tool over the other.

This study applied the survey method of collecting data. Questionnaires were used to collect data amongst Building Contractors and structured Interviews were used to collate information from other stakeholders that work closely with Building Contractors like National Construction Authority (NCA) and Kenya Association of Building and Civil Engineering Contractors (KABCEC).

1.9 Study Limitations

The basic unit of data collection, to whom the questionnaire was administered to, was a Building Contractor with an NCA classification 4 and above, with an active project within the zones mentioned in the figure 18 in appendix 6. This set of respondents do not necessarily represent all Building Contractors in Kenya, whose classification ranges from NCA 8 to NCA 1. There was apathy towards collection of data using online surveys. The researcher experienced this during the pilot survey where physical questionnaires were preferred to online ones. To overcome this, the researcher opted to use manual questionnaires during actual data collection. The current working environment within the construction industry in Kenya has created an environment of fear. This results in most Building Contractors not being receptive to the researcher when issuing questionnaires to them, which they looked at with suspicion.

1.10 Study Organisation

This thesis is organised in five chapters. The first chapter is an introduction to the research problem, and has background information about the research study, consolidation of the problem in a problem statement. Explanation of the reasons for the study, clear articulation of the study objectives and explanation of the study assumptions. Study significance and justification are then articulated, study scope follows then the study limitations are illustrated.

The second chapter looks at in-depth information about BIM. It starts with definitions and historical approaches of BIM. Various BIM capabilities are reviewed to give tangible deliverables associated with BIM. Theoretical Framework of Technology Adoption is discussed, giving rise to the conceptual framework that assists in identifying specific variables and associated indicators that forms the basis of data collection. The study further looks at two global cases of good practice with relation to BIM adoption by Building Contractors, scrutinises its level of adoption, and how the identified concepts act as catalyst or barrier towards BIM adoption. Hypotheses and Research Questions of the study are presented for scrutiny with the terms associated with the hypotheses defined.

The third chapter looks at the research methods used to investigate the variables and associated indicators discussed in the literature review. Research Design and sampling design are explained to make it clear how they will assist in dissecting the identified variables. Methods of collection are explained followed by how data is analysed and presented taking into consideration ethical issues. The fourth chapter discusses the results based on the various variables that were tested. It goes further to explain various inferences established during data analysis. Correlations are also identified and discussed in detail. The fifth chapter makes conclusions on what the study found out, followed by recommendations that can be implemented. A framework based on the results is generated to propose ways of improving BIM adoption within Building Contractors.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This chapter presents information that other authors in the built environment and found to be relevant to the study of BIM Adoption. This review is benchmarked with the objectives of this study which focuses on the BIM adoption levels by Building Contractors within the Construction Industry establishing the barriers and enablers of BIM Adoption by Building Contractors within the spheres of factors associated with BIM Essentials, BIM Maturity and BIM Risk Tolerance. This study is therefore expected to broaden our understanding on levels of BIM adoption both at the global and local level. The topics that will form the basis of this literature review include basics of documentation in building construction, definition, history and multi-dimensional capabilities of BIM, theories of technology adoption and how BIM relates to these theories and cases of best practice of BIM adoption at the global level.

2.2 Construction Industry Attributes

The construction industry has many actors who include the client, design actors, government agencies, construction actors, manufacturers and researchers (Graphisoft, 2015). These actors are further subdivided into various specialities. In Kenya, the design actors include but are not limited to the construction project manager (CPM) , architect (NCLR, The Architects And Quantity Surveyors Act, 2010), civil structural, mechanical, and electrical engineer (NCLR, Engineers Act, 2011). Government agencies include but not limited to the Ministry of Public Works, County Governments (NCLR, The Constitution of Kenya, 2010), State Corporations like Kenya Power and Kenya Railways, Statutory bodies like BORAQS, EBK and NCA (NCLR, State Corporations Act, 2012). Construction actors include but not limited to Civil, Building, Electrical and Plumbing Contractors (NCLR, The National Construction Authority Act, 2011). Researchers include but not limited to R&D departments in manufacturing companies, universities, software resellers and Kenya Building Research Centre. To successfully execute a project, Building Contractors interact with all these actors by going through documentation from the design actors to enable them to understand it before implementation.

Project documentation is divided into graphical and non-graphical documentation. Graphical documentation can be presented visually in different ways depending on the purpose of the actual representation. They include orthographic projections, parallel projections, and perspective projections. Non graphical documentations are text-based documentations that enhance and clarify the graphical documentation. They include specifications, calculations, quantity take offs, cost estimation and construction schedules (Bond Bryan Architects, 2015; Graphisoft, 2015)

2.3 Approaches to BIM Definitions

The easiest way of defining BIM is to first and clearly describe the meaning of these three words namely Building, Information and Modelling. A building is a structure put up for human habitation. Information is a package of knowledge that is easily understandable to a specific target audience. Modelling is the ability to represent something in the various dimensions.

BIM is a concept revolving around virtual construction or modelling of a building. During this modelling process, relevant information is embedded into the virtual model. BIM as a set of interacting policies, processes and technologies generating a methodology to manage the essential building design and project data format throughout the life cycle of the said building (Masood et al., 2014). These policies and processes create a collaborative environment where various actors deposit or retrieve information with regards to the building. This virtual model therefore becomes an 'information bank' on all matters relating to the actual building. Intelligent and parametric information is embedded on all Building Elements, Components and Services parts of the virtual model, mirroring the implementation in the actual building.

Globally, various jurisdictions have come up with their own definition of BIM. The Malaysian Construction Development Board summarises BIM as a process supported by technology of computer generated model used in a collaborative environment to populate information and simulate the planning, design, construction and operation of a building (Takim et al., 2013) while the Royal Institute of Chartered Surveyors (2015) describes BIM as a central electronic depository of information with regards to the physical and functional aspect of a project (RICS, 2015). This information changes over time and the success of BIM is in its ability to quickly adopt to these changes. This information is broadly used to derive secondary information, calculate relevant information, or analyse the provided information. For this to be achieved, this information needs to be intelligent and parametric.

2.4 Historical Development of BIM

Building design, documentation and construction has evolved to conform to or meet user requirements during the various stages of human development. This has resulted into three distinct periods of development namely the Traditional period, the CAD period, and the BIM period. This study shall compare the three periods in terms of when they happened, who were the players involved, how different there are from one another, and the place of Building Contractors in these developments.

The Traditional Period is the period up to 1950's. The responsibilities of the various design actors had already been refined. Information concerning a building gathered during inception, information documented and analysed during design stage were done manually using paper, pen and ruler. (Bopalgni, 2013). The architect would avail architectural documents to the other design actors namely the Quantity Surveyor, the Civil/Structural Engineer, Mechanical Engineer, and Electrical Engineer to generate their respective graphical and non-graphical documents. Depending on the CDM, these documents would be availed to the Building Contractor for scrutiny and execution. Conflicts due to genuine errors and omissions arising during the implementation of the design due to the manual nature of the process would result into a lot of Request For Information (RFI) between the Building Contractor and design actors which bogs down the process.(FWCI, 2009).

The advent of personal computers in the early 1960's made the possibility of using computer-based programs for office work a reality and CAD therefore came into being. CAD first appeared as developed by Ivan Sutherland as part of his PhD thesis

"Sketchpad" at MIT in 1963 (Yan & Damian, 2008). Computers became an improved tool of basic drafting besides improving visualisation and simulation (Bopalgni, 2013) thereby enhancing the speed of information generation and documentation. The issue of RFI between the Building Contractors and design actors persisted since conflicts as a result of genuine errors and omissions were not eliminated. The CAD programs could not store relevant information concerning each part of the modelled building.

BIM period which started in early 2000's arose due to the need to minimise or eliminate RFI between Building Contractors and design actors as experienced during the CAD period. Most innovators for the BIM tools had been involved in creation of their respective CAD tools and their transition to BIM followed their strategic plans of continuously improving their tools. As a result, these tools still hold their traditional "CAD" brand names when they are having sophisticated BIM capabilities. BIM stands out above CAD owing to its ability to easily collect and disseminate information about any part of the building. Migilinskas *et al* (2013) observed that this has vastly reduced RFI between Building Contractors and design actors thereby improving efficiencies within the construction industry.

2.5 Multi-Dimensional Capabilities of BIM

2.5.1 'N' Dimension Capabilities.

3D in BIM assists in giving a visual and virtual image of how the building will look like. This capability has been the main interface of communication between the design actors and the Building Contractor throughout the three periods of BIM development. Several capabilities associated with 3D have been developed to ensure clarity in communication and understanding. These capabilities include 2D CAD drafting, 2D documentation, 3D CAD modelling, 3D parametric modelling, 3D Computer Numerical Control (CNC) machining which includes 3D printing and 3D laser cutting, mobile interfacing and 3D Augmented Reality. Continuous improvements from 2D drafting to 3D modelling has also resulted in continuous changes with regards to global CAD and BIM standards for example, while Construction Index/Samarbetskommitten for Byggnadsfragor (Ci/Sfb) was a predominant classification tool for CAD tools (Afsari & Eastman, 2016), it became irrelevant with the advent of BIM tools and was therefore replaced by better classification tools like uniclass (NBS, 2020), omniclass and CAWS (RICS, 2015)

4D in BIM broadly refers to the all-time related information with regards to the construction of a project. This becomes critical when planning for the construction phases, scheduling of various activities before, during and after construction. This information can be documented and represented using simple methods like the Gantt charts or complex methods like 4D animation to show the sequential process of construction. 4D in BIM has been the main interface of communication between the design actors and the Building Contractor with regards to the time factor in the Iron Triangle metrics. Improvement of 4D has continuously created new capabilities. Chronologically, these capabilities include 4D manual scheduling, 4D parametric modelling and 4D-3D scheduling. 4D manual scheduling is where relationship and dependency of activities is not intelligent, not parametric, can be referred to as 'dumb' and as a result, a change in one of the activities does not automatically adjust the dependent activities (Nyberg & Kullven, 2014). 4D parametric scheduling is where there is a parametric linkage between relationship and dependency of activities to parametric 3D models for example the planet tool can be easily integrated into the Archicad tool to generate parametric schedules (Tse, 2009). 4D-3D scheduling is where 3D simulation of the activities are projected to simulate how the activities affect one another (Huang et al., 2007). Scheduling methods generally show relationships and dependency of activities. For the 2D scheduling tools, this relationship and dependency is not intelligent, not parametric or can be broadly referred to as 'dumb'. As a result, a change in one of the activities does not automatically adjust the dependent activities. This has to be done manually. For large scale projects, this will involve a lot of intensive manual labour. Nyberg et al (2014) explained that this action results in a reactive construction project management which involves firefighting of problems experienced on site and trying to resolve these problems while the site activities are ongoing (Nyberg & Kullven, 2014).This always results into a crisis with a resultant compromise on cost, time and quality. Current 4D BIM modelling tools tries to resolve this problem. Tse (2009), in outlining the development of 4D BIM modelling observes that 4D was initially based on a combination of a standalone 3D modelling tool and a respective standalone scheduling tool, for example 3D studio max would be used with Primavera. Fundamentally, there was no difference in terms of scheduling between this method and the 2D method, the problem of non-intelligence still persisted. Over time, 4D models have improved to a level of having parametric linkages to parametric 3D models for example the planet tool can be easily integrated into the Archicad tool to generate parametric schedules (Tse, 2009) which Czmoch *et al* calls this parametric scheduling. Several benefits have accrued as a result of using these parametric scheduling tools. The process of execution can be simulated and parametric scheduling on the virtual 3D model can be done to ensure that the visualisation of execution is logical. This gives a realistic and knowledgeable understanding of the schedule and sequence to all parties involved in the project. The Critical Path of the project are automatically generated thereby giving information to the parties concerned to properly plan to ensure that associated deadlines are met. With this clearer schedule, proper planning of the associated human resources, equipments and materials can be done at a global level of the project. Huang *et al* (2007) observes that despite advances in 4D BIM tools, there still lacks construction specific components for example scaffolding integrated into 3D models. These models also do not show the space needs and potential congestions and delays that may be occasioned by temporary works. Resolution of this problem has given rise to the Construction Virtual Prototyping (CVP) tools that easily generate, reuse and modify 3D models of building components, construction equipment, temporary works and labour. Regardless of the type of tool used for 4D modelling, the deliverables expected include a table of elements, schedule that clearly shows the critical path, animation of the implementation process, construction site organisation, choice of construction technology, material and equipments. Some of the 4D scheduling tools that can achieve these deliverables include Autodesk Naviswork, MS Project, Planet (Tse, 2009), Synchro 4D (Fazli et al., 2014) and DELMA (Huang et al., 2007).

5D in BIM is broadly described as the cost aspect in a construction. The success of costing in the construction industry has always been pegged on the success of quantification. Just like the 4D aspect in BIM, 5D modelling started in the traditional pen and paper 2D system where the QS would manually calculate all needed quantities in a project manually. A change in size or specification during design would result into manually redoing the whole costing exercise afresh. This manual process has slowly been replaced by BIM modelling in 5D. Research shows that 5D BIM is efficient than the 2D manual method of cost estimation. Abanda *et al* (2017) gives specific examples: A mass housing project in Finland managed to increase profits by 45%, reduce waste by 45% and even reduce on site accidents by 5% (Abanda et al., 2017) by adopting and using 5D BIM tools during the design and construction process. 5D in BIM has been the main interface of communication between the design actors and the Building Contractor with regards to the quality and cost factors in the Iron Triangle metrics. Improvement of 5D has continuously created new capabilities which include 5D manual Quantity Take-Off (QTO) and costing, 5D parametric QTO and costing, 5D classification systems and living cost plan. 5D manual QTO and costing is where the Quantity Surveyor would manually calculate all needed quantities in a project manually, and a change in size or specification during design would result into manually redoing the whole costing exercise afresh (Zhu, 2017). 5D parametric QTO and costing is where model based estimation is done using intelligent, parametric, automated and real-time linkage to a parametric 3D model and change in specification or quantity in the model automatically reflects in the change of cost (Mitchell, 2012). During the early days of using 5D BIM tools, they were nonparametric and therefore involved using 2 distinct standalone tools, a 3D modelling tool for example Sketch up, and a spreadsheet tool for example MS Excel. This was as good as the manual quantity take off (QTO) processes. Improvement of 5D capabilities was enhanced by the formation of SMART alliance in 2008(Smith, 2016) in the United States of America (USA), with an aim of solving various cost engineering problems that were plaguing the American market. Smith (2016) observes that this resulted into development of systems and protocols for collaboration and coordination of cost engineering and estimation throughout a project life cycle. This was further boosted in 2014 by the Royal Institute of Chartered Surveyors (RICS) publishing an International BIM implementation guide for construction professionals. In doing so, RICS acknowledged the increased importance of BIM in cost management hence the need to embrace 5D in BIM. These two developments have improved the overall QTO and costing environment since most of the current 5D BIM tools are intelligent, parametric, automated and real-time. With these tools, a change in specification or quantity automatically reflects in the change of cost. Mitchell (2012) avers that this gives the

Quantity Surveyor the chance to extremely quickly and limitlessly do quantity take-offs, a privilege that is not available to a 2D based QS (Mitchell, 2012). This aspect also makes re-measurement of work on site a less tedious exercise. Despite these developments, three main challenges still persist with regards to 5D BIM modelling. The first challenge is that most QSs are not fully conversant with the available automated QTO tools. Owing to the sensitive nature of their work, there is a perceived less trust on these tools. Besides, most of them feel that is double work since they still have to sit down and scrutinise the generated documents word by word to ensure that there is no error. The second challenge with regards to development of 5D BIM modelling is the level of accuracy of the availed BIM model. Since QSs are not the original generators of the model, this becomes a problem especially where information availed by the principal modeller, mainly the architect, CSE or BSE is not adequate or accurate to do costing. Smith (2014) notes that this is a global problem especially in jurisdictions where BIM has not been standardised (Smith, 2014a). The third challenge is the reality of various classification systems, of which most of them are not compatible thus making it difficult for practitioners to collaborate. Global attempts have been made to resolve some of these problems. New 5D BIM tools have been designed with some sense of flexibility to ensure that there is provision of consistent information growth based on the availability of the said information. Mitchell (2012) refers to this as having a Living Cost Plan (Mitchell, 2012) This is done on the understanding that during the inception stage, information is normally scanty compared to the as built documentation stage. Australian Institute of Architects have come up with a classification system for this, known as Level of Development (LOD). LOD 100 for initial cost estimating, LOD 200 for schematic designs, LOD 300 for developed design, LOD 400 for cost integration during construction and LOD 500 for as built cost data (Mitchell, 2012). 5D BIM tools have greatly improved over time that most of them are now parametric. Some of these tools include Cost X, Autodesk QTO, Innovaya and iTWO (Smith, 2016). Some of the tangible deliverable include cost estimates, cashflow projections, basis of change management throughout the project (Jankowski et al., 2015) and value engineering.

2.5.2 Integrated Design Coordination and Collaboration.

Construction Delivery Methods (CDMs) are broadly categorised as either Design-Bid-Build (DBB) or Integrated Project Delivery (IPD) (Azhar et al., 2012). In DBB, the Building Contractor comes in through a bid process after design team prepares their designs as shown in figure 1 below. They have minimal contribution to make with regards to design since it is already done. In IPD, the Building Contractor comes in early and collaborate with the design team during design and construction as shown in figure 2.2 below.

Regardless of the CDM, all these actors have specific roles that normally overlap and influence one another hence the need to work together as a team by coordinating and collaborating to ensure that the project requirements are met. BIM enhances this attribute by introducing new capabilities. Virtual coordination of design work and documentation enables easier management of design changes. Several BIM tools for design and analysis with overlapping data requirements are used during the design stage. Tools like Solibri, Tekla, Naviswork help to visualise and identify relevant design issues and their source, and helps in tracking steps taken in solving these design issues (RICS, 2015) minimising RFI.

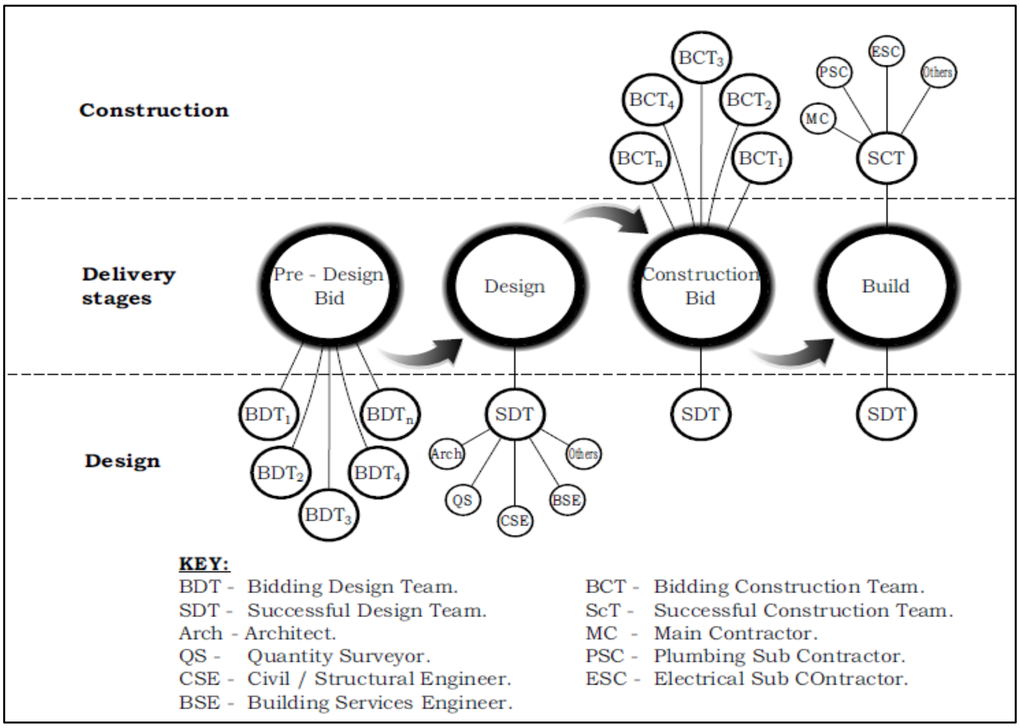


Figure 2.1: Workflow Process for the Design-Bid-Build Delivery Method

Source: Author (2017).

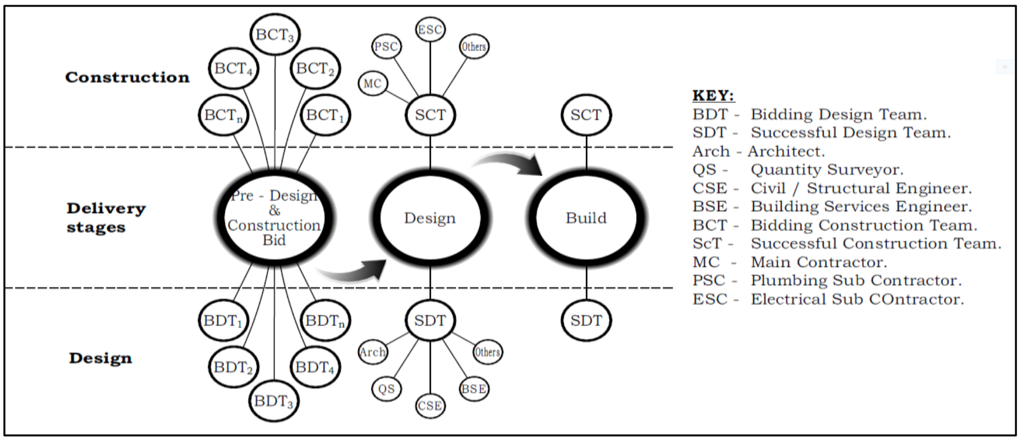


Figure 2.2: Workflow Process for the Integrated Project Delivery Method

Source: Author (2017).

Coordination and collaboration is achieved by having a native model (Møller & Bansler, 2017) and a federated model (Bond Bryan Architects, 2015). Native models are the specialist models generated by each design actor where all specialised designs and information are stored. A federated model is a model consisting of linked but distinct native model from the various design actors. For construction purposes, the Building Contractor generates this model to assist in analysing all native models to ensure all outstanding issues are resolved.

Improved internet penetration has enabled cloud computing technology to be integrated to BIM further enhancing coordination and collaboration. It is used to create a virtual online depository and all native models are collected, the Building Contractor uses them to create a federated model (RICS, 2015). This has disrupted the whole concept of localised working location and working hours. It allows for the various design actors to collaborate from diverse locations and time zones.

2.5.3 Interoperability and Clash Detection (ICD)

Various actors use BIM tools that are consistent with their speciality for example an architect using Archicad, while the CSE uses Tekla. Within a design speciality, actors still use different BIM tools owing to personal preferences, cost, and capability. To ensure coordination and collaboration between the Building Contractor and these actors, there is need for a common interoperable (Nyberg & Kullven, 2014) platform on which these actors can exchange information. Interoperability is achieved by creating a common data environment either by using standard file formats that are compatible with various BIM tools like IFC and XML (Akinade et al., 2017) as shown in figure 3a below or by using a BIM tool that is compatible with the other BIM tools (Kolarić et al., 2017) as shown in figure 3b below. This gives the most compatible BIM tool an edge over the others. The Building Contractor therefore needs the most compatible BIM tool to be able to seamlessly collaborate with other actors.

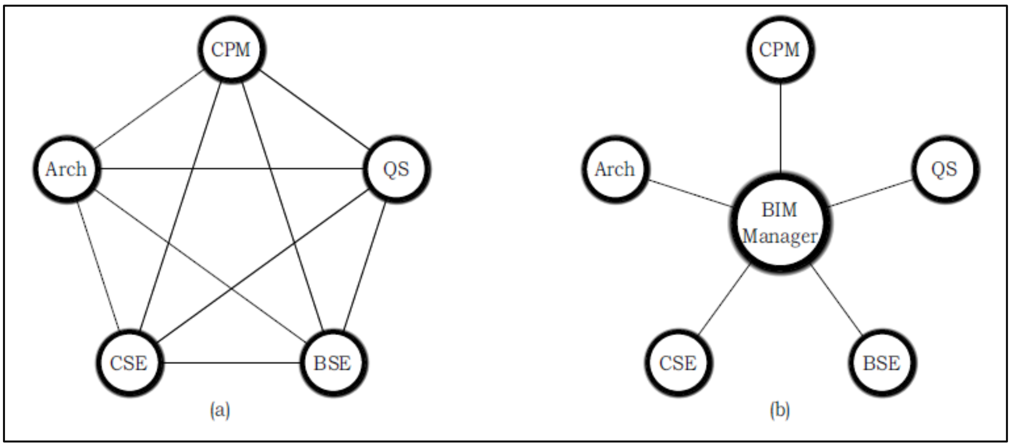


Figure 2.3: Various Interoperability Options with (a) Representing Use of Standard File Formats while (b) Representing Use of a BIM Tool Compatible with all the Other BIM TOOLS

Source: Author (2017).

Interoperability enables Clash detection, the process of identifying and detecting possible collisions between elements in a BIM from two different design actors which would not otherwise be desirable or buildable on site (Arayici, 2015; Bond Bryan Architects, 2015; RICS, 2015). Clashes can be hard, soft or workflow. Hard clash occurs when two important objects occupy the same space, and one cannot be sacrificed for the sake of the other, soft clash occurs where two objects occupy the same space though one can be moved without interfering with the whole and 4D workflow clash occurs when work schedules clash can be flagged by the Building Contractor. This action helps in reducing design flaws before actual construction and eliminating workflow complications during construction.

2.5.4 Structural Analysis and Modelling (SAM)

This is a process in which analytical modelling tools utilize the BIM tool to determine the behaviour of a given structural system (CICRP, 2011) taking into consideration the minimum standards for structural design and analysis. Traditional structural analysis was largely done manually, resulting into many calculation sheets of paper which did not give room for any collaboration with the Building Contractor and a design change by any design actor would heavily affect the workflow. BIM structural analysis resolves this by automating calculations and a design change from any actor would not heavily affect the workflow for the structural engineer and the Building Contractor (Ahuja et al., 2017). Structural Analysis and Modelling helps saves time and cost by creating one virtual model for visualisation, simulation and analysis, helps to achieve the optimal efficient design solutions by applying various automated and vigorous analysis (Fazli et al., 2014).

2.5.5 MEP Analysis and Modelling (MEPAM)

MEP modelling is the process of creating virtual building services systems more accurately and easily, with the help of available MEP modelling tools (Hartmann & Fischer, 2008). MEP systems have long been associated with complexity and coordination challenges in construction. In the traditional method of MEP design and documentation, incidences of clashes and higher RFI between MEP designers and other design fields has always been high since it was difficult to reconcile these designs in 2D (Yalcinkaya & Arditi, 2013). MEP modelling using BIM tools has resolved these problems resulting into better BIM coordination

2.6 Available BIM Tools And Their Capabilities

Owing to the dynamic nature of BIM, new tools are being created everyday besides the existing tools that are undergoing improvements every day (Seed, 2015). These BIM tools vary in terms of their capability and speciality. A detailed table 113 showing 40 BIM tools considered currently relevant and their associated capabilities has been availed in appendix 2.

Out of these 40 BIM tools, more than 80% are standalone BIM tools. This is due to the specialised developer/consumer relationship (CWRU, 2008) that is normally influenced by the tacit factors of demand and supply. These standalone tools are mainly based on their capabilities with 4D and 5D BIM standalone tools having more demand compared to the other BIM capabilities. With regards to 4D capabilities, standalone BIM tools include DELMA, MS Project (Nyberg & Kullven, 2014), Primavera, Naviswork, Planet and Syncro4D. The huge demand for these 4D BIM tools have enabled these 4D BIM tool developers to thrive and specialise, so most of them have been able to create a niche within the spheres of 4D in BIM. With regards to 5D capabilities, standalone BIM tools include Autodesk QTO, Bluebeam (Hardin & McCool, 2015), Cost X Innovaya, iTWO and SAP. The huge demand for these 5D BIM tools has enabled these 5D BIM tool developers to thrive and specialise, so most of them have been able to create a niche within the spheres of 5D in BIM.

Studies have indicated that BIM works well when certain thresholds are achieved with a minimum construction area of 1,500 square metres and a minimum cost of USD 1 million inferred as the minimum thresholds for BIM to thrive (Hore et al., 2017). Greater cost during implementation of a building is the actual construction cost, when compared to other cost voteheads like consultancy fees, statutory payments, insurance etc. This explains why Building Contractors easily find it easier to adopt BIM tools when compared with other stakeholders like designers, insurers etc. even in situations where the Design-Bid-Build is the predominant CDM (NBS, 2017) especially where a project easily achieves the thresholds mentioned above. Since time and cost are the factors more important to the Building Contractor compared to quality (Mahamadu et al., 2019), they tend to invest on 4D and 5D related BIM tools hence the higher demand for these tools

Out of these 40 BIM tools, less than 15% are integrated BIM tools which include Archicad, D Profiler (Abanda et al., 2017), Digital Project, Micro Station and Revit. Most construction related activities are integrated and all cadres within the construction workflow process (Building Contractors and associated subcontractors) normally interact since each of their work is integrated. The design team is inevitably compelled to integrate, to ensure that their outputs are seamless enough to be easily interpreted and implemented by the Building Contractors and associated subcontractors. This trend is resulting in more and more of integrated BIM tools and less and less of standalone tools. Besides the integrated nature of the construction industry, several factors are influencing the trend of Integrated BIM tools being adopted. Economies of scale makes it cheaper to own an integrated BIM tool as opposed to acquiring five or more standalone BIM tools (Underwood & Isikdag, 2010) to fulfil these tasks, and therefore BIM users are moving towards these integrated tools. Advent of cloud technology has also helped in improving integrated BIM tools

(Redmond et al., 2012). This is enabled by having a common data environment where all designers log in and handle the scope of their specialities.

2.7 Theoretical Framework

2.7.1 Introduction

BIM is regarded as the most prominent, radical and transformative innovation to be experienced the construction industry (Alhusban et al., 2017). BIM, as a new technology in the construction industry follows the pattern of adoption of other new technologies in their respective fields. Several theories and models have been generated to explain this. This research shall limit itself to two technology adoption theories namely the Diffusion of Innovation Theory and the Hype-Cycle Theory of Technology Adoption. It will be good to note that innovation and technology has been used interchangeably in this research study. Innovation refers to all inventions that been modelled to fit its associated market structure, while technology limits the field of innovation to Information Technology (IT) related innovations. In the context of this research study, innovation and technology have the same meaning.

2.7.2 Diffusion of Innovation Theory

Diffusion is a mechanism that spreads successful variety of products and processes through an economic structure, and in the process, displaces the existing inferior variety. Adoption is the implementation and use of a new technology (Hanel & Niosi, 2007). Diffusion of Innovation Theory was pioneered by Peter Schumpeter in 1912 when he outlined the linear progression on spread of Technology emphasising that any innovation followed a certain pattern in its lifecycle - invention, innovation, diffusion, and adoption. From the feedback gotten from the adopters, the innovation would be improved and further diffused. This creates a cyclic relationship between innovation and adoption until the saturation point of mass adoption is achieved, a process called sustaining innovation (Sarkar, 1998).

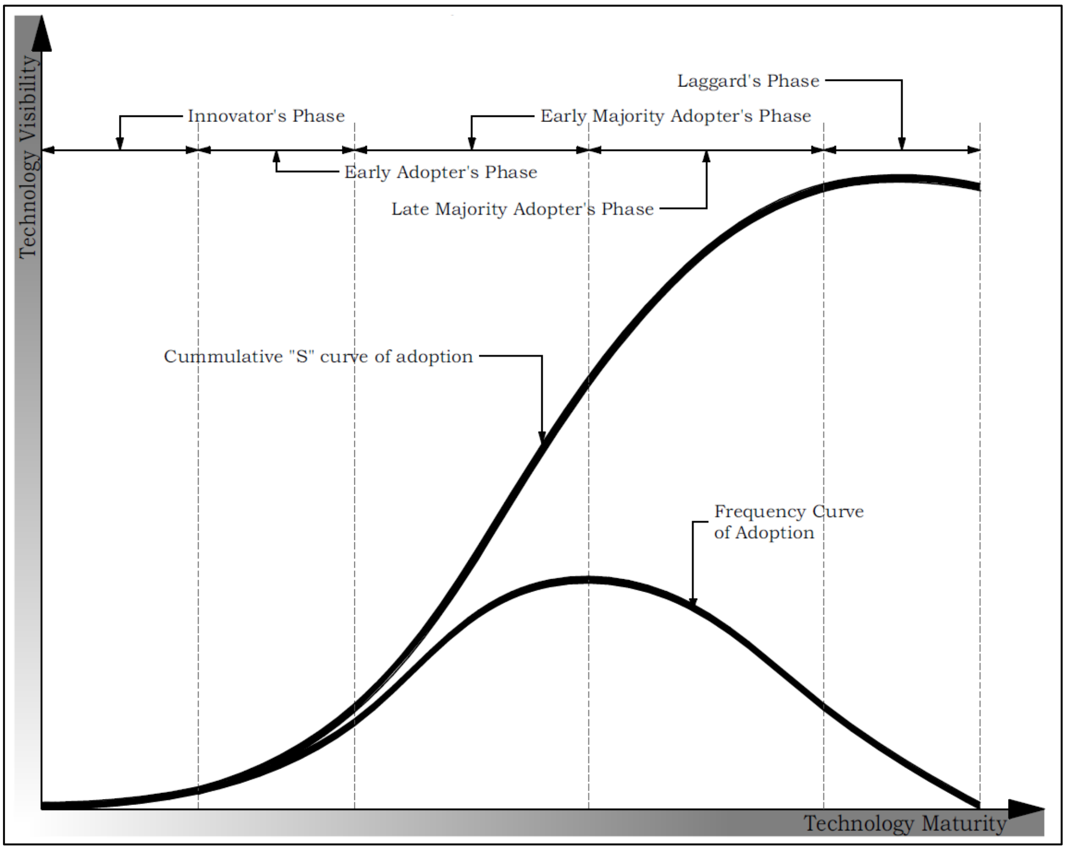


Figure 2.4: Diffusion of Innovation Graph

Source: Author (2017), adapted from (Walasek & Barszcz, 2017)

As indicated in figure 4 above, this theory has five distinct phases namely i) the innovator's phase, ii) the early adopter's phase, iii) the early majority adopter's phase, iv) the late majority adopter's phase and v) the laggards (Walasek & Barszcz, 2017). The Innovator's Phase is a phase for a group of adopters who are venturesome , risk takers and are always eager to try new ideas. They have the financial and psychological resource to absorb and accept possible losses when innovations go wrong and therefore play a gate keeping role in the flow of ideas to the social system. They are regarded as pacesetters in adoption of innovation. This group of adopters make up about 2.5% of the total population of the social system. The Early Adopter's Phase is a phase for a group of adopters who are regarded as opinion leaders and shapers in a social system and potential adopters look at them for information and advice to be able to make a decision with regards to adoption. This is because they are respected amongst their peers. These adopters also know that their reputation is at stake, and as a result, they are always keen to give a correct unbiased opinion about the innovation. This group of adopters reduce the uncertainty about the new innovation by adopting it and conveying this information through their interpersonal network. This group of adopters make up about 13.5% of the total population of the social system.

The Early Majority Adopter's Phase is a phase for a group of adopters who though are not opinion leaders, they are in a unique position to influence a large number of potential adopters thereby creating an important link between the ones who have adopted, and the ones who have not. This group makes a rational and deliberate attempt to adopt the innovation after seeing concrete success stories and effectiveness of the innovation from the early adopters. This is the most pragmatic group of adopters, who invest in the innovation only when value for investment of time and money is clearly seen. This group of adopters make up about 34% of the total population of the social system. The Late Majority Adopter's Phase is a phase for a group of adopters who are sceptical about change, they only adopt an innovation when a bulk of the adopters have done so. This is a group of adopters who are normally very cautious and are not risk takers. One of the reason of this extreme caution is due to having relatively scarce resources, information and knowhow about the new technology and therefore would not take any risk or having a previous experience which was not good. This group of adopters make up about 34% of the total population of the social system. The Laggard's Phase is a phase for a group of adopters who are downright conservative hence very sceptical of change are therefore the most difficult people to be brought on board. Most of them adopt an innovation out of coercion for example through government policies and mandates or because of redundancies on the innovation that they are currently using. This group of adopters make up about 16% of the total population of the social system.

The innovator’s phase where the venturesome and risk-takers especially opinion leaders and social shapers snap up the opportunity to take up the innovation, the early adopter’s phase where the opinion leaders and social shapers come back and convince peers to take up the innovation, the early majority adopters phase where the pragmatic peers who were convinced to become the foot soldiers of the innovation in a quiet and effective way convince more colleagues and peers to take up the innovation, The late majority adopters phase where the bulk of members who are normally sceptical, hesitant to change and do not like taking any risk take up the innovation having seen it working for a large group of peers and the Laggard's phase where members of the society who are downright conservative are forced into adopting the innovation (Froise & Shakantu, 2014; Hanel & Niosi, 2007; Rogers, 1983; Walasek & Barszcz, 2017).

Four factors influence the innovation diffusion namely innovation, communication channels, time, and social systems as shown in figure 5 below. Innovation, the ability to package an idea to be beneficial to a specific social group is critical. A potential adopter looks at the success of innovation in terms of relative advantage, level of complexity, visibility, observability and compatibility (Rogers, 1983).

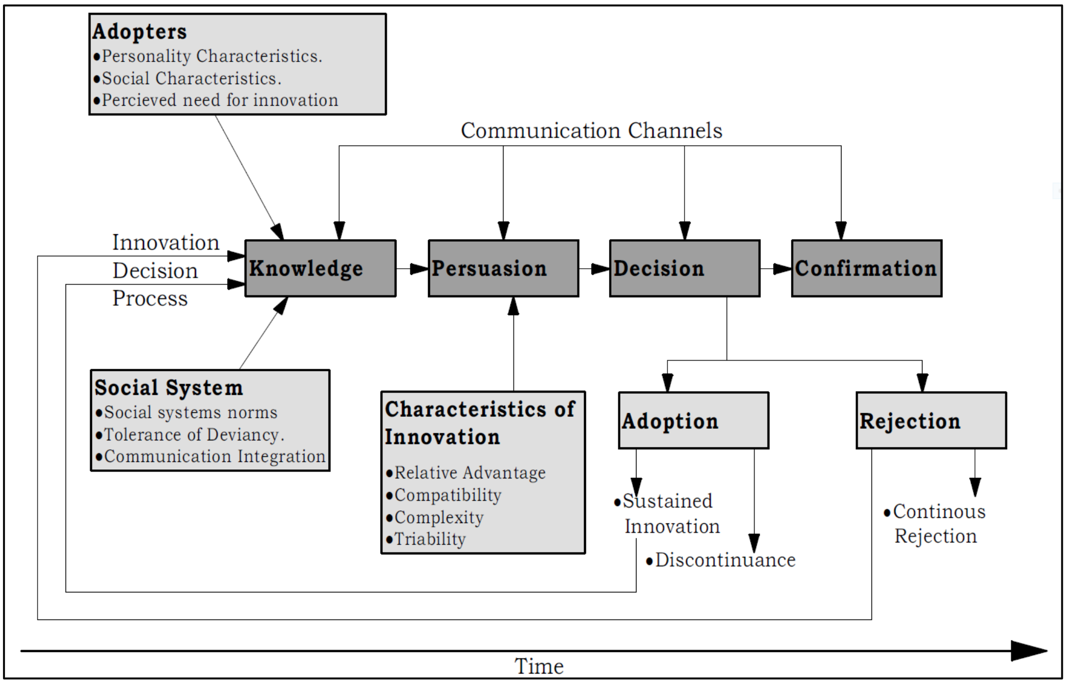


Figure 2.5: Components of Innovation Diffusion

Source: Author (2017), adapted from (Chang, 2010; Rogers, 1983)

Communication channel, how the information on the innovation is spread is also important for the success of diffusion. Mass media is normally preferred as the channel of communication, though it comes with a probability of mass hyping and misinformation (Chang, 2010). Time duration between innovation and use also influences the success of diffusion. The shorter the duration the better since longer durations creates user fatigue and inertia to further diffuse. Lastly, social systems, the ability to bind a specific segment of the society that has common goals and expectations, is crucial for the success of the diffusion especially where norms and doctrines are clear, there is a strong presence of opinion leaders, and the positive consequences of the innovation can be clearly seen by the members of the social group (Rogers, 1983).

Looking at the global status of BIM adoption, using the Diffusion of Innovation theory, various capabilities are at different phases of the diffusion frequency curve. The graph shown in figure 6 below shows current status of BIM capabilities using the Diffusion of Innovation model as explained in detail in table 115 in appendix 3.

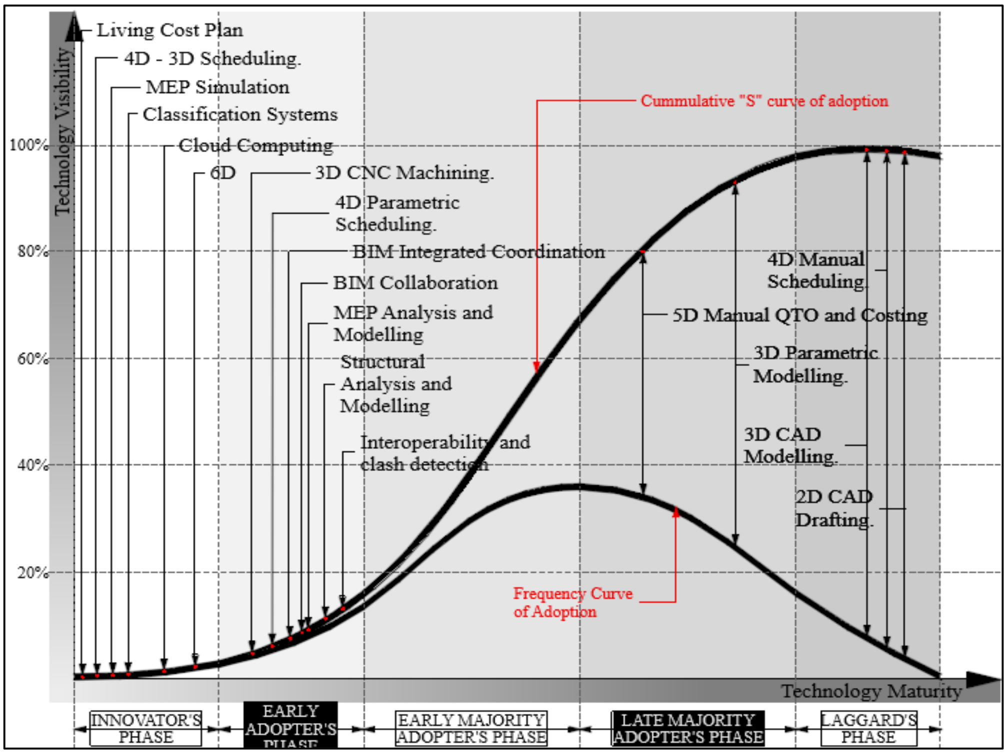


Figure 2.6: Status of Various BIM Capabilities in the Diffusion of Innovation Model

Source: Author (2018)

2D CAD Drafting and 3D CAD Modelling are in their laggard stage since most Building Contractors have moved from manual table drafting to computer drafting. 3D parametric modelling is at late majority adopter's phase since this capability has been tested for quite some time and Building Contractors have seen its value for money. 3D CNC machining is at early adopter's phase with many building manufacturers especially in Europe using it for prefabrication. Mobile Interfacing and Augmented Reality are at the innovator's phase, not many Building Contractors are using them, but the innovators are continuously refining these capabilities. 4D manual scheduling is in its laggard stage, tools like MS Excel are widely used to produce simple Gantt charts. 4D parametric scheduling is at the early adopter's phase and Building Contractors are using tools like MS Project and Primavera for scheduling. 4D-3D Scheduling is at the innovator's stage and tools like Naviswork and Delma are not common. 5D Manual QTO and costing is at late majority Adopter's Phase and most Building Contractors are using MS Excel to generate these documents. 5D Parametric QTO and costing is at early majority Adopter's Phase and BIM Tools like WinQs are being introduced in the market. Classification systems is still at innovator's stage, and with the main problem being incompatibility of various classification systems fronted by various BIM innovators. Living Cost plan is still a new idea to most Building Contractors.

BIM Integrated Coordination is at early adopter's stage, and Building Contractors are now appreciating low RFI, and reworks associated with it. Collaboration is at the early adopter's stage especially in jurisdictions that have created laws resolving issues of copyright and indemnity when using BIM. Cloud computing is at Innovator's phase and most innovations like OneDrive, BIMCloud and Revit Cloud Work-sharing are still new to Building Contractors. Structural Analysis and Modelling are in the early majority adopter's phase since most Structural Engineers learning how to work with architects in the same model. MEP Analysis and Modelling is at early majority adopter's phase and most 3D parametric BIM Tools innovators integrate MEP into their platforms. MEP Analysis and Simulation are still at Innovators Phase and most BIM innovators are trying to introduce capabilities, most Building Contractors have not used it.

2.7.3 Hype-Cycle Theory of Technology Adoption

The Hype-Cycle Theory of Technology adoption was introduced in 1995 by Gartner Research Inc. It characterises the typical progression of an emerging technology from over enthusiasm through a period of disillusionment to an eventual understanding of the technology's relevance and role in its market (Fenn & Linden, 2003; Lajoie & Bridges, 2014; Steinert & Leifer, 2010). When visibility of the technology is matched against maturity, the Hype-Cycle is generated. Though there are a number of theories comparing technology visibility and maturity for example the diffusion of innovation theory, the Hype Cycle stands out since it adds the aspect of human attitudes towards technology (Fenn & Linden, 2003) as a result of exposure to mass media and mass communication interfaces.

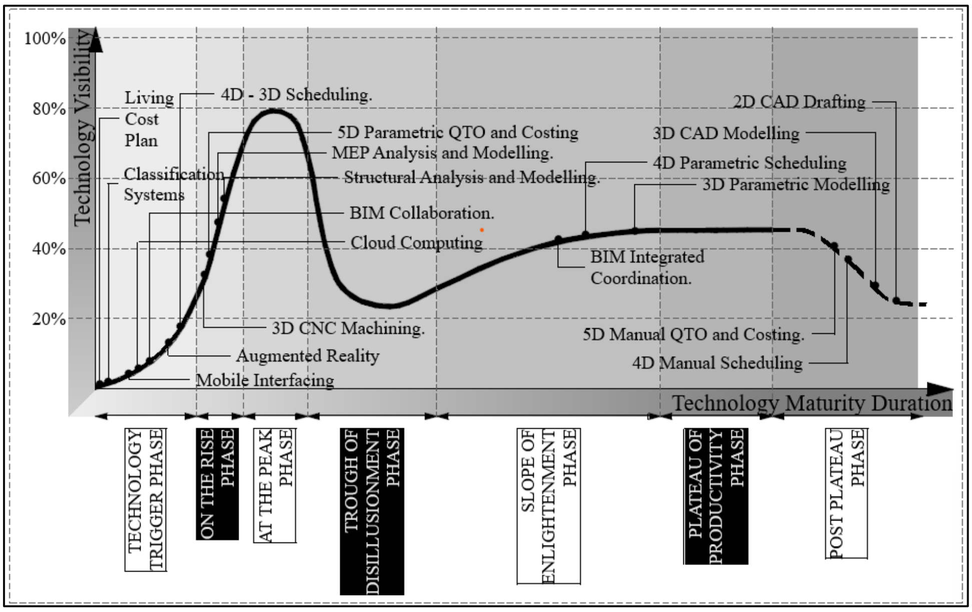


Figure 2.7: The Hype- Cycle of Technology Adoption Graph

Source: Author (2018).

This theory has six phases as shown in figure 7 above. The ‘technology trigger phase’ is where there is an attempt to introduce adoption for an invention through public demonstrations. ‘On the rise phase’ is where a buzz is created through media hyping of the innovation. ‘At the peak phase’ is where adoption reaches its saturation point after so much hyping. ‘The trough of disillusionment phase’ is where many adopters who were convinced by the hype realise that it was not a good innovation thereby abandoning the innovation. ‘The slope of enlightenment phase’ is where the loyal adopters, who never abandoned the innovation slowly build confidence again in the said innovation based on pragmatism and the ‘Plateau of productivity phase’ is where genuine mainstream adoption of the innovation takes place (Lajoie & Bridges, 2014; Steinert & Leifer, 2010; Zainon et al., 2011).

Hype and the extent of disillusionment are unique factors that heavily influence the Hype-Cycle as shown in figure 8 below. Hype is the intensive promotion of an innovation to improve its success. Well hyped products through broadcasts and demonstrations encourage potential adopters to try the product. Extent of disillusionment after trying the product influence continuous adoption. High levels of disillusionment affect adoption levels after hyping is gone, resulting into high levels of rejection.

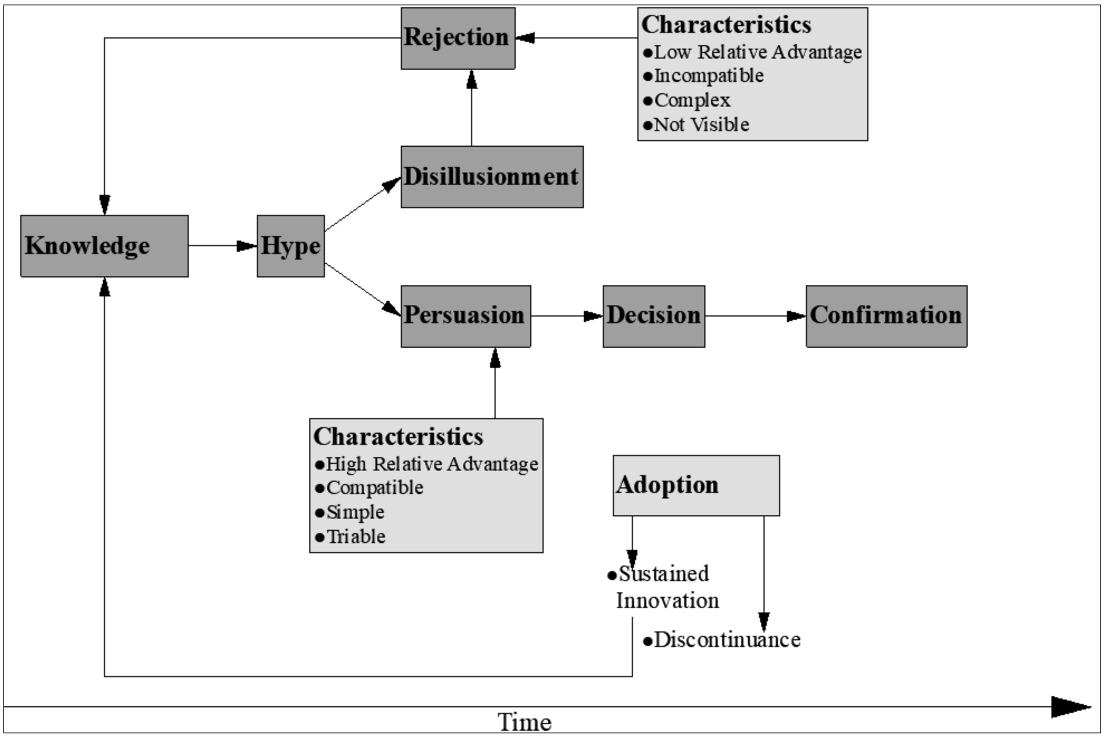


Figure 2.8: Components of Hype-Cycle

Source: Author (2018)

Looking at the global status of BIM adoption, using the Hype-Cycle, various aspects and capabilities are at the various phases of the hype-cycle frequency curve. The graph shown in figure 9 below shows status of BIM capabilities using the Hype – Cycle model as explained in detail in the table 116 in appendix 4. 2D CAD Drafting and 3D CAD Modelling are at the post-plateau stage since most Building Contractors have moved from manual table drafting to computer drafting. 3D parametric modelling is at the slope of enlightenment phase since this capability has been tested for quite some time and Building Contractors have seen its value for money. 3D CNC machining is on the rise phase, many building manufacturers especially in Europe are using it for prefabrication. Mobile Interfacing and Augmented Reality are at the technology trigger phase, not many Building Contractors are using them, but the innovators are continuously refining these capabilities.

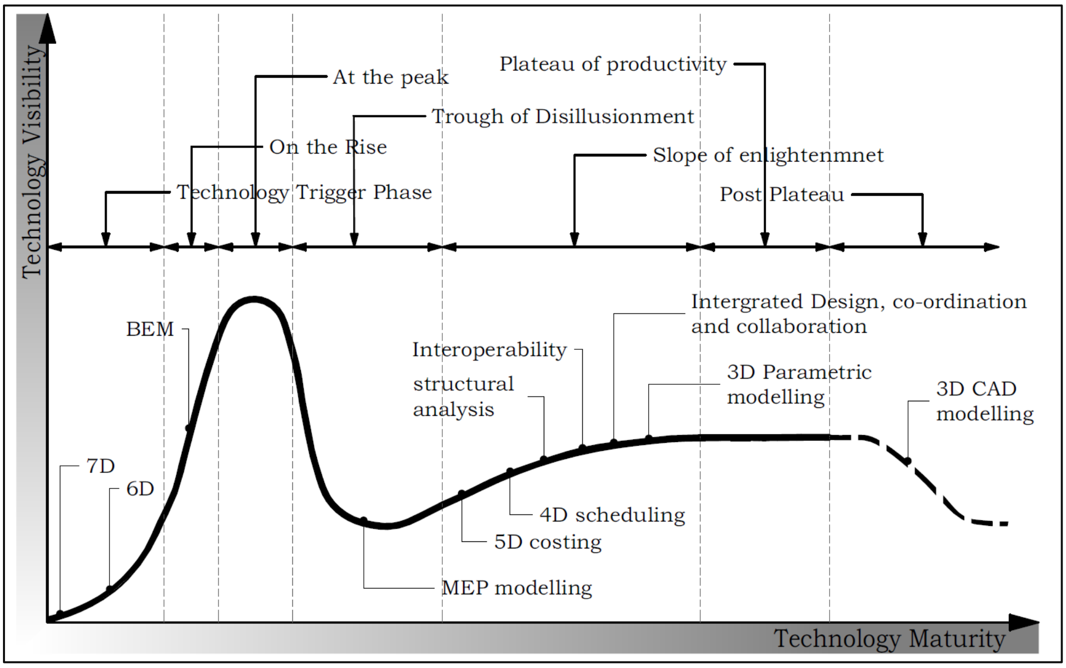


Figure 2.9: Status of Various BIM Capabilities in the Hype - Cycle Model

Source: Author (2018).

4D Manual Scheduling is at the post plateau stage, tools like MS Excel are widely used to produce simple Gantt charts. 4D parametric scheduling is at the slope of enlightment phase and Building Contractors are using tools like MS Project and Primavera for scheduling. 4D -3D Scheduling is on the rise stage and tools like Naviswork and Delma are not common. 5D Manual QTO and costing is in post plateau phase and most Building Contractors are using MS Excel to generate these documents. 5D Parametric QTO and costing is on the rise phase and BIM Tools like WinQs are being introduced in the market. Classification systems is still at technology trigger phase. Living Cost plan is still a new idea to most Building Contractors.

BIM integrated coordination is on the slope of enlightment stage, and Building Contractors are now appreciating low RFI, and reworks associated with it. Collaboration is at the technology trigger stage especially in jurisdictions that have created laws resolving issues of copyright and indemnity when using BIM. Cloud computing is at technology trigger phase and most innovations like OneDrive, BIM Cloud and Revit Cloud Work-sharing are still new to Building Contractors. Structural Analysis and Modelling are on the rise phase. Structural Modelling and visualization are on the plateau of productivity phase since most Structural Engineers liaising with architects to do this. MEP modelling and visualization are on the rise phase and most 3D parametric BIM Tools innovators integrate MEP into their platforms. MEP Analysis and Simulation are still at technology trigger phase and most BIM innovators are trying to introduce capabilities, most Building Contractors have not used it.

2.7.4 Theoretical Framework.

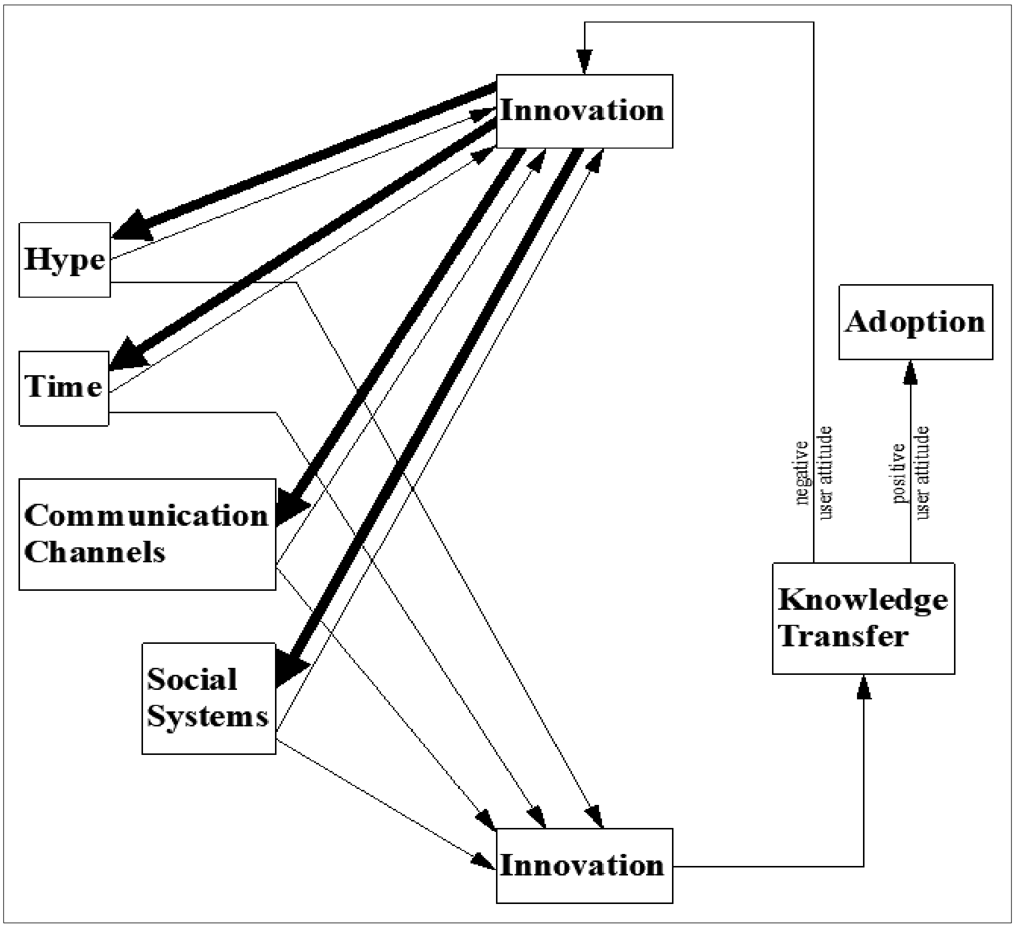


Figure 2.10: Theoretical Framework

Source: Author (2018)

As shown in figure 10 above, for adoption to take place, there must be a clear method of knowledge transfer. The success of this knowledge transfer helps potential adopters in making pragmatic decisions about the innovation. The success of knowledge transfer is based on the methodology used to transfer this knowledge. The methodology is influenced by time, communication channel, type of innovation and social systems. The ultimate success in adoption is influenced by user attitude after knowledge transfer. Where user experiences are positive, adoption becomes successful. Where user experiences are negative, adoption is usually low, compelling the innovator to go back to the drawing board.

2.8 Conceptual Framework

2.8.1 Introduction

BIM has grown due to the need of tackling bottlenecks that contribute to low levels of productivity in the Construction Industry (Walasek & Barszcz, 2017). It uses the Information Technology processes to try streamline the various processes involved during design and actual construction. BIM innovators continuously try to seal in these gaps through creation and refinement of the various BIM tools. Success of these tools will only be seen or felt when the bulk of the potential adopters are able to adopt and use these BIM tools.

2.8.2 Factors Influencing BIM Adoption

Through various literature resources, several factors have been identified as influencing the levels of BIM adoption. These factors are broadly classified under BIM Essentials, BIM Maturity and BIM Risk Tolerance. Table 1 below shows the classification of these in summary form and this study shall limit itself to the nine factors highlighted in the table. These nine factors were identified as having more effect on Building Contractors when compared to the other remaining factors.

2.8.2.1 Availability, Observability and Trialability (AOT) of BIM Tools

Availability is the ability for a potential adopter to have access to the BIM tool in question, observability is the degree to which the results of a BIM tool are visible to other potential adopters to make an opinion while trialability is the degree to which a BIM tool may be experimented with on a limited basis before making a decision on adoption (Ali, 2016; Rogers, 1983). The decision by adopters to take up an innovation is based on local behaviour routines rather than the global trends (Sarkar, 1998). The potential adopter, being a rational being, needs to have information about the innovation availed to them to enable them to make a rational decision.

Table 2.1: Factors Influencing BIM Adoption

	Innovations	Communication Channels	Time	• Social System
• BIM Benefits	• Availability • Visibility • Observability • Trialability	• Contagion • Hyping		• Social Organisation
• BIM Maturity	• Simplicity • Interoperability	• Demonstration • Training • Collaboration		• Government Policy
• BIM Risk Tolerance	• Relative Advantage • Intellectual Property • Proffesional Liability • Confidentiality		• User Fatigue • Experience	

Source: Author (2018).

To enhance availability, information is given through shipping of software CD or DVD in well packaged containers or allowing online downloads. To enhance observability, innovators organise demonstration seminars and webinars (Ahmed, 2016) to emphasise to potential adopters the strengths of the said BIM tool. To enhance trialability, innovators use flexible methods that allow potential adopters interact and experiment with the BIM tool before deciding to adopt it or not. This is done through student licences (Aranda-Mena, 2017), trial versions or trial periods. (Ahmed, 2016; Memon et al., 2014). Due to the heavy investments in creatin these BIM tools, you will rarely get free BIM licences. The level of AOT of a BIM tool affects its level of adoption. BIM tools whose information is readily available and have a degree of flexibility in terms of trialability tend to have a higher rate of adoption (Rogers, 1983). New BIM tools that can be tried on a piecemeal basis(beta softwares) before full roll out are known to be adopted quickly.

2.8.2.2 Social Organisation

This is a group of individuals, groups, organisations and subsystems that have a common denomination (Dearing, 2009). For BIM, the society is made up of various BIM users who include the design actors, clients, construction team, government agencies and trade suppliers (Graphisoft, 2015). Globally, this social system for BIM users is highly stratified, specialised and the level of adoption of a specific BIM tool is normally influenced by how successful the innovator has been able to convince a specific social group amongst the BIM practitioners. This has led to specialised BIM tools that cater for specific niches in this social system.

Opinion leaders, professional institutions, and statutory bodies with government mandates in the BIM social system are a source of authority and their opinion towards a BIM tool influences success of adoption. Where a known and respected BIM user or a professional institution endorse a product, most of the social colleagues adopt the said tool without hesitation. Resistance to changing the culture of the industry is common in any construction industry (Adae, 2013). Where the opinion leaders are at the frontline of this resistance for example practitioners with experience and are used to the traditional way and culture of doing things, then low adoption of BIM tools will be experienced. This resistance is caused by secondary factors chief among them is the low level of IT skills (Arayici, 2015) amongst these practitioners and the fear of being embarrassed that they do not know how to use the BIM tool yet they are regarded as opinion leaders in the construction industry.

2.8.2.3 Government Policies.

Governments come into the construction industry as major policy makers. Various studies have shown a strong link between the government, a social system and the policy making process (Murphy, 2007). Governments as the biggest consumers (Al-abri et al., 2018) becomes the chief adopter of BIM technologies. Where the government needs to internally design and execute various economic and infrastructural projects and therefore has a department of Public Works (Musa et al., 2018), BIM adoption tends to go up if there is mass adoption by government entities. Most governments take advantage of this to showcase the technology by broadcasting it and where possible, demonstrate its capabilities to the public in a bid to convince the public to join them too in using the BIM tool. Where there is need to intervene on the level of BIM adoption, the government needs to use legal instruments/mandates (Cao & Chen, 2018) to make it compulsory for professionals to adopt BIM. The UK government has come out as a global leader in the digital transformation of the construction industry (NBS, 2019) due to the imposition of BIM Level 2 mandate in the UK in 2016.

Where the government externally and indirectly uses BIM technologies as a Project Client, it comes in as a strong regulator by imposing minimum requirements of using BIM in their projects for potential service providers to conform (Eadie et al., 2015) if at all they want to do business with the government. The General Services Administration (GSA) of the US government is outstanding in this. Though there is no existing BIM mandate in USA, GSA imposed a regulation in 2007 that all public projects must be done in BIM (Tse, 2009). To accelerate the rate of BIM adoption, governments fund various facets of BIM activities. Singapore (Tahrani et al., 2015) and UK (Arayici, 2015) are outstanding when it comes to funding of the mandated bodies, while UK is outstanding on research funding of BIM (Underwood & Ayoade, 2015) and Singapore is outstanding in funding of BIM training (Kalfa, 2018).

To guide certain aspects and standards in terms of methodology and deliverables for BIM, the government creates certain policies for this. Examples of such policies include the creation of template files (NBS, 2017), open BIM and interoperability (McAuley et al., 2017), eBIM permits (Tse, 2009) and BIM software certification (NIBS, 2012). Where these policies need attention to ensure proper implementation of the said specific policies, then time-limited task groups are normally created to assist in this (NBS, 2017). Examples of such task groups include the EU BIM Task group formed in 2016 for 2 years (NBS, 2017) whose task was to gather collective experience of BIM stakeholders within the EU zone with an aim of understanding various aspects of BIM like what each country has already done on issues of BIM, what benefits have been accrued from these actions and generate a common EU definition of BIM (EUBIM, 2016). The Bew led UK BIM Task group was formed in 2012 with a task of delivering BIM and soft landings in the UK public sector by 2016 (Enynon, 2016).

2.8.2.4 BIM Training

Most BIM innovators have seen the need to start educational training at the university level (Aranda-Mena, 2017; Hooper, 2012) by creating university based laboratories used for training and validating BIM methodologies, standards and protocols. This method varies from short term BIM training boot camps and focussed in-house training to long term BIM training through integration of BIM into the curriculum of diploma and degree programmes in the Built Environment (Tse, 2009). Due to the sustaining characteristic of BIM tools, continuous professional training is needed to ensure that BIM practitioners have up-to-date skills for handling BIM tools regardless of the level of proficiency (Venkatachalam, 2017). This is done through continuous development programme (CPD) seminars and workshops (Zainon et al., 2016).

2.8.2.5 Simplicity and Interoperability of the BIM tools

Simplicity is how easy or difficult a BIM tool is to understand and use (Dearing, 2009) while interoperability is the ability of a BIM tool to be used in various platforms (Bosch-Sijtsema et al., 2017). BIM tools have varied levels of complexity. Tools for algorithmic modelling, for example Rhino and Grasshopper, (Graphisoft, 2015; Touloupaki & Theodosiou, 2017), structural analysis and MEP analysis are generally regarded as complex and therefore have low levels of simplicity (Bosch-Sijtsema et al., 2017; Kaner et al., 2008; Knight et al., 2010). The rise in government mandated compulsory use of IFC as an open standard file type and the complexities involved during data exchange make BIM be perceived as complex (Eastman et al., 2011; Tse, 2009). Perceived complexity of BIM tools reduces the self-motivation for potential adopters to learn how to use the said tool thereby impeding adoption. On the other hand, BIM tools perceived to be easier and simpler are easily embraced by potential users thereby catalysing adoption. For BIM tools perceived to be complex, continuous training and use helps in reducing this perception thereby improving its adoption.

Interoperability of BIM tools used by various actors is equally important. BIM tools that are interoperable and compatible with other BIM tools are favoured compared to stand alone BIM tools (Arayici, 2015). Most of the government mandates insist on use of BIM tools that ensure open BIM standards so that regardless of the BIM tool one uses, no party is disadvantaged (McAuley et al., 2017).

2.8.2.6 Relative Advantage.

All BIM tools available are because of invention, innovation, and continuous R&D to improve their quality. All these activities incur costs that are transferred to the eventual adopter. These adopters make rational decisions on whether to adopt the BIM tool based on the Relative Advantage that the BIM tool has over others and a perception on whether the innovation is better than the current innovations in the market (Memon et al., 2014; Straub, 2009). A potential adopter looks at the cost involved in purchasing the BIM tool, the duration it will take to offset this cost (ROI duration) and the general benefits the adopter will accrue from the said BIM tool. Where benefits exceed costs, BIM adoption rate is high. Where costs exceed benefits, the BIM adoption rate is low. Where costs and benefits are not clearly known, a general inhibition of BIM adoption is will be observed due to the "fear of change" (Newton & Chileshe, 2012).

2.8.2.7 Experience.

This is the skill gained after going through training while under employment. Aspects regarding experience that influences adoption are the adopters attitude during and after interacting with the tool and the duration of interaction with the said tool (Stanley et al., 2013). Practitioners with low or no interaction with BIM have low adoption levels. Poor attitudes after interacting with the BIM also leads to low adoption levels. Experience is gained due to the duration of interaction that matures with time. BIM adopters who consistently use a BIM tool end up being competent in the use of the tool, thereby adopting it. This leads to improved adoption of the BIM tool.

2.8.2.8 Intellectual Property Ownership and Rights.

Intellectual ownership of federated model is an issue that affects BIM adoption (Ashurst Australia, 2014). In jurisdictions with no legal structures to recognise this, most design actors shy off from collaborating and sharing native models since it is difficult to split ownership of the model, link it to specific design actors (Adae, 2013; McGraw Hill Construction, 2012) and the value of data contained within a BIM file transcends the Standard Building Contract. Besides, where the intellectual property is unique in nature, the actors are usually very reluctant to share this information (RICS, 2015), for example a Quantity Surveyor who has developed a template BQ finds it difficult to share a BIM file with the template embedded since it can be misused by other parties in other projects without formal consent from the author. For Building Contractors, this scenario results into remodelling the whole project again in BIM once the information is availed in 2D (McGraw Hill Construction, 2012), which does not make economic sense to do especially if 2D documents are recognised in a contract. This results into low BIM adoption rates.

2.8.2.9 Liability Cover

Traditional delivery methods spread responsibilities and liabilities in any design and construction project and the insurance industry understands the extent of liability of each actor (Adae, 2013). Though BIM reduces risk levels in a project, in the event of a problem, it becomes difficult to lay blame on a specific actor (Ashurst Australia, 2014; Azhar et al., 2011, 2012; Smith, 2014b) and all the actors are held jointly liable. While individual actors would accept professional liability on errors of their own making, it becomes unpalatable for an actor to be held liable for an error that is not originally from them, because of a shared BIM model. The issue of liability cover has been partially resolved by having blanket indemnity covers for the whole team as opposed to individual indemnity cover for each actor. These covers tend to be more expensive due to the large extent of the cover value, and the perceived high risk by the insurance firms. This in the long run becomes an impediment and the team will go for this option only if use of BIM is compulsory. Where actors are not in charge of choosing their collaborators, it becomes a huge risk which hinders collaboration, which in turn hinders BIM uptake.

2.8.3 Conceptual Framework.

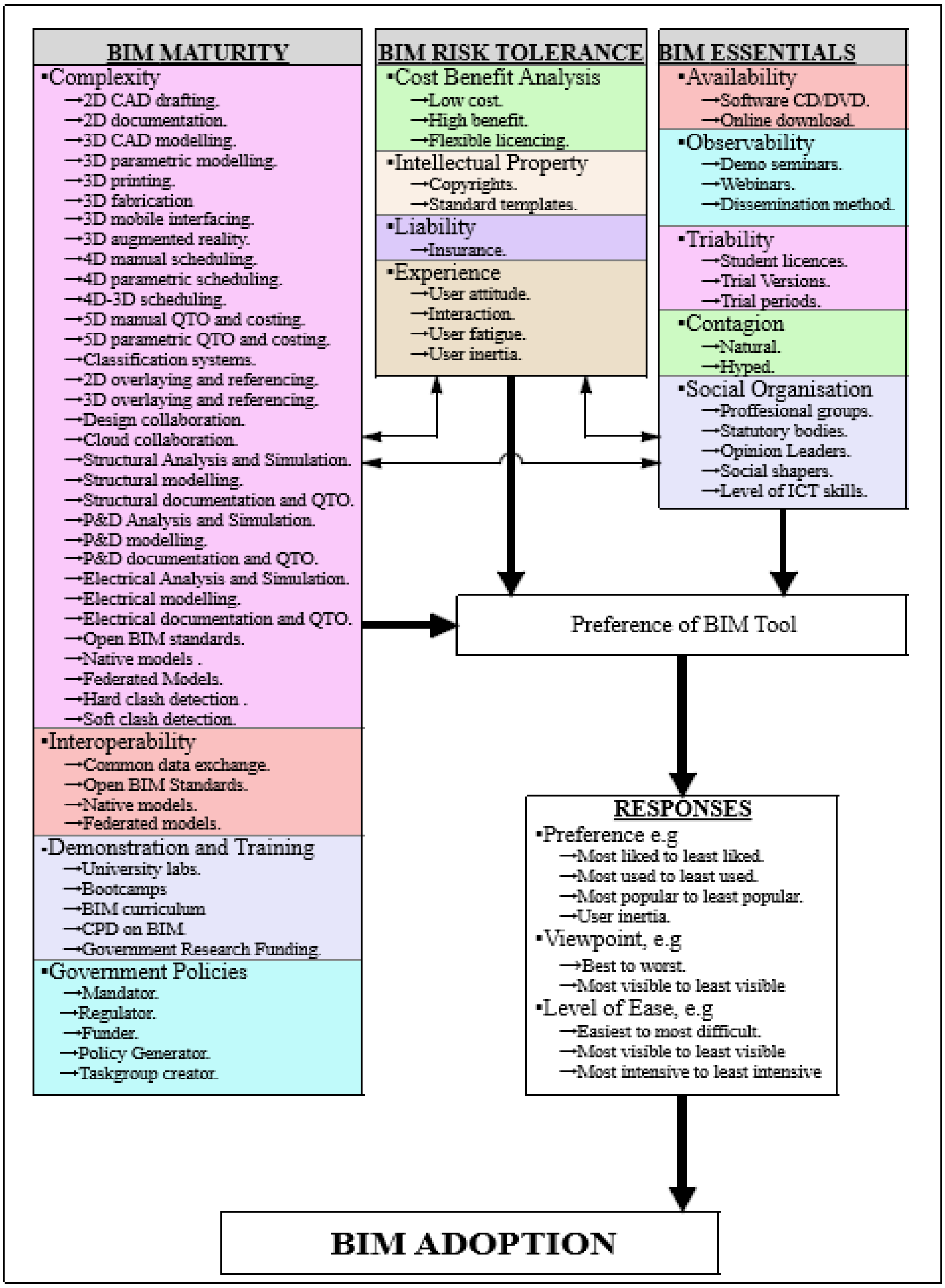


Figure 2.11: Conceptual Framework for BIM Adoption

Source: Author (2018)

As shown in figure 11 above, Availability, Observability and Trialability (AOT) of a BIM Tool influences preferences. Where the tool is highly innovated, natural contagion takes place within a social system thus resulting into high preference levels for the tool. Where innovation is not good, but there are intervention mechanisms like hyping and mandating, preference of the tool increases. The nature of social organisation influences taste and preferences. These attributes consolidate to form a perception index on the extent of benefits that can be derived from a BIM Tool. Level of complexity of a BIM Tool influences tastes and preferences. Unless complex capabilities are government mandated, Building Contractors will avoid using them since they would further complicate the workflows. Ability of a BIM tool to be compatible with most of the other BIM tools using a common data environment or being able to open most of the BIM file types increases preferences of the said BIM Tool. Availability of demonstration and training of BIM tools influences users to prefer it. These attributes consolidate to create a BIM Maturity Index with regards to BIM adoption.

The Relative Advantage or the cost benefit analysis, concise laws and enforcement of copyright protection improves preference of using BIM. Incentives of lower insurance premium and positive user experience due to using a BIM tool improves preferences towards the said tool. These attributes consolidate to create a BIM Risk Tolerance Index with regards to BIM Adoption. Where these indices are negative, they become a barrier towards adoption, and a catalyst when positive. A high preference of BIM tool results to positive reviews of the BIM tool, are most liked and perceived to be user friendly which results into high levels of adoption.

2.9 Research Question

This study is guided by the following question.

How do BIM Essentials, BIM Maturity and BIM Risk Tolerance indices affect BIM Adoption?

2.10 Hypothesis

2.10.1 Null Hypothesis (H_o)

There is no relationship between BIM Essentials, BIM Maturity and BIM Risk Tolerance and the level of BIM Adoption.

2.10.2 Alternate Hypothesis (H_a)

There is a relationship between BIM Essentials, BIM Maturity and BIM Risk Tolerance and the level of BIM Adoption.

2.10.3 Statistical Assumption.

It is assumed that the results gathered from a purposive sample (specific zones and ongoing constructions) are random, independent and a representation of the whole population of Building Contractors.

2.11 Theoretical and Operational Definition of Terms

2.11.1 Building Information Modelling (BIM) Tool.

BIM is a concept of using Information Technology based interfaces to try streamline the various workflow processes in the construction industry (Enynon, 2016) through creation of a virtual model of a building, and making the said virtual building a depository of all information relating to the building, including physical and functional characteristics and life cycle information (Azhar et al., 2011). BIM tools can be measured using adjectives such as cheap-expensive, easy-difficult, prefer-dislike, available-scarce.

2.11.3 Adoption.

This is the actual installation of a new technology or innovation at the basic (Hanel & Niosi, 2007) or grassroots level which is normally at the individual or firm level which potentially leads to BIM implementation. Adoption goes hand in hand with diffusion which is the spread of the new technology across a jurisdiction. Adoption can be measured using adjectives such as contagious-uncontagious, successful-unsuccessful, fast-slow.

2.11.4 BIM Essentials.

These are the basic and minimum conditions that must be met for BIM to thrive which include BIM Availability, Observability and Trialability, Natural contagion through availability of authentic social organisations. BIM Essentiality can be measured using adjectives like cheap-expensive, available-unavailable, observable-unobservable, triable-untriable, contagious-uncontagious.

2.11.5 BIM Maturity

This is the quality, repeatability and degree of excellence and perfection within a BIM tool's ability to perform a specific task or deliver a specific service or product (Sher et al., 2012) which include simplicity, compatibility, demonstration and training, experience and consistency of government policies . BIM Maturity can be measured using adjectives such as simple-complex, compatible-incompatible, trainable-untrainable, governable-ungovernable, novice-expert.

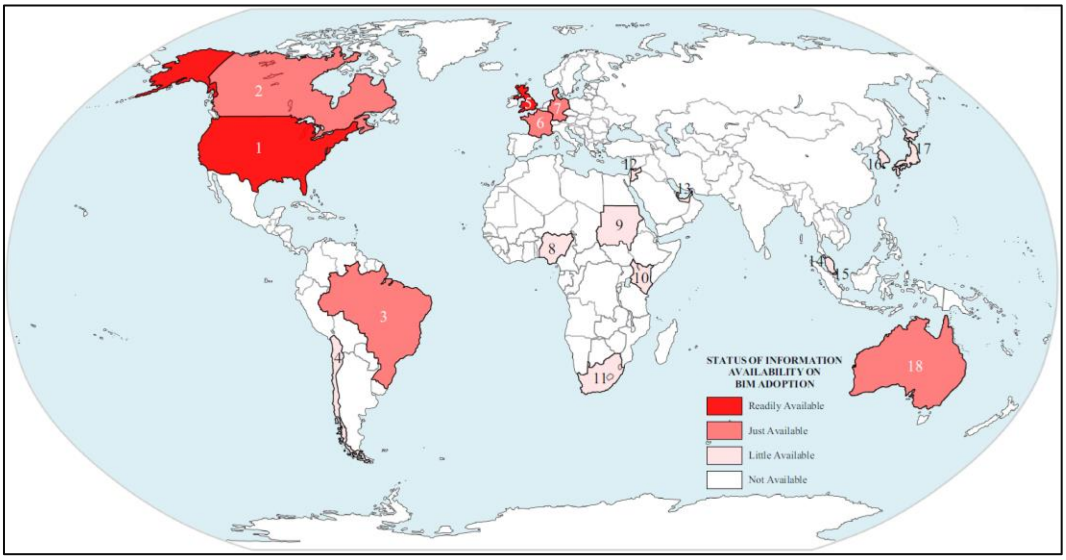
2.11.6 BIM Risk Tolerance

This is the ability of a potential BIM user to adopt (Zajko, 2015) a BIM tool regardless of the potential costs, challenges and losses that might be experienced in using the said BIM tool. These challenges include BIM generated mistakes and BIM generated failures which result into secondary problems like professional liability (McGraw Hill Construction, 2012), infringement of intellectual property rights (Adae, 2013) and loss of confidentiality (Redmond et al., 2012). BIM Risk Tolerance can be measured using adjectives such as beneficial-deleterious, flexible-inflexible, experienced-inexperienced.

2.12 Cases of Global Best Practises on BIM Adoption.

There is consensus amongst researchers that the awareness levels for BIM on a global level is relatively high. BIM awareness in the UK was at 97% by the end of 2015

(NBS, 2017). BIM awareness in Sudan was at 88% in 2016 (Ahmed, 2016) and 93% in Nigeria in 2016 (James et al., 2016). While the epidemic model of the innovation diffusion theory would assume that contact (awareness) to the innovation would automatically result into spread (adoption and diffusion), various available studies show otherwise. The map in figure 12 below and the associated table 116 in appendix 5 shows jurisdictions where information regarding BIM adoption is available, though the level of availability varies.



KEY

1: USA	6: France	11: South Africa	16: South Korea
2: Canada	7: Germany	12: Jordan	17: Japan
3: Brazil	8: Nigeria	13: United Arab Emirates	18: Australia
4: Chile	9: Sudan	14: Malaysia	
5: UK	10: Kenya	15: Singapore	

Figure 2.12: Level of BIM Adoption on a global Level

Source: Author (2018)

This research study shall shine the spotlight on BIM adoption in United States of America (USA) and United Kingdom (UK) to understand how the nine factors discussed above were used to catalyse BIM adoption in these jurisdictions.

2.12.1 BIM Adoption in the USA.

2.12.1.1 Background Information.

United States of America has witnessed rapid increase of BIM adoption from 28% in 2007 to 79% in 2013 (McGraw Hill Construction, 2012, 2014). Within the various actors in the construction industry, adoption by Contractors (74%) exceeded that of architects (70%) in 2012 with adoption for engineers and owners being at 42% and 44% respectively. Most organisations that have adopted BIM tend to be medium to large organisations (at 91%) compared to small organisations (at 49%). BIM implementation rate was at 55% amongst contractors in 2013 (Alhusban et al., 2017). With improved cloud and mobile phone technology, BIM in this jurisdiction is exploring new fronts like the use of iBIM and augmented reality tools like BIMx and BIM 360 to further enhance BIM (McGraw Hill Construction, 2014).

2.12.1.2 AOT of BIM Information, Tools, Models and Data.

Most of the BIM innovators originate from the US. In collaboration with various entities like GSA, they readily avail up-to-date BIM tools. Secondary innovators and trade suppliers have created a market for BIM models objects that can be easily accessed integrated in BIM models (Eastman et al., 2011).

2.12.1.3 Government Policies

Though there is no government backed mandate on BIM use (McGraw Hill Construction, 2014), the GSA, owing to its large portfolio of constructing and maintaining public buildings, designated BIM as a compulsory requirement for all public construction projects since 2007 (Eastman et al., 2011; Underwood & Isikdag, 2010). This, together with the backing of major BIM tool innovators, major design firms, contractors, and professional bodies like BuildingSMART has ensured improved adoption. In fact, BIM adoption is highest among the medium to large size contractors because two main government policies converge to the favour of this group - IPD being the predominant construction delivery method and GSA’s demand for compulsory use of BIM in public construction projects.

GSA in collaboration with the National Institute of Standards and Technology (NIST) and the BuildingSMART Alliance (BSA) have created policies and standards that assist in improving BIM adoption. Through the National 3D-4D program that was established in 2003, the National BIM Standards (NBIMS) 2.0 policy document was created to assist in use of the open file format like IFC. Since most BIM innovators are domiciled within this jurisdiction, the National Institute of Building Sciences (NIBS) does software certification testing of the various BIM tools to determine the extent to which these tools are compatible to the national standards before they are released to this market (NIBS & BSI, 2012). Besides GSA, there are other big entities that have also created their own BIM guides and standards. They include the United States Army Corps of Engineers (USACE) , the Association of General Contractors (AGC) and US Coastguard(Bopalgni, 2013).

2.12.1.4 BIM Training and Experience

There are three forms of training undertaken within this jurisdiction. They include educational training, formal professional training, and informal professional training. Computer related training have for a long time been integrated in educational institutions that teach programmes in the built environment (Underwood & Isikdag, 2010) though for a very long time, there was no systemic teaching framework and it was left to the educational institution's discretion to choose what to teach. This has improved over time with the curriculum for teaching BIM tools being standardised and emphasis laid on integrating BIM into studio education. Though this has improved BIM skills and subsequent adoption, the dynamic and versatile nature of these BIM technologies pose a challenge for the educational institutions. The rate of BIM tool improvements and turnover is so fast for these institutions to manage in terms of continuously changing curriculum, upgrading hardware and software and relevant re-training of the trainers to cope with the ever improving standards.

GSA, as part of the National 3D-4D program, educates the public and various actors in the construction industry on issues concerning BIM. This is done in collaboration with the BIM innovators and professional organizations like the AIA, AGC and educational institutions through sponsored seminars and workshops. GSA has also identified regional BIM champions to assist in continuous training of BIM. To ensure that standards and procedures are not an impediment towards training and adoption, GSA has ensured that their knowledge and expertise is non-proprietary.

Various BIM protagonists have come up with informal ways of training BIM. They include Suther Health (Eastman et al., 2011) who offer training by holding informal workshops and subsequently giving the trainers opportunities to implement the knowledge acquired in their projects. Bobrow Consulting Group is another protagonist that specialises in offering tutorials and online training on the use of Archicad as a BIM tool.

BIM Management is coming out as a line of training specialisation, just like architecture and engineering. BIM Managers come in as moderators of intellectual ownership since they are in charge of the overall management and leadership (Underwood & Isikdag, 2010). Due to these multifaceted forms of training, the level of BIM experience is relatively high and still growing. This has a direct impact on BIM adoption levels since exposure of potential adopters through peer to peer training increases expertise in BIM. In 2012, 53% of BIM users under contractors were considered to have advanced levels of BIM expertise.

2.12.1.5 Relative Advantage

Within this jurisdiction, benefits accruing from using BIM far much exceed associated costs and challenges. In 2013, 75% of Contractors gave a favourable verdict in using BIM (McGraw Hill Construction, 2014). Some of the benefits highlighted include higher Return of Investment (ROI) as a result of reduced costs, higher profitability and higher productivity, fewer RFI thereby ensuring that the process is not bogged down, clear and manageable change management processes, improved collaboration among the various actors thereby improving design integration, ability to create and manage Facilities Management enabled models after construction, reduced errors, omissions and reworks, better cost control and predictability, reduced cycle time for workflows and approvals, reduced claims and litigation and improved staff recruitment and retention. Some of the costs or challenges experienced are continuous cost of upgrading computer hardwares and BIM tools as a result of the rapid obsolesce of these items, continuous cost of training staff, initial and continuous cost of creating and improving internal workflows, processes, and standards, developing external collaborative BIM processes, low client demand for BIM and low levels of model sharing especially by the design actors resulting into double work for the contractors.

2.12.1.6 Intellectual Ownership and Liability Cover.

Contractors share BIM models within themselves more frequently than architects and engineers (McGraw Hill Construction, 2012) because the design actors have strong intellectual property and professional liability concerns. GSA together with other professional institutions like AIA are developing new procurement and contract options that will ensure that these concerns are addressed (Underwood & Isikdag, 2010) for example "The ConsensusDOC 301 - BIM Addendum" (FWCI, 2009). Some of the aspects being changed include definition of the scope and detail of the parametric model, extent of liability amongst the design actors, extent of use of the model information and the organisation of the model information, fees structure, relationship between the various actors and the types of deliverables. (Eastman et al., 2011).

2.12.2 BIM Adoption in the United Kingdom

2.12.2.1 Background Information.

By 2016, BIM awareness in the UK was at 97% while BIM adoption was at 62%. This is attributed to the enforcement of the government BIM mandate in 2016 (NBS, 2017). There was a higher adoption rate for medium practices (16 to 50 staff members) and larger practices (over 50 staff members) at 74% compared to small practices (under 15 staff members) at 48%. The BIM implementation rate stood at 67% of all BIM users who adopted BIM. The predominant BIM tools are Revit, Archicad, Autocad, Vectorworks and Microstation.

2.12.2.2 AOT of BIM Information, Tools, Models and Data.

There is ready accessibility of the various BIM tools, only that the various actors are strict in ensuring that the BIM tool they adopt conforms to the government COBie standards. There is a high level of BIM maturity within this jurisdiction. The BIM users are exploring new fronts like availability of BIM on mobile platforms thus making BIM to field and field to BIM possible (RICS, 2015).

2.12.2.3 Government Policies

The UK government created relevant BIM mandates to enhance the use of model-based BIM in the construction industry. This has given rise to various policies, bodies, and standards to assist in achieving this. One of the outstanding policy is the introduction of a five year plan in 2011 to ensure that all government procurement of public buildings use BIM by 2016 (McGraw Hill Construction, 2014; NBS, 2017). To achieve this, the government created a five-year term BIM Task Group whose main task was to ensure the rollout plan to bring all public funded projects to BIM Maturity level 2, and to support all actors in the construction industry in transitioning. This Task group currently headed by Mark Bew (of the Bew - Richard maturity ramp) has aided in the creation of the information sharing environment platform called Construction Operations Building Exchange (COBie). The BIM Task Group, through the British Standards Institute (BSI) created an information sharing standards known as PAS 1192:2 and PAS 1192:3 specifically to assist in facilities and asset management. Various professional institutions and federations such as RICS and the Royal Institute of British Architects (RIBA) have also been instrumental in actualising this mandate.

2.12.2.4 BIM Training and Experience

The dynamic improvement of BIM technologies, at a rate faster than how the educational institutions can improve their curricula, hardwares, softwares and trainers is a major challenge with regards to BIM educational training. Relevant organisations are exploring if availability of free licenses of BIM tools to students is feasible and sustainable in tackling this challenge (Underwood & Ayoade, 2015). RICS and RIBA have been instrumental in organising training courses for BIM managers, courses that are aligned to the BIM Task Group expected learning outcomes. In 2013, UK had the highest portion of actors using BIM who had less than 1 year experience (MHC, 2014). This was attributed to the introduction and progressive enforcement of the government

BIM mandate. Currently the UK is recognised as one of the jurisdictions with the highest level of BIM expertise (Waterhouse & Philp, 2016).

2.12.2.5 Relative Advantage

Within the UK, BIM users have highlighted several benefits accruing from using BIM. Some of these benefits include cost reduction in the design, build and maintain lifecycle, Time reduction from inception to completion thereby increasing speed and efficiency and increased coordination of construction documents. The users have highlighted some associated costs and challenges with the most outstanding ones including the continuous cost of replacing hardware and software, continuous cost of training.

CHAPTER THREE

RESEARCH METHODOLOGY.

3.1 Introduction

The aim of this chapter is to explain the research design, research techniques and specific procedures used to investigate study objectives identified in Chapter one. This chapter looks at the research approach used, with emphasis laid on how sentiments were covered, and how concepts were broken down into constructs that were then tested. This chapter then looked at the research design showing steps, procedures, and precautions necessary for collecting and analysing data in a manner relating to the objective. Thereafter, this chapter looks at research methods used, together with data collection techniques. This study then looks at sampling the population and the sample size, sampling methods and subjects of sampling. This chapter ended with an explanation on data collection, processing, analysing and presentation techniques, an explanation on pilot study and the research ethics this study was based on.

3.2 Research Approach

Emphasis is laid on establishing inferences about the population from the data collected, analysed, and generated from the sample. Through constructs and indicators generated during the literature review, this study measures with precision, sentiments of Building Contractors on the various indicators measured using the Likert scale of 5 that for example ranged from strongly disagreed, disagreed, undecided, agreed and strongly agreed. These binary antonyms included disagree-agree and difficult-easy. Biographical data were collected from respondents, information which include age, years of practise after undergraduate studies, years of using BIM and number of projects done in BIM.

3.3 Research Design

This study is a survey research that mainly aims at getting information about the status of BIM adoption amongst Building Contractors in Kenya. This study has three other secondary aims which include establishing the relationship between BIM Essentials and BIM Adoption, the relationship between BIM Maturity and BIM Adoption and the relationship between BIM Risk Tolerance and BIM Adoption. This study contains several dependent and independent variables that are generated from the theories, concepts, constructs, and indicators identified in the literature review.

3.2.1 Research Situ

This study is domiciled in Nairobi County and in specific planning zones with building types and size that allows seamless use of BIM as shown in the table in appendix 6. Several studies have indicated that BIM works well when certain thresholds are achieved. Hore (2017) in his various studies indicate that these thresholds are at least 1,500 sqm of built up space and Kshs 70 million in construction cost. This study used active construction sites with completion levels between 10% and 90%. Questionnaires were used to collect data from Building Contractors while interviews were used to collect data from statutory bodies, professional bodies, resellers, and insurers.

3.2.2 RESEARCH METHODS.

3.2.2.1 Primary Data

3.2.2.1.1 Questionnaire Method.

This method involves dissemination of a set of printed questions that are relevant to the research hypothesis with a choice of answers to persons concerned, with an aim of doing a statistical study (Kothari, 2004). The researcher piloted both manual and online surveys and opted for the manual survey due to better sentiments from pilot respondents.

3.2.2.1.2 Interview Method

This is a form of self-report (Marczyk et al., 2010) where respondents spontaneously give answers to a set of questions that are relevant to the research hypothesis. This method was used to collect information from statutory bodies, professional bodies, BIM tool resellers and insurers with an aim of getting information that would explain inferences observed during analysis of questionnaires. Due to the distance between the researcher and respondents at the time of data collection, telephone interviews were conducted.

3.2.2.2 Secondary Data.

3.2.2.2.1 Archival Method

This method involves broad range of activities to assist in collection of historical documents and textual materials generated by an organisation (Ventresca & Mohr, 2017). Data about various facets of this research, for example Building Contractors, zoning schedules and construction rates was obtained from various sources including government offices and professional bodies. Internet was used to complement physical collection of this archived information.

3.3 Data Collection Techniques

This is regarded as a way of implementing a method (Singh, 2006). Techniques used depended on the research method as shown below.

3.3.1 Technique for Questionnaires

The questionnaire was divided into five sections. The first section consisted of closed categorical questions about respondents' demographic information. The second to fourth sections consisted of closed categorical questions about specific information for specific BIM using, a five point Likert scale (Kothari, 2004) with the scales ranging from 1 (strongly agree), 2(agree), 3(not sure), 4(disagree) and 5(strongly disagree) with an opt-out option of 0 (I do not know) (Chimi & Russell, 2009) where applicable. The third section consisted of closed categorical questions about general information on BIM using, a five-point Likert scale. The fifth section was open ended seeking general views on eight specific issues about BIM.

3.3.2 Technique for Interviews.

The respondent's answers to the various questions were recorded. Standard themes emanating from inferences extracted from the data analysis were availed to the respondent before the interview.

3.3.3 Technique for Archival Method.

Statistical Abstracts from Kenya National Bureau of Statistics, zoning information from Nairobi City Development Ordinance and Zones, construction cost within Nairobi from Building Construction Costs Handbook and schedule of NCA registered Building Contractors from the National Construction Authority website were used to retrieve archival data that was relevant to the data collection and analysis process.

3.4 Sampling

3.4.1 Sampling Unit

This is the unit of selection in a sampling process (Degu & Yigzaw, 2006). The sampling unit in this study is a commercial unit that is the Building Contractor. The NCA Act defines a Building Contractor as a person, organized within an organisation who carries on business for reward and other valuable considerations, undertakes building construction, installation or erection of any building structure below, on or above the ground (NCLR, The National Construction Authority Act, 2011). This sampling unit was further refined to NCA registered Building Contractor class 4 and above who can lawfully carry construction projects with whose built up area exceeds 1,500 sqm and construction cost exceeding Kshs 70 million.

3.4.2 Sampling Frame

This is a list of area units that covers the area from which the sample is retrieved (Pettersson, 2002). The sample frame for this study was based on the planning zones of Nairobi County that could achieve the threshold that would allow seamless use of BIM by Building Contractors as indicated in the table 117 in appendix 6.

3.4.3 Sampling Method

A two-step sampling procedure was used to determine the samples for this population. The first step was done using purposive sampling where the research purposefully chose a particular geographical portion of the population (Degu & Yigzaw, 2006), in this case, the various zones in Nairobi based on Nairobi City Development Ordinances and Zones (NCC, 2010) where construction cost would exceed Kshs 150 Million as indicated in Table 118 in the appendix. Nairobi County is divided into 24 planning zones. Out of these, 6 zones met the threshold namely zones 1, 3, 4, 9, 10 and 16. The second step was done using the simple random sampling where active and ongoing projects in these zones were randomly identified as long as their levels of completion was not less than 10% (not mobilising) or more than 90% (preparing for practical handover). The distribution of these samples was as shown in the figure 13 below as indicated in the table 118 in appendix 6

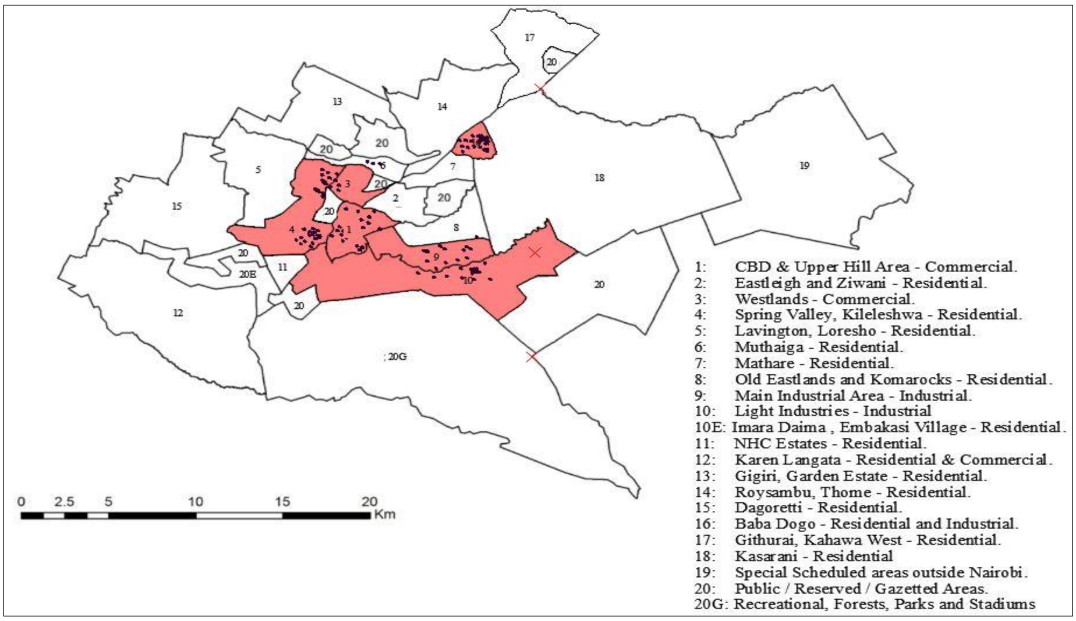


Figure 3.1: Geographical Mapping of Respondent

Source: Author (2019)

3.4.3.1 Subjects

111 questionnaires were availed to research assistants for distribution and filling by the Building Contractors within the identified zones as shown in figure 13 above. Out of these questionnaires, 49 were returned either filled incorrectly or not filled in at all and 62 were accepted, representing a response rate of 56%. Normality tests were done to test the hypothesis that were naturally distributed, and the results are discussed in Chapter 4.

3.4.4 Population and Sample Size.

This study generally limited itself to the population of Building Contractors within the Kenyan Construction Industry. It specifically limited itself to Building Contractors who had NCA registration of class 4 and above.

Using Cochran's equation, several parameters were determined beforehand to assist in establishing the minimum sample size. With the sampling error (e) being at ± 5%, confidence level being at 95% hence (z) is 1.96, variability level being at 50% and the actual population (N) being 1,665, the data being collected being predominantly continuous and not categorical (Bartlett et al., 2001; Cochran, 1977) the resulting sample size was 111 as shown in figure 14 below which is extracted from table 118 in appendix 7.

Table 1: Table for Determining Minimum Returned Sample Size for a Given Population Size for Continuous and Categorical Data

Population size	Sample size					
	Continuous data (margin of error=.03)			Categorical data (margin of error=.05)		
	alpha=.10 t=1.65	alpha=.05 t=1.96	alpha=.01 t=2.58	p=.50 t=1.65	p=.50 t=1.96	p=.50 t=2.58
1,500	79	110	183	230	306	461
1665		111				
2,000	83	112	189	239	323	499

Figure 3.2: Extrapolated (03) Sample Size Using Continuous Data (01) with a 'z' of 1.96 (02)

Source: (Bartlett et al., 2001)

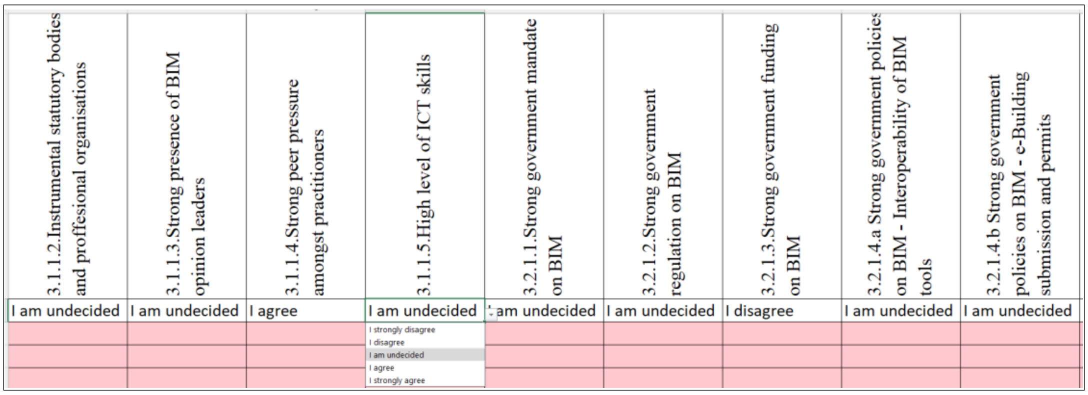
3.5 Data Management

3.5.1 Program for Data Collection

Permission was sought from the Department of Construction Management, Jomo Kenyatta University of Agriculture and Technology (JKUAT) and the National Commission of Science, Technology, and Innovation (NACOSTI) to run data collection, which was granted.

3.5.2 Data Processing

After data collection, it was processed in the standard sequential method. The researcher availed to the research assistants a data entry template file in MS Excel, that were already automatically coded to aid in data entry. As shown in figure 15 below pre-designed dropdown lists with matching answers in the questionnaires were used for keying in the answers to minimise errors due to wrong data entry.



3.1.1.2.Instrumental statutory bodies and proffesional organisations	3.1.1.3.Strong presence of BIM opinion leaders	3.1.1.4.Strong peer pressure amongst practitioners	3.1.1.5.High level of ICT skills	3.2.1.1.Strong government mandate on BIM	3.2.1.2.Strong government regulation on BIM	3.2.1.3.Strong government funding on BIM	3.2.1.4.a Strong government policies on BIM - Interoperability of BIM tools	3.2.1.4.b Strong government policies on BIM - e-Building submission and permits
I am undecided	I am undecided	I agree	I am undecided	am undecided	I am undecided	I disagree	I am undecided	I am undecided

Figure 3.3: Pre-Designed Dropdown Lists for Data Entry

Source: Author (2019).

The research assistants physically sorted the questionnaires separating responsive questionnaires from non-responsive questionnaires. They afterwards did data entry which autocoded themselves since the excel file used had been programmed by th researcher to autocode itself. The researcher then merged and consolidated the files from respective research assistants to create a master data file.

3.5.3 Data Analysis and Presentation

Data Analysis is the process of studying availed data with an aim of determining or inferring inherent facts, patterns, relationship or meaning. amongst the data group (Singh, 2006). This study utilised the inferential or statistical method of data analysis. This method involves analysing samples of a population with an aim of identifying consistent patterns and relationships that have universal application (Kothari, 2004) and thereby assist in generalisation of result. This was achieved through use of Statistical Package for Social Sciences (SPSS) version 22, PSPP and Ms Excel 2016.

Data analysed were presented through numerical based deliverables. Inferential analysis methods deployed were normality of data using skewness and kurtosis, mean comparison of population mean and hypothesised mean using one sample t test, comparison of relationships using Pearson Correlation, measure extent of variance using ANOVA and generation of linear relationship using bivariate regression model.

3.6 Data Validity and Reliability

Data Validity is the degree to which the data generates truthful and accurate results (Heale & Twycross, 2015). Content validity (Bajpai & Bajpai, 2014; Creswell, 2009) was achieved by ensuring that all questions in the questionnaire covered all the content with regards to the various concepts that this research study wanted to test. Construct validity (Heale & Twycross, 2015) was achieved by ensuring that questionnaires were comprehensively packaged in a manner to conform to the weighting of the Likert scale thereby ensuring that inferences could be made from the test score.

Data Reliability is the ability to consistently, and without bias, return the same results each time the same test is done (Bajpai & Bajpai, 2014). While the stability of data could not be tested using the test- retest reliability test owing to the limited time and resources, the researcher used the Cronbach's alpha (α) to measure homogeneity and internal consistency of data with the acceptable reliability scale being 0.7 and above (Heale & Twycross, 2015)

3.7 Pilot Study

This is the process of administering questionnaires to a select number of respondents in the population before the actual mass administration of the said questionnaires. Eight respondents were identified to assist in the pre-test of the questionnaires. These respondents were regarded to as experts in this field. After reviewing comments received from this pilot study, corrections were made accordingly to ensure that the questionnaire was comprehensible and error free. The researcher also used pilot study to compare efficacy of manual surveys and online surveys. The pilot respondents advised on use of manual surveys.

3.8 Ethical Considerations

With respect to ethical requirements in research, this research study upheld research ethics with regards to planning and conducting this research study. This was achieved at various levels in various ways. At the institutional level, a research permit was obtained from NACOSTI to enable easier and legal access of information considered sensitive. With the research permit, the researcher was able to formally request for information from the various statutory bodies involved in this study which they were able to avail without any legal restriction. At the respondents' level, consent was sought from the respondent before the questionnaire was administered. This ensured that there was no coercion when collecting data thus ensuring the information was accurate as possible. Privacy and confidentiality was upheld when communicating or corresponding with the respondents. Their identity was deliberately made anonymous to ensure that personal information relating to the respondent remained private.

CHAPTER FOUR

DATA ANALYSIS AND DISCUSSIONS.

4.1 Data Reliability

Cronbach's alpha was used to measure reliability amongst the 166 questions as shown in table 2 below. The result indicated a high level of data reliability (166 items: α = 0.96).

Table 4.1: Cronbach's Alpha Reliability Test

Reliability Statistics	
Cronbach's Alpha	**Number of Items**
.963	166

Source: Author (2019).

4.2 Normality of Data

A three-step normality test was done on the demographic data of responsive respondents. In the first step, a table of descriptive statistics was generated to see the extent of distribution as shown in table 3 below.

Table 4.2: Demographics of Respondents

Age	21-25	26-30	31-35	36-40	41-45	46-50	51-55	56-60	Above 60	
	2	-	8	14	26	10	2	-	-	62
	3%	0%	13%	23%	42%	16%	3%	0%	0%	100%
Years of	0-5	6-10	11-15	16-20	21-25	26-30	31-35	36-40	Above 40	
Practice	14	4	24	8	10	2	-	-	-	62
	23%	6%	39%	13%	16%	3%	0%	0%	0%	100%
Years of	0-2	3-4	5-6	7-8	9-10	11-12	13-14	15-16	Above 16	
using	8	10	10	10	6	4	-	4	10	62
BIM	13%	16%	16%	16%	10%	6%	0%	6%	16%	100%
Number	0-5	6-10	11-15	16-20	21-25	26-30	31-35	36-40	Above 40	
of	18					-			-	62
Projects	29%	19%	16%	23%	3%	0%	3%	6%	0%	100%

Source: Author (2019).

As shown in table 4.4 above complemented with figure 4.1 below, respondents were diverse with the predominant age being between 41 to 45 (42%) though the majority were mid-aged between 36 to 50 years representing 81% of the respondents. With regards to practice experience, the predominant band was 11 to 15 (39%) though majority had abundant experience between 11 to 30 years representing 71%. With regards to specific experience of using BIM, the spread was even though the majority had mid experience between 3 and 8 years representing 48% of the respondents. With regards to usage of BIM in projects, the predominant range was 0 – 5 projects (29%) and the majority had used BIM for less than 15 projects representing 64% of the respondents.

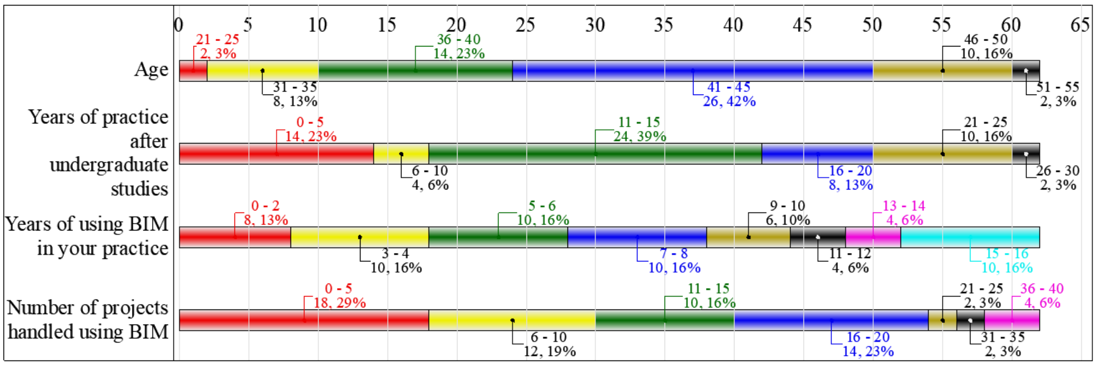


Figure 4.1: Graphical Presentation of the Respondent's Demographics

Source: Author (2019)

In the second step, normality tests were done on these demographics as shown in table 4.3 below

Table 4.3: Normality Tests on Demographics

	N	Mean	Std. Deviation	Skewness		Kurtosis	
	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Std. Error
Age	62	4.61	1.192	-.757	.304	1.317	.599
Years of Practice	62	3.03	1.437	.079	.304	-.796	.599
Years of using BIM	62	4.42	2.707	.573	.304	-.944	.599
Number of projects using BIM	62	2.97	1.975	1.155	.304	.918	.599
Valid N (listwise)	62						

Source: Author (2019)

The age of participants ranged from 21 to 55 years (M = 39, SD = 1.20) and was normally distributed, with skewness of -0.76 (SE = 0.304) and kurtosis of 1.31(SE = 0.60). The years of practice of participants ranged from 0 to 30 years (M = 11, SD = 1.44). and was normally distributed, with skewness of -0.08 (SE = 0.304) and kurtosis of -.80(SE = 0.60). The years of using BIM for the participants ranged from 0 to above 16 years (M = 8, SD = 2.71) and was normally distributed, with skewness of 0.57 (SE = 0.304) and kurtosis of -.94(SE = 0.60). The number of projects done using BIM by the participants ranged from 0 to 40 projects (M = 13, SD = 2.67) and was non-normally distributed, with skewness of 1.16 (SE = 0.304) and kurtosis of 0.918(SE = 0.60).

In the third step, a Kolmogorov-Smirnov Test and Shapiro Wills test of normality was done for demographics that recorded non-normal distribution, with the result indicated in table 4.4 below.

Table 4.4: K-S and Shapiro Wilk Test of Normality

Tests of Normality						
	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Number of projects handled using BIM	.212	62	.000	.806	62	.000

a. Lilliefors Significance Correction

Source: Author (2019)

With the null hypothesis (H_o) in this context meaning that number of projects done using BIM are not normally distributed and the alternate hypothesis (H_a) meaning that number of projects done using BIM are normally distributed, the K-S test ($p < 0.05$) and Shapiro test ($p < 0.05$) accepts the null hypothesis. A box and whisker diagram was generated for this independent variable (number of projects done using BIM) to identify the outlier cases that were causing the abnormality as shown in figure 4.2 below.

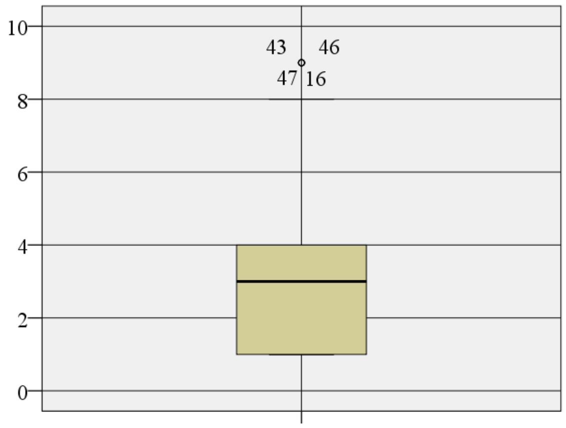


Figure 4.2: Box and Whisker Plot

Source: Author (2019).

These 4 cases were winsorised to match the upper quartile (16 -20 projects) to eliminate these abnormalities as shown in figure 4.3 below.

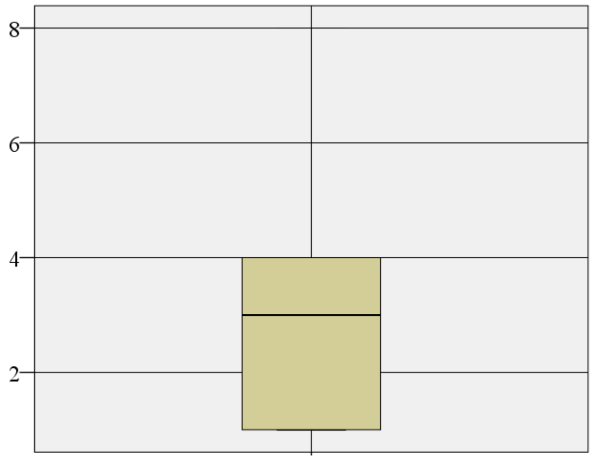


Figure 4.3: Winsorised Box and Whisker Plot

Source: Author (2019).

4.3 Survey Results

This study adopted a structured way to analyse the results of the data collected. For each parameter, this study looked at the performance, its correlation with BIM Adoption, the analysis of variance (ANOVA) amongst the subjects, bivariate and multivariate regression. With regards to performance, one sample t statistics and test were used to check the degree of freedom, the 2 tailed significance, mean, standard deviation in the context of the test value where in most cases, '2' representing low was used. With regards to corelation, the Pearson corelation was used to compare parameters to BIM adoption with a special emphasis if 'p' was smaller than 0.05 signifying a correlation. Values of the Pearson corelation were then looked at to see the extent of corelation, from weak to strong. Where this corelation was established, ANOVA was done to see which subjects contributed more to the corelation and a regression model, either bivariate or multivariate was used to get an equation that best represent the relationship. We capped up the is process by providing a bivariate graph that gives a visual representation of the regression model.

4.3.1 Adoption of BIM Tools

The first primary task of this study was to investigate the level of BIM Adoption amongst Building Contractors in Kenya. The null and alternate hypothesis stated that:

- H_o – The adoption levels of BIM by Building Contractors in Kenya is low.
- H_a – The adoption levels of BIM by Building Contractors in Kenya is not low meaning that either the adoption levels of BIM by Building Contractors in Kenya is lower than the low score or the adoption levels of BIM by Building Contractors in Kenya is higher than the low score.

BIM Adoption level was a score generated using the average of the highest level of preference for the various BIM tools associated capabilities.

BIM Adoption Score = (Highest preferred 2D CAD Tool(Archicad, Autocad, Revit or Sketchup) + Highest preferred 3D BIM Tool(Archicad, Revit or Sketchup) + Highest preferred 4D BIM Tool(MS Project or Primavera) + Highest preferred 5D BIM Tool(Archicad, Bluebeam, Cost X, Revit, SAP or WinQs) + Highest preferred Structural Analysis and Modelling BIM Tool(Prokon or Autocad) + Highest preferred MEP Analysis and Modelling BIM Tool(MEP Modeller and Revit) + Highest preferred Integrated Design, Coordination and Collaboration BIM Tool(Archicad, Revit or Sketchup) + Interoperability and Clash Detection BIM Tools (Archicad, Revit or Sketchup))/8

The BIM Adoption Score was scaled from 1(very low adoption score), 2(low adoption score), 3(neutral), 4(high adoption score) to 5(very high adoption score). One sample t test was used was used to check this hypothesis as shown in tables 4.5 and 4.6 below.

Table 4.5: One Sample Statistics for BIM Adoption Score

	One-Sample Statistics			
	N	**Mean**	**Std. Deviation**	**Std. Error Mean**
Overall BIM Adoption	62	1.9778	1.47425	.18723

Source: Author (2019)

Table 4.6: One Sample *t* Test for BIM Adoption Score

	One-Sample Test					
	Test Value = 2 (Low BIM Adoption Score)					
	t	**Df**	**Sig. (2-tailed)**	**Mean Difference**	**95% Confidence Interval of the Difference**	
					Lower	**Upper**
Overall BIM Adoption Score	-.118	61	.906	-.02218	-.3966	.3522

Source: Author (2019)

t (61) = -.118, α > .05. *t* at 61 degrees of freedom is -.118. The probability that the observed difference between our sample mean and the population mean was due to mere chance rather than to a real difference in achievement is greater than 5%.Our survey is not significantly different from the null hypothesis and therefore BIM Adoption score (M=1.98, SD=1.47) scored is not significantly lower than the low BIM Adoption (M=2).

This study narrowed into the individual BIM capabilities to establish their respective level of Adoption as shown in tables 4.7 and 4.8 below.

Table 4.7: One Sample Statistics for Adoption Score for Each Capability

One-Sample Statistics				
	N	Mean	Std. Deviation	Std. Error Mean
2D-CAD Adoption Score	62	2.5806	2.19947	.27933
3D-BIM Adoption Score	62	2.3548	2.18112	.27700
4D-BIM Adoption Score	62	1.6290	1.96054	.24899
5D-BIM Adoption Score	62	2.5161	2.07832	.26395
SAM-BIM Adoption Score	62	1.0645	1.71656	.21800
MEPAM-BIM Adoption Score	62	.9677	1.78305	.22645
IDCC-BIM Adoption Score	62	2.3548	2.18112	.27700
ICD-BIM Adoption Score	62	2.3548	2.18112	.27700

Source: Author (2019)

For 2D-CAD Adoption, t(61) = 2.08, α < .05 means that the level of adoption is significantly different from the null hypothesis that the adoption level is low (M=2), and therefore at (M=2.58, SD=2.20) the adoption level is significantly higher than low (moderate). For 3D-BIM Adoption, IDCC-BIM Adoption and ICD-BIM Adoption, t(61) = 1.28, α > .05 means that the level of adoption is not significantly different from the null hypothesis that the adoption level is low (M=2), and therefore at (M=2.35, SD=2.18) the adoption level is equal to low.

Table 4.8: One Sample t Test for Adoption Score for Each Capability

One-Sample Test						
	Test Value = 2 (Low Adoption)					
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
2D-CAD Adoption Score	2.079	61	.042	.58065	.0221	1.1392
3D-BIM Adoption Score	1.281	61	.205	.35484	-.1991	.9087
4D-BIM Adoption Score	-1.490	61	.141	-.37097	-.8689	.1269
5D-BIM Adoption Score	1.955	61	.055	.51613	-.0117	1.0439
SAM-BIM Adoption Score	-4.291	61	.000	-.93548	-1.3714	-.4996
MEPAM-BIM Adoption Score	-4.558	61	.000	-1.03226	-1.4851	-.5794
IDCC-BIM Adoption Score	1.281	61	.205	.35484	-.1991	.9087
ICD-BIM Adoption Score	1.281	61	.205	.35484	-.1991	.9087

Source: Author (2019)

For 4D-BIM Adoption, t(61) = -1.49, α > .05 means that the level of adoption is not significantly different from the null hypothesis that the adoption level is low (M=2), and therefore at (M=1.63, SD=1.96) the adoption level is equal to low. For 5D-BIM Adoption, t(61) = 1.96, α > .05 means that the level of adoption is not significantly different from the null hypothesis that the adoption level is low (M=2), and therefore at (M=2.52, SD=2.08) the adoption level is equal to low. For SAM-BIM Adoption, $t(61) = -4.29$, $\alpha < .05$ means that the level of adoption is significantly different from the null hypothesis that the adoption level is low (M=2), and therefore at (M=1.06, SD=1.72) the adoption level is the adoption level is significantly lower than low (very low). For MEP-BIM Adoption, $t(61) = -4.56$, $\alpha < .05$ means that the level of adoption is significantly different from the null hypothesis that the adoption level is low (M=2), and therefore at (M=0.97, SD=1.78) the adoption level is significantly lower than low (very low).

The study also looked at the correlations between BIM Adoption amongst Building Contractors and the various independent variables as shown in table 10 below. Where $p < .05$, correlation was significant, with the extent of correlation varying from weak ($0.2 < r < 0.4$), moderate ($.4 < r < 0.6$) to strong ($0.6 < r$).

Table 4.9: Pearson Correlation between Independent Variables and BIM Adoption

		Age	Years of Practice after Undergraduate Studies	Years of using Building Information Modelling	Number of projects handled using BIM	Overall BIM Adoption Score
Age	Pearson Correlation	1	.486**	.457**	.343**	-.469**
	Sig. (2-		.000	.000	.006	.000
	N	62	62	62	62	62
Years of Practice after Undergraduate Studies	Pearson Correlatio	.486**	1	.898**	.647**	-.342**
	Sig. (2-	.000		.000	.000	.006
	N	62	62	62	62	62
Years of using Building Information Modelling (BIM)	Pearson Correlatio n	.457**	.898**	1	.653**	-.288*
	Sig. (2-tailed)	.000	.000		.000	.023
	N	62	62	62	62	62
Number of projects that you have handled using BIM	Pearson Correlatio	.343**	.647**	.653**	1	-.252*
	Sig. (2-tailed)	.006	.000	.000		.048
	N	62	62	62	62	62
Overall BIM Adoption Score	Pearson Correlatio	-.469**	-.342**	-.288*	-.252*	1
	Sig. (2-	.000	.006	.023	.048	
	N	62	62	62	62	62

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

Source: Author (2019)

As shown in table 4.9 above, the results indicated that $p < .05$ for the four relationships (Age vs BIM Adoption Level, Years of practice vs BIM Adoption Level, Years of using BIM in practice vs BIM Adoption Level and Number of Projects handled vs BIM Adoption Level) showing that these variables were significantly correlated. The Pearson correlation indicated a moderate negative correlation between age and BIM Adoption meaning that adoption levels decreased with increased age within the Building Contractors if all other factors were held constant. The Pearson correlation indicated a weak negative correlation between years of practice and BIM Adoption meaning that adoption levels decreased with increased years of practice within the Building Contractors if all other factors were held constant. The Pearson correlation indicated a weak negative correlation between years of using BIM in practice and BIM Adoption meaning that adoption levels decreased with increased years of using BIM in practice within the Building Contractors if all other factors were held constant.. There was a weak negative correlation between Number of projects handled in BIM and BIM Adoption, meaning adoption levels decreased with the increased number of projects handled using BIM Contractors if all other factors were held constant.

A One -way ANOVA test was done on the four independent variables to see if there was variance between the various groups in these variables and how these variances affected levels of BIM Adoption. One-way ANOVA results for age versus BIM adoption was as shown in table 4.10 below.

Table 4.10: One-Way ANOVA Test on Age vs BIM Adoption

Tests of Between-Subjects Effects						
Dependent Variable: Overall BIM Adoption Score						
Source	**Type III Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**	**Partial Eta Squared**
Corrected Model	38.274[a]	5	7.655	4.546	.002	.289
Intercept	93.459	1	93.459	55.498	.000	.498
Age	38.274	5	7.655	4.546	.002	.289
Error	94.305	56	1.684			
Total	**375.109**	**62**				
Corrected	132.579	61				

a. R Squared = .289 (Adjusted R Squared = .225)

Source: Author (2019)

The ANOVA summary indicates that with $p < 0.05$, the null hypothesis that variances were equal amongst age groups was rejected hence means of BIM adoption across the age groups were different with 29% of the variance of BIM Adoption explained by age and variance between groups was 4.6 times greater than variances within the groups. With the extent of variance confirmed, a post-Hoc test was done to confirm where the differences occurred between these age groups as shown in table 4.11 below.

Table 4.11: SNK Post Hoc Test on Age vs BIM Adoption

Overall BIM Adoption Score				
Student-Newman-Keuls [a,b,c]				
Age	N	Subset		
		1	2	3
51-55	2	.0000		
46-50	10	.6250	.6250	
41-45	26	2.0288	2.0288	2.0288
31-35	8		2.5156	2.5156
36-40	14		2.6250	2.6250
21-25	2			3.3750
Sig.		.058	.108	.412

Means for groups in homogeneous subsets are displayed.
Based on observed means.
The error term is Mean Square(Error) = 1.684.

a. Uses Harmonic Mean Sample Size = 4.495.
b. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.
c. Alpha = .05.

Source: Author (2019)

The SNK Post Hoc test generated 3 subsets with ages 21-25 being significantly different from ages 46-50 and 51-55.

With regards to ANOVA test between years of practice and BIM Adoption, the results were as shown in table 4.12 below.

Table 4.12: One-Way ANOVA Test on Years of Practice vs BIM Adoption

Tests of Between-Subjects Effects						
Dependent Variable: Overall BIM Adoption Score						
Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	18.400[a]	5	3.680	1.805	.127	.139
Intercept	96.136	1	96.136	47.151	.000	.457
Years of Practice	18.400	5	3.680	1.805	.127	.139
Error	114.179	56	2.039			
Total	**375.109**	**62**				
Corrected Total	**132.579**	**61**				

a. R Squared = .139 (Adjusted R Squared = .062)

Source: Author (2019)

The ANOVA summary indicates that with $p > 0.05$, the null hypothesis that variances were equal amongst years of practice groups was accepted hence means of BIM adoption across the years of practise groups were not different with 14% of the variance of BIM Adoption explained by years of practice and variance between groups was 1.9 times greater than variances within the groups. With the extent of variance confirmed, a post-Hoc test was done to confirm where the differences occurred between these years of practice as shown in table 4.13 below.

Table 4.13: SNK Post Hoc Test on Years of Practice vs BIM Adoption

Overall BIM Adoption Score Student-Newman-Keuls			
Years of Practice	**N**	**Subset**	
		1	**2**
26 to 30	2	.0000	
21 to 25	10	1.3750	1.3750
16 to 20	8	1.6250	1.6250
11 to 15	24	2.0937	2.0937
0 to 5	14		2.5089
6 to 10	4		2.6250
Sig.		.082	.596

Means for groups in homogeneous subsets are displayed.
Based on observed means.
The error term is Mean Square(Error) = 2.039.
a. Uses Harmonic Mean Sample Size = 5.514.
b. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.
c. Alpha = .05.

Source: Author (2019)

The SNK Post Hoc test generated 2 subsets with years of practice 0-5 and 6-10 being significantly different from 26-30.

With regards to ANOVA test between years of using BIM and BIM Adoption, the results were as shown in table 4.14 below.

Table 4.14: One-Way ANOVA Test on Years of Using BIM vs BIM Adoption

Tests of Between-Subjects Effects						
Dependent Variable: Overall BIM Adoption Score						
Source	**Type III Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**	**Partial Eta Squared**
Corrected Model	17.032[a]	7	2.433	1.137	.354	.128
Intercept	198.209	1	198.209	92.631	.000	.632
Years of using BIM	17.032	7	2.433	1.137	.354	.128
Error	115.547	54	2.140			
Total	375.109	62				
Corrected	132.579	61				

a. R Squared = .128 (Adjusted R Squared = .015)

Source: Author (2019)

The ANOVA summary indicates that with p > 0.05, the null hypothesis that variances were equal amongst years of BIM use groups was accepted hence means of BIM adoption across the years of BIM use groups were not different with 13% of the variance of BIM Adoption explained by years of BIM use and variance between groups was 1.1 times greater than variances within the groups. With the extent of variance confirmed, a post-Hoc test was done to confirm where the differences occurred between these years of using BIM as shown in table 4.15 below.

Table 4.15: SNK Post Hoc Test on Years of Using BIM vs BIM Adoption

Overall BIM Adoption Score		
Student-Newman-Keuls		
Years of using BIM	**N**	**Subset**
		1
15 to 16	4	1.0625
Above 16	10	1.3750
9 to 10	6	1.6250
5 to 6	10	1.8750
7 to 8	10	1.9750
11 to 12	4	2.2500
0 to 2	8	2.3438
3 to 4	10	2.8625
Sig.		.337

Means for groups in homogeneous subsets are displayed.
Based on observed means.
The error term is Mean Square(Error) = 2.140.

a. Uses Harmonic Mean Sample Size = 6.713.
b. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.
c. Alpha = .05.

Source: Author (2019)

The SNK Post Hoc test generated 1 subset indicating homogeneity amongst the various groups

With regards to ANOVA test between number of projects done using BIM and BIM Adoption. the results were as shown in table 4.16 below.

Table 4.16: One-Way ANOVA Test on Number of Projects Using BIM vs BIM Adoption

Tests of Between-Subjects Effects						
Dependent Variable: Overall BIM Adoption Score						
Source	**Type III Sum of**	**df**	**Mean Square**	**F**	**Sig.**	**Partial Eta**
Corrected Model	19.893[a]	6	3.315	1.618	.160	.150
Intercept	75.586	1	75.586	36.892	.000	.401
Projects done using BIM	19.893	6	3.315	1.618	.160	.150
Error	112.686	55	2.049			
Total	375.109	62				
Corrected	132.579	61				

a. R Squared = .150 (Adjusted R Squared = .057)

Source: Author (2019)

The ANOVA summary indicates that with $p > 0.05$, the null hypothesis that variances were equal amongst Projects done in BIM groups was accepted hence means of BIM adoption across the projects done in BIM groups were not different with 15% of the variance of BIM Adoption explained by number of projects done using BIM and variance between groups was 1.6 times greater than variances within the groups. With the extent of variance confirmed, a post-Hoc test was done to confirm where the differences occurred between these numbers of projects as shown in table 4.17 below.

Table 4.17: SNK Post Hoc Test on Number of Projects using BIM vs BIM Adoption

Overall BIM Adoption Score		
Student-Newman-Keuls		
Projects handled in BIM	**N**	**Subset**
		1
31 to 35	2	.0000
21 to 25	2	.6250
11 to 15	10	1.7250
16 to 20	14	1.7321
6 to 10	12	2.0625
36 to 40	4	2.1250
0 to 5	18	2.5903
Sig.		.115

Means for groups in homogeneous subsets are displayed.
Based on observed means.
The error term is Mean Square(Error) = 2.049.
a. Uses Harmonic Mean Sample Size = 4.486.
b. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.
c. Alpha = .05.

Source: Author (2019)

The SNK Post Hoc test generated 1 subset indicating homogeneity amongst the various groups

Bivariate regression models were generated between the BIM Adoption score and the 4 independent variables, having established that there were correlations. With regards to age, the following hypotheses were generated:

- H_o: None of the coefficients in age predict BIM Adoption Score.
- H_a: Most of the coefficients in age predict BIM Adoption Score.

Table 4.18: Bivariate Regression Model on Age vs BIM Adoption

Coefficients[a]								
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B	
		B	Std. Error	Beta			Lower Bound	Upper Bound
1	(Constant)	4.653	.671		6.930	.000	3.310	5.996
	Age	-.580	.141	-.469	-4.113	.000	-.862	-.298

a. Dependent Variable: Overall BIM Adoption Score

Source: Author (2019)

As indicated in table 4.18 above, with sig (p) < 0.05, the null hypothesis was rejected, meaning that age predicted BIM Adoption Score with the regression equation as shown below as long as all the other factors (years of practise, years of using BIM and number of projects done in BIM) are held constant:

- BIM Adoption Score = 4.653 – 0.580 x Age

With regards to years of practice, the following hypotheses were generated:

- H_o: None of the coefficients in years of practice predict BIM Adoption Score
- H_a: Most of the coefficients in years of practice predict BIM Adoption Score

Table 4.19: Bivariate Regression Model on Years of Practice vs BIM Adoption

Coefficients[a]								
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B	
		B	Std. Error	Beta			Lower Bound	Upper Bound
1	(Constant)	3.042	.417		7.295	.000	2.208	3.876
	Years of Practice	-.351	.124	-.342	-2.820	.006	-.600	-.102

a. Dependent Variable: Overall BIM Adoption Score

Source: Author (2019)

As indicated in table 4.19 above, with sig (p) < 0.05, the null hypothesis was rejected, meaning that years of practice predicted BIM Adoption Score with the regression equation as shown below as long as all the other factors (age, years of using BIM and number of projects done in BIM) are held constant. This was further articulated using the linear graph in figure 4.4 below.

- BIM Adoption Score = 3.042 – 0.351 x Years of Practice

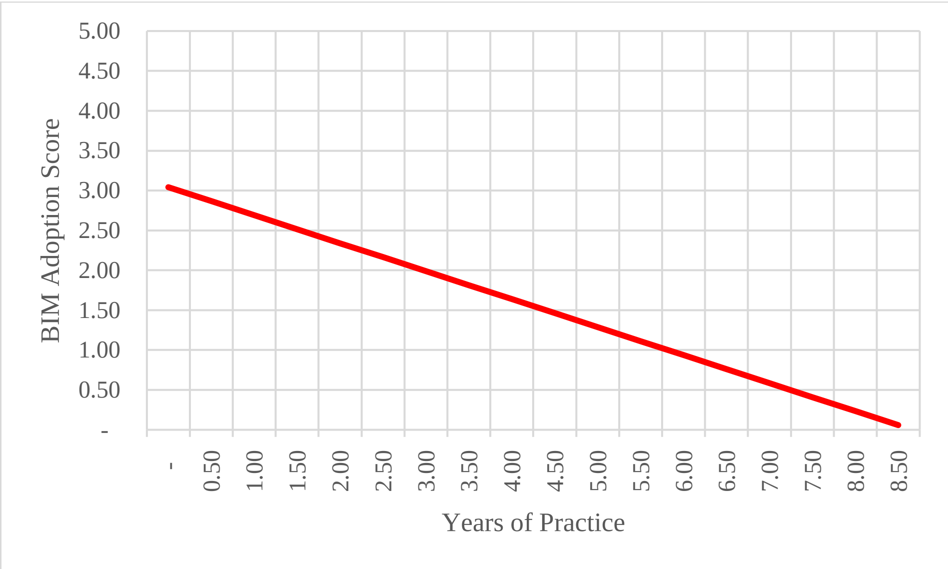


Figure 4.4: Bivariate Graph of Years of Practice vs BIM Adoption Score

Source: Author (2019)

With regards to years of using BIM, the following hypotheses were generated:

- H_o: None of the coefficients in years of using BIM predict BIM Adoption Score
- H_a: Most of the coefficients in years of using BIM predict BIM Adoption Score

Table 4.20: Bivariate Regression Model on Years of using BIM vs BIM Adoption

Coefficients[a]								
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B	
		B	Std. Error	Beta			Lower Bound	Upper Bound
1	(Constant)	2.671	.348		7.674	.000	1.975	3.368
	Years of using BIM	-.157	.067	-.288	-2.332	.023	-.292	-.022

a. Dependent Variable: Overall BIM Adoption Score

Source: Author (2019)

As indicated in table 4.20 above, with sig (p) < 0.05, the null hypothesis was rejected, meaning that years of using BIM predicted BIM Adoption Score with the regression equation as shown below as long as all the other factors (age, years of practice and number of projects done in BIM) are held constant:

- BIM Adoption Score = 2.671 – 0.157 x Years of using BIM

With regards to years of using BIM, the following hypotheses were generated:

- H_o: None of the coefficients in number of projects done using BIM predict BIM Adoption Score.
- H_a: Most of the coefficients in number of projects done using BIM predict BIM Adoption Score.

Table 4.21: Bivariate Regression Model on Age vs BIM Adoption

Coefficients[a]								
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B	
		B	Std. Error	Beta			Lower Bound	Upper Bound
1	(Constant)	2.537	.332		7.649	.000	1.873	3.200
	Number of projects using BIM	-.188	.093	-.252	-2.019	.048	-.375	-.002

a. Dependent Variable: Overall BIM Adoption Score

Source: Author (2019)

As indicated in table 4.21 above, with sig (p) < 0.05, the null hypothesis was rejected, meaning that years of using BIM weakly predicted BIM Adoption Score with the regression equation as shown below as long as all the other factors (age, years of practice and years of using BIM) are held constant):

- BIM Adoption Score = 2.537 – 0.188 x Number of Projects using BIM.

A multivariate regression model was generated between the BIM Adoption score and all the 4 independent variables using the following hypotheses.

- H_o: None of the coefficients in the independent variables predict BIM Adoption Score.
- H_a: Most of the coefficients in the independent variables predict BIM Adoption Score.

Table 4.22: Multivariate Regression Model on Independent variables vs BIM Adoption

Coefficients[a]								
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B	
		B	Std.	Beta			Lower Bound	Upper Bound
1	(Constant)	4.157	.683		6.084	.000	2.782	5.531
	Age	-.305	.184	-.269	-1.652	.105	-.676	.066
	Years of Practice	-.703	.321	-.704	-2.190	.034	-1.349	-.057
	Years of using BIM	.244	.142	.465	1.719	.092	-.042	.530
	Number of projects using	.215	.149	.280	1.444	.156	-.085	.515

a. Dependent Variable: Overall BIM Adoption Score - CORRECT

Source: Author (2019)

As indicated in table 4.22 above, all independent variables with sig (p) < 0.05 had their null hypothesis rejected, meaning that they predicted BIM Adoption Score while all independent variables with sig (p) > 0.05 had their null hypothesis accepted, meaning that they did not predict BIM Adoption Score. The multivariate regression equation is as shown below:

- BIM Adoption Score = 4.157 – 0.703 x Years of Practice

4.3.2 Relationship between BIM Essentials Score and BIM Adoption.

The first secondary task of this study was to investigate the relationship between the BIM Essentials Score and BIM Adoption amongst Building Contractors in Kenya. The null and alternate hypothesis stated that:

- H_o – There is no relationship between the BIM Essentials Score and BIM Adoption amongst Building Contractors in Kenya.
- H_a – There is a relationship between the BIM Essentials Score and BIM Adoption amongst Building Contractors in Kenya.

Before testing these hypotheses, there was need to look at BIM Essentials and its associated constructs and indicators. BIM Essential Score was generated by using the average the highest scores for the various indicators in the context of the various BIM

Capabilities which include BIM Trialability, BIM Availability, BIM Observability and BIM Social System while BIM Adoption level was a score generated using the average of the highest level of preference for the various BIM tools associated capabilities. It was there imperative that the various indicators for BIM Essentials be keenly looked at using the BIM Capabilities classifications.

4.3.2.1 BIM Trialability.

There was need to investigate the level of BIM Trialability amongst Building Contractors in Kenya. The null and alternate hypothesis for this stated that:

- H_o – The BIM Trialability Level by Building Contractors in Kenya is low.
- H_a – The BIM Trialability Level by Building Contractors in Kenya is not low meaning that either the BIM Trialability Level by Building Contractors in Kenya is lower than the low score or the BIM Trialability Level by Building Contractors in Kenya is higher than the low score.

BIM Trialability Level was tested using the averages of the highest values of trialability indicators amongst the various BIM capabilities.

BIM Trialability for 2DCAD Tools (BT_1) = (Highest Available for Trialability 2D Tool (Archicad, Autocad, Revit or Sketchup) + Longest Trial Period 2D Tool(Archicad, Autocad, Revit or Sketchup) + Highest Available student license for 2D Tool(Archicad, Autocad, Revit or Sketchup))/3

BIM Trialability for 3DBIM Tools (BT_2) = (Highest Available for Trialability 3D Tool (Archicad, Revit or Sketchup) + Longest Trial Period 3D Tool (Archicad, Revit or Sketchup) + Highest Available student license for 3D Tool (Archicad, Revit or Sketchup))/3

BIM Trialability for 4DBIM Tools (BT_3) = (Highest Available for Trialability 4D Tool (MS Project or Primavera) + Longest Trial Period 4D Tool (MS Project or Primavera) + Highest Available student license for 4D Tool (MS Project or Primavera))/3

BIM Trialability for 5DBIM Tools (BT_4) = (Highest Available for Trialability 5D Tool (Archicad, Bluebeam, Cost X, Revit, SAP or WinQS) + Longest Trial Period 5D Tool(Archicad, Bluebeam, Cost X, Revit, SAP or WinQs) + Highest Available student license for 5D Tool (Archicad, Bluebeam, Cost X, Revit, SAP or WinQs))/3

BIM Trialability for SAMBIM Tools (BT_5) = (Highest Available for Trialability SAM Tool (Prokon or Autocad) + Longest Trial Period SAM Tool (Prokon or Autocad) + Highest Available student license for SAM Tool (Prokon or Autocad))/3

BIM Trialability for MEPBIM Tools (BT_6) = (Highest Available for Trialability MEP Tool (MEP Modeller and Revit) + Longest Trial Period MEP Tool (MEP Modeller and Revit) + Highest Available student license for MEP Tool (MEP Modeller and Revit)/3

BIM Trialability for IDCCBIM Tools (BT_7) = (Highest Available for Trialability IDCC Tool (Archicad, Revit or Sketchup) + Longest Trial Period IDCC Tool (Archicad, Revit or Sketchup) + Highest Available student license for IDCC Tool (Archicad, Revit or Sketchup))/3

BIM Trialability for ICDBIM Tools (BT_8) = (Highest Available for Trialability ICD Tool (Archicad, Revit or Sketchup) + Longest Trial Period ICD Tool (Archicad, Revit or Sketchup) + Highest Available student license for ICD Tool (Archicad, Revit or Sketchup))/3

BIM Trialability Score = (BT_1 + BT_2+ BT_3+ BT_4+ BT_5+ BT_6+ BT_7+ BT_8)/8

The BIM Trialability Score was scaled from 1 (very low trialability score), 2 (low trialability score), 3 (neutral), 4 (high trialability score) to 5 (very high trialability score). One sample t test was used was used to check this hypothesis as shown in tables 4.23 and 4.24 below.

Table 4.23: One Sample Statistics for BIM Trialability Score

One-Sample Statistics				
	N	Mean	Std. Deviation	Std. Error Mean
Overall BIM Trialability Score	62	1.7534	1.23535	.15689

Source: Author (2019)

Table 4.24: One Sample *t* Test for BIM Trialability Score

One-Sample Test						
	Test Value = 2 (Low BIM Trialability Score)					
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
Overall BIM Trialability	-1.572	61	.121	-.24664	-.5604	.0671

Source: Author (2019)

t (61) = -1.572, α > .05. *t* at 61 degrees of freedom is -1.572. The probability that the observed difference between our sample mean and the population mean was due to mere chance rather than to a real difference in achievement is greater than 5%.Our survey is not significantly different from the null hypothesis and therefore BIM Trialability score (M=1.75, SD=1.24) scored is not significantly lower than the low BIM Trialability (M=2).

This study narrowed into the individual BIM capabilities to establish their respective level of Trialability as shown in tables 4.25 and 4.26 below.

Table 4.25: One Sample Statistics for Trialability Score for Each Capability

One-Sample Statistics				
	N	Mean	Std. Deviation	Std. Error Mean
BIM Trialability Score for 2D CAD	62	2.3978	1.93975	.24635
BIM Trialability Score for 3D BIM	62	2.0430	1.91008	.24258
BIM Trialability Score for 4D BIM	62	1.4194	1.77612	.22557
BIM Trialability Score for 5D BIM	62	2.1989	1.70658	.21674
BIM Trialability Score for SAM BIM	62	.9677	1.52060	.19312
BIM Trialability Score for MEP BIM	62	.9140	1.12260	.14257
BIM Trialability Score for IDCC BIM	62	2.0430	1.91008	.24258
BIM Trialability Score for ICD BIM	62	2.0430	1.91008	.24258

Source: Author (2019)

Table 4.26: One Sample *t* Test for Trialability Score for each capability

One-Sample Test						
	Test Va lue = 2 (Low Trialability)					
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
BIM Trialability Score for 2D CAD	1.615	61	.111	.39785	-.0948	.8905
BIM Trialability Score for 3D BIM	.177	61	.860	.04301	-.4421	.5281
BIM Trialability Score for 4D BIM	-2.574	61	.012	-.58065	-1.0317	-.1296
BIM Trialability Score for 5D BIM	.918	61	.362	.19892	-.2345	.6323
BIM Trialability Score for SAM BIM	-5.345	61	.000	-1.03226	-1.4184	-.6461
BIM Trialability Score for MEP BIM	-7.617	61	.000	-1.08602	-1.3711	-.8009
BIM Trialability Score for IDCC BIM	.177	61	.860	.04301	-.4421	.5281
BIM Trialability Score for ICD BIM	.177	61	.860	.04301	-.4421	.5281

Source: Author (2019)

For 2D-CAD Trialability, $t(61) = 1.62$, $\alpha > .05$ means that the level of trialability is not significantly different from the null hypothesis that the trialability level is low (M=2), and therefore at (M=2.40, SD=1.94) the trialability level is equal to low. For 3D-BIM Trialability, IDCC-BIM Trialability and ICD-BIM Trialability, $t(61) = 0.177$, $\alpha > .05$ means that the level of trialability is not significantly different from the null hypothesis that the trialability level is low (M=2), and therefore at (M=2.04, SD=1.91) the trialability level is low. For 4D-BIM Trialability, $t(61) = -2.57$, $\alpha < .05$ means that the level of trialability is significantly different from the null hypothesis that the trialability level is low (M=2), and therefore at (M=1.42, SD=1.78) the trialability level is significantly lower than low (very low). For 5D-BIM Trialability, $t(61) = 0.92$, $\alpha > .05$ means that the level of trialability is not significantly different from the null hypothesis that the trialability level is low (M=2), and therefore at (M=2.20, SD=1.71) the trialability level is low. For SAM-BIM Trialability, $t(61) = -5.345$, $\alpha < .05$ means that the level of trialability is significantly different from the null hypothesis that the trialability level is low (M=2), and therefore at (M=0.97, SD=1.52) the trialability level is significantly lower than low (very low). For MEP-BIM trialability, $t(61) = -7.62$, $\alpha < .05$ means that the level of trialability is significantly different from the null hypothesis that the trialability level is low (M=2), and therefore at (M=0.91, SD=1.12) the trialability level is significantly lower than low (very low).

The study also looked at the correlations between BIM Adoption and BIM Trialability amongst Building Contractors as shown in table 4.27 below. Where $p < .05$, correlation was significant, with the extent of correlation varying from weak ($0.2 < r < 0.4$), moderate ($.4 < r < 0.6$) to strong ($0.6 < r$).

Table 4.27: Pearson Correlation between BIM Trialability and BIM Adoption

Correlations			
		Overall BIM Trialability Score	**Overall BIM Adoption Score**
Overall BIM Trialability Score	Pearson Correlation	1	.704**
	Sig. (2-tailed)		.000
	N	62	62
Overall BIM Adoption Score	Pearson Correlation	.704**	1
	Sig. (2-tailed)	.000	
	N	62	62

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

Source: Author (2019

As shown in table 4.27 above, the results indicated that $p < .05$, showing that these variables were significantly correlated. The Pearson correlation indicated a strong positive correlation between BIM Trialability and BIM Adoption meaning that adoption levels increased with increased BIM Trialability levels within the Building Contractors.

A one-way ANOVA test was done on these variables to see if there was variance between the various groups in these variables and how these variances affected levels of BIM Adoption. One-way ANOVA results for BIM Trialability versus BIM adoption was as shown in table 4.28 below.

Table 4.28: One-Way ANOVA Test on BIM Trialability vs BIM Adoption

Tests of Between-Subjects Effects						
Dependent Variable: Overall BIM Adoption Score						
Source	**Type III Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**	**Partial Eta Squared**
Corrected Model	107.374[a]	23	4.668	7.038	.000	.810
Intercept	205.166	1	205.166	309.323	.000	.891
BIM Trialability Score	107.374	23	4.668	7.038	.000	.810
Error	25.204	38	.663			
Total	375.109	62				
Corrected Total	**132.579**	**61**				

a. R Squared = .810 (Adjusted R Squared = .695)

Source: Author (2019)

The ANOVA summary indicates that with $p < 0.05$, the null hypothesis that variances were equal amongst trialability scores was rejected hence means of BIM adoption across the trialability scores were different with 81% of the variance of BIM Adoption explained by BIM Trialability and variance between groups was 7.0 times greater than variances within the groups.

Having established that there was a correlation, a bivariate regression model was generated between the BIM Adoption score and BIM Trialability Score using the following hypothesis:

- H_o: None of the coefficients in BIM Trialability Score predict BIM Adoption Score.
- H_a: Most of the coefficients in BIM Trialability Score predict BIM Adoption Score.

Table 4.29: Bivariate Regression Model on BIM Trialability vs BIM Adoption

Coefficients[a]								
Model		**Unstandardized Coefficients**		**Standardized Coefficients**	**t**	**Sig.**	**95.0% Confidence Interval for B**	
		B	**Std. Error**	**Beta**			**Lower Bound**	**Upper Bound**
1	(Constant)	.506	.234		2.159	.035	.037	.974
	Overall BIM Trialability	.840	.109	.704	7.669	.000	.621	1.059

a. Dependent Variable: Overall BIM Adoption Score

Source: Author (2019)

As indicated in table 4.29 above, with sig (p) < 0.05, the null hypothesis was rejected, meaning that BIM trialability predicted BIM Adoption with the regression equation as shown below and further articulated using the linear graph in figure 4.5 below.

- BIM Adoption Score = 0.840 x BIM Trialability Score + 0.506

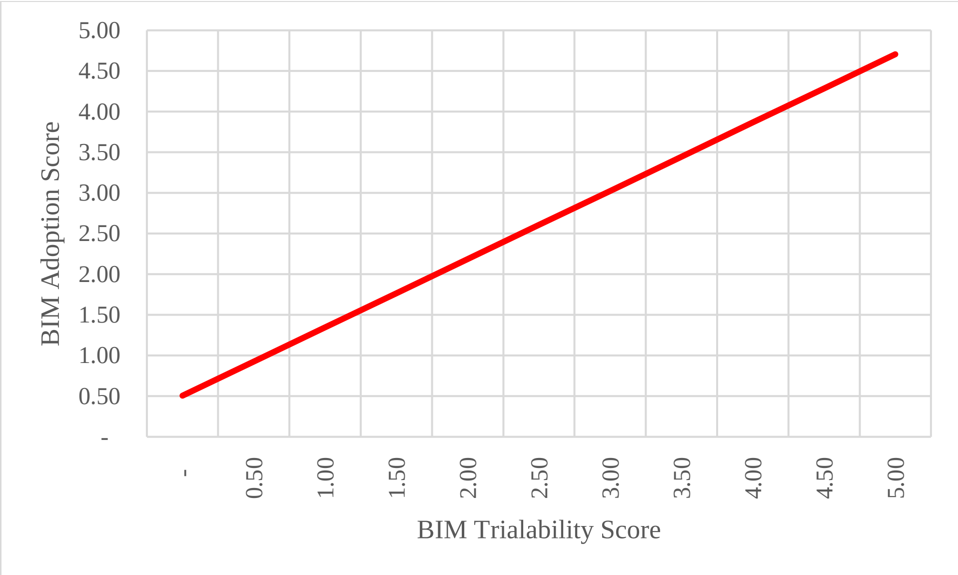


Figure 4.5: Bivariate graph of BIM Trialability Score vs BIM Adoption Score

Source: Author (2019)

4.3.2.2 BM Availability.

There was need to investigate the level of BIM Availability amongst Building Contractors in Kenya. The null and alternate hypothesis for this stated that:

- H_o – The BIM Availability Level by Building Contractors in Kenya is low.
- H_a – The BIM Availability Level by Building Contractors in Kenya is not low meaning that either the BIM Availability Level by Building Contractors in Kenya is lower than the low score or the BIM Availability Level by Building Contractors in Kenya is higher than the low score.

BIM Availability Level was tested using the averages of the highest values of availability indicators amongst the various BIM capabilities.

BIM Availability for 2DCAD Tools (BA_1) = (Highest Available 2D Tool (Archicad, Autocad, Revit or Sketchup) + Highest Available information on 2D Tool (Archicad, Autocad, Revit or Sketchup)/2

BIM Availability for 3DBIM Tools (BA_2) = (Highest Available 3D Tool (Archicad, Revit or Sketchup) Highest Available information on 3D Tool (Archicad, Revit or Sketchup)/2

BIM Availability for 4DBIM Tools (BA_3) = (Highest Available 4D Tool (MS Project or Primavera) + Highest Available information on 4D Tool (MS Project or Primavera)/2

BIM Availability for 5DBIM Tools (BA_4) = (Highest Available 5D Tool (Archicad, Bluebeam, Cost X, Revit, SAP or WinQs) +) Highest Available information on 5D Tool(Archicad, Bluebeam, Cost X, Revit, SAP or WinQs)/2

BIM Availability for SAMBIM Tools (BA_5) = (Highest Available SAM Tool (Prokon or Autocad) + Highest Available information on SAM Tool (Prokon or Autocad)/2

BIM Availability for MEPBIM Tools (BA_6) = (Highest Available MEP Tool (MEP Modeller and Revit) + Highest Available information on MEP Tool (MEP Modeller and Revit)/2

BIM Availability for IDCCBIM Tools (BA_7) = (Highest Available IDCC Tool (Archicad, Revit or Sketchup) + Highest Available information on IDCC Tool (Archicad, Revit or Sketchup)/2

BIM Availability for ICDBIM Tools (BA_8) = (Highest Available ICD Tool (Archicad, Revit or Sketchup) + Highest Available information on ICD Tool (Archicad, Revit or Sketchup))/2

BIM Availability Score = (BA_1 + BA_2+ BA_3+ BA_4+ BA_5+ BA_6+ BA_7+ BA_8)/8

The BIM Availability Score was scaled from 1(very low availability score), 2(low availability score), 3(neutral), 4(high availability score) to 5 (very high availability score. One sample t test was used was used to check this hypothesis as shown in tables 4.30 and 4.31 below.

Table 4.30: One Sample Statistics for BIM Availability Score

One-Sample Statistics				
	N	**Mean**	**Std. Deviation**	**Std. Error Mean**
Overall BIM Availability Score	62	2.3024	1.60231	.20349

Source: Author (2019)

Table 4.31: One Sample t Test for BIM Availability Score

One-Sample Test						
	Test Value = 2 (Low Availability Score)					
	t	**df**	**Sig. (2-tailed)**	**Mean Difference**	**95% Confidence Interval of the Difference**	
					Lower	**Upper**
Overall BIM Availability Score	1.486	61	.142	.30242	-.1045	.7093

Source: Author (2019)

$t(61) = 1.486$, $\alpha > .05$. t at 61 degrees of freedom is 1.486. The probability that the observed difference between our sample mean and the population mean was due to mere chance rather than to a real difference in achievement is greater than 5%.Our survey is not significantly different from the null hypothesis and therefore BIM Availability score (M=2.30, SD=1.60) scored is not significantly higher than the low BIM Availability (M=2).

This study narrowed into the individual BIM capabilities to establish their respective level of Availability as shown in tables 4.32 and 4.33 below.

Table 4.32: One Sample Statistics for Availability Score for Each Capability

One-Sample Statistics				
	N	**Mean**	**Std. Deviation**	**Std. Error Mean**
BIM Availability Score for 2DCAD	62	2.6774	2.26719	.28793
BIM Availability Score for 3DBIM	62	2.5161	2.27417	.28882
BIM Availability Score for 4DBIM	62	2.3871	2.18306	.27725
BIM Availability Score for 5DBIM	62	2.9355	2.18693	.27774
BIM Availability Score for SAMBIM	62	1.3226	1.88848	.23984
BIM Availability Score for MEPBIM	62	1.5484	2.06197	.26187
BIM Availability Score for IDCCBIM	62	2.5161	2.27417	.28882
BIM Availability Score for ICDBIM	62	2.5161	2.27417	.28882

Source: Author (2019)

Table 4.33: One Sample *t* Test for Availability Score for each capability

One-Sample Test						
	Test Value = 2 (Low Availability Score)					
	t	**df**	**Sig. (2-tailed)**	**Mean Difference**	**95% Confidence Interval of the Difference**	
					Lower	**Upper**
BIM Availability Score for 2DCAD	2.353	61	.022	.67742	.1017	1.2532
BIM Availability Score for 3DBIM	1.787	61	.079	.51613	-.0614	1.0937
BIM Availability Score for 4DBIM	1.396	61	.168	.38710	-.1673	.9415
BIM Availability Score for 5DBIM	3.368	61	.001	.93548	.3801	1.4909
BIM Availability Score for SAMBIM	-2.824	61	.006	-.67742	-1.1570	-.1978
BIM Availability Score for MEPBIM	-1.725	61	.090	-.45161	-.9753	.0720
BIM Availability Score for IDCCBIM	1.787	61	.079	.51613	-.0614	1.0937
BIM Availability Score for ICDBIM	1.787	61	.079	.51613	-.0614	1.0937

Source: Author (2019)

For 2D-CAD Availability, $t(61) = 2.35$, $\alpha < .05$ means that the level of availability is significantly different from the null hypothesis that the availability level is low (M=2), and therefore at (M=2.68, SD=2.27) the availability level is significantly higher than low (moderate). For 3D-BIM Availability, IDCC-BIM Availability and ICD-BIM Availability, $t(61) = 1.787$, $\alpha > .05$ means that the level of availability is not significantly different from the null hypothesis that the availability level is low (M=2), and therefore at (M=2.52, SD=2.27) the availability level is equal to low. For 4D-BIM Availability, $t(61) = 1.40$, $\alpha > .05$ means that the level of adoption is not significantly different from the null hypothesis that the availability level is low (M=2), and therefore at (M=2.39, SD=2.18) the availability level is low. For 5D-BIM Trialability, $t(61) = 3.37$, $\alpha < .05$ means that the level of availability is significantly different from the null hypothesis that the availability level is low (M=2), and therefore at (M=2.93, SD=2.19) the availability level is significantly higher than low BIM availability level (moderate). For SAM-BIM Availability, $t(61) = -2.82$, $\alpha < .05$ means that the level of availability is significantly different from the null hypothesis that the availability level is low (M=2), and therefore at (M=1.32, SD=1.89) the availability level is significantly lower than low BIM availability level (very low). For MEP-BIM availability, $t(61) = -1.72$, $\alpha > .05$ means that the level of availability is not significantly different from the null hypothesis that the availability level is low (M=2), and therefore at (M=1.55, SD=2.06) the availability level is low.

The study also looked at the correlations between BIM Adoption and BIM Availability amongst Building Contractors as shown in table 4.34 below. Where $p < .05$, correlation was significant, with the extent of correlation varying from weak ($0.2 < r < 0.4$), moderate ($.4 < r < 0.6$) to strong ($0.6 < r$).

Table 4.34: Pearson Correlation between BIM Availability and BIM Adoption

Correlations			
		Overall BIM Adoption Score	**Overall BIM Availability Score**
Overall BIM Adoption Score	Pearson Correlation	1	.443**
	Sig. (2-tailed)		.000
	N	62	62
Overall BIM Availability Score	Pearson Correlation	.443**	1
	Sig. (2-tailed)	.000	
	N	62	62

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

Source: Author (2019)

The results indicated that $p < .05$ showing that these variables were significantly correlated. The Pearson correlation indicated a moderate positive correlation between BIM Availability and BIM Adoption meaning that adoption levels moderately increased with increased BIM Availability levels within the Building Contractors.

A one-way ANOVA test was done on these variables to see if there was variance between the various groups in these variables and how these variances affected levels of BIM Adoption. One-way ANOVA results for BIM Availability versus BIM adoption was as shown in table 4.35 below.

Table 4.35: One-Way ANOVA Test on BIM Availability vs BIM Adoption

Tests of Between-Subjects Effects						
Dependent Variable: Overall BIM Adoption Score						
Source	**Type III Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**	**Partial Eta Squared**
Corrected Model	74.996[a]	13	5.769	4.809	.000	.566
Intercept	184.258	1	184.258	153.595	.000	.762
BIM Availability Score	74.996	13	5.769	4.809	.000	.566
Error	57.582	48	1.200			
Total	375.109	62				
Corrected Total	132.579	61				

a. R Squared = .566 (Adjusted R Squared = .448)

Source: Author (2019)

The ANOVA summary indicates that with $p < 0.05$, the null hypothesis that variances were equal amongst availability scores was rejected hence means of BIM adoption across the availability scores were different with 57% of the variance of BIM Adoption explained by BIM Availability and variance between groups was 4.8 times greater than variances within the groups.

Having established that there was a correlation, a bivariate regression model was generated between the BIM Adoption score and BIM Availability Score, using the following hypothesis:

- H_o: None of the coefficients in BIM Availability Score predict BIM Adoption Score
- H_a: Most of the coefficients in BIM Availability Score predict BIM Adoption Score

Table 4.36: Bivariate Regression Model on BIM Availability vs BIM Adoption

Coefficients[a]								
Model		**Unstandardized Coefficients**		**Standardized Coefficients**	**t**	**Sig.**	**95.0% Confidence Interval for B**	
		B	**Std.**	**Beta**			**Lower Bound**	**Upper Bound**
1	(Constant)	1.040	.298		3.489	.001	.444	1.636
	Overall BIM Availability	.408	.106	.443	3.827	.000	.194	.621

a. Dependent Variable: Overall BIM Adoption Score

Source: Author (2019)

As indicated in table 4.36 above, with sig (p) < 0.05, the null hypothesis was rejected, meaning that BIM availability predicted BIM Adoption with the regression equation as shown below and further articulated using the linear graph in figure 4.6 below.

BIM Adoption Score = 0.408 x BIM Availability Score + 1.040

Figure 4.6: Bivariate Graph of BIM Availability Score vs BIM Adoption Score

Source: Author (2019)

4.3.2.3 BIM Observability.

There was need to investigate the level of BIM Observability amongst Building Contractors in Kenya. The null and alternate hypothesis for this stated that:

- H_o – The BIM Observability Level by Building Contractors in Kenya is low.
- H_a – The BIM Observability Level by Building Contractors in Kenya is not low meaning that either the BIM Observability Level by Building Contractors in Kenya is lower than the low score or the BIM Observability Level by Building Contractors in Kenya is higher than the low score.

BIM Observability Level was tested using the averages of the highest values of availability indicators amongst the various BIM capabilities.

BIM Observability for 2DCAD Tools (BO_1) = Highest Focused Continuous Training Score for 2D Tool (Archicad, Autocad, Revit or Sketchup)

BIM Observability for 3DBIM Tools (BO_2) = Highest Focused Continuous Training Score for 3D Tool (Archicad, Revit or Sketchup)

BIM Observability for 4DBIM Tools (BO_3) = Highest Focused Continuous Training Score for 4D Tool (MS Project or Primavera)

BIM Observability for 5DBIM Tools (BO_4) = Highest Focused Continuous Training Score for 5D Tool (Archicad, Bluebeam, Cost X, Revit, SAP or WinQs)

BIM Observability for SAMBIM Tools (BO_5) = Highest Focused Continuous Training Score for SAM Tool (Prokon or Autocad)

BIM Observability for MEPBIM Tools (BO_6) = Highest Focused Continuous Training Score for MEP Tool (MEP Modeller and Revit)

BIM Observability for IDCCBIM Tools (BO_7) = Highest Focused Continuous Training Score for IDCC Tool (Archicad, Revit or Sketchup)

BIM Observability for ICDBIM Tools (BO_8) = Highest Focused Continuous Training Score for ICD Tool (Archicad, Revit or Sketchup)

BIM Observability Score = $(BO_1 + BO_2 + BO_3 + BO_4 + BO_5 + BO_6 + BO_7 + BO_8)/8$

The BIM Observability Score was scaled from 1(for very low observability score), 2(for low observability score), 3 (for neutral), 4 (for high observability score) to 5 (for very high observability score). One sample t test was used was used to check this hypothesis as shown in tables 4.37 and 4.38 below.

Table 4.37: One Sample Statistics for BIM Observability Score

One-Sample Statistics				
	N	**Mean**	**Std. Deviation**	**Std. Error Mean**
Overall BIM Observability Score	62	1.4677	1.54889	.19671

Source: Author (2019)

Table 4.38: One Sample t test for BIM Observability Score

One-Sample Test						
	Test Value = 2 (Low Observability Score)					
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
Overall BIM Observability Score	-2.706	61	.009	-.53226	-.9256	-.1389

Source: Author (2019)

t(61) = -2.706, α < .05. *t* at 61 degrees of freedom is 2.706. The probability that the observed difference between our sample mean and the population mean was due to mere chance rather than to a real difference in achievement is less than 5%.Our survey is significantly different from the null hypothesis and therefore BIM Observability score (M=1.47, SD=1.55) scored is significantly lower than the low BIM Observability (M=2) meaning that it was very low.

This study narrowed into the individual BIM capabilities to establish their respective level of Observability as shown in tables 4.39 and 4.40 below.

Table 4.39: One Sample Statistics for Observability Score for Each Capability

One-Sample Statistics				
	N	Mean	Std. Deviation	Std. Error Mean
BIM Observability Score for 2DCAD	62	1.8065	2.16408	.27484
BIM Observability Score for 3DBIM	62	1.6452	2.10461	.26729
BIM Observability Score for 4DBIM	62	.9355	1.75435	.22280
BIM Observability Score for 5DBIM	62	2.0000	2.18790	.27786
BIM Observability Score for SAMBIM	62	1.0806	1.78609	.22683
BIM Observability Score for MEPBIM	62	.9839	1.58365	.20112
BIM Observability Score for IDCCBIM	62	1.6452	2.10461	.26729
BIM Observability Score for ICDBIM	62	1.6452	2.10461	.26729

Source: Author (2019)

Table 4.40: One Sample *t* Test for Observability Score for Each Capability

	One-Sample Test					
	Test Value = 2 (Low Observability Score)					
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
BIM Observability Score for 2DCAD	-.704	61	.484	-.19355	-.7431	.3560
BIM Observability Score for 3DBIM	-1.328	61	.189	-.35484	-.8893	.1796
BIM Observability Score for 4DBIM	-4.778	61	.000	-1.06452	-1.5100	-.6190
BIM Observability Score for 5DBIM	.000	61	1.000	.00000	-.5556	.5556
BIM Observability Score for SAMBIM	-4.053	61	.000	-.91935	-1.3729	-.4658
BIM Observability Score for MEPBIM	-5.052	61	.000	-1.01613	-1.4183	-.6140
BIM Observability Score for IDCCBIM	-1.328	61	.189	-.35484	-.8893	.1796
BIM Observability Score for ICDBIM	-1.328	61	.189	-.35484	-.8893	.1796

Source: Author (2019)

For 2D-CAD Observability, $t(61) = -0.704$, $\alpha > .05$ means that the level of observability is not significantly different from the null hypothesis that the observability level is low (M=2), and therefore at (M=1.81, SD=2.16) the observability level is equal to low. For 3D-BIM Observability, IDCC-BIM Observability and ICD-BIM Observability, $t(61) = -1.328$, $\alpha > .05$ means that the level of observability is not significantly different from the null hypothesis that the observability level is low (M=2), and therefore at (M=1.65, SD=2.10) the observability level is low. For 4D-BIM observability, $t(61) = -4.778$, $\alpha < .05$ means that the level of observability is significantly different from the null hypothesis that the observability level is low (M=2), and therefore at (M=0.94, SD=1.75) the observability level is significantly lower than low (very low). For 5D-BIM observability, $t(61) = 0.000$, $\alpha > .05$ means that the level of observability is not significantly different from the null hypothesis that the observability level is low (M=2), and therefore at (M=2.00, SD=2.19) the observability level is low. For SAM-BIM Availability, $t(61) = -4.053$, $\alpha < .05$ means that the level of observability is significantly different from the null hypothesis that the observability level is low (M=2), and therefore at (M=1.08, SD=1.79) the observability level is significantly lower than low (very low). For MEP-BIM observability, $t(61) = -5.05$, $\alpha < .05$ means that the level of observability is significantly different from the null hypothesis that the observability level is low (M=2), and therefore at (M=0.98, SD=1.58) the observability level is significantly lower than low (very low).

The study also looked at the correlations between BIM Adoption and BIM Observability amongst Building Contractors as shown in table 4.41 below. Where $p < .05$, correlation was significant, with the extent of correlation varying from weak ($0.2 < r < 0.4$), moderate ($.4 < r < 0.6$) to strong ($0.6 < r$)

Table 4.41: Pearson Correlation between BIM Observability and BIM Adoption

Correlations			
		Overall BIM Observability Score	**Overall BIM Adoption Score**
Overall BIM Observability Score	Pearson Correlation	1	.762**
	Sig. (2-tailed)		.000
	N	62	62
Overall BIM Adoption Score	Pearson Correlation	.762**	1
	Sig. (2-tailed)	.000	
	N	62	62

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

Source: Author (2019)

The results indicated that $p < .05$ showing that these variables were significantly correlated. The Pearson correlation indicated a strong positive correlation between BIM Observability and BIM Adoption meaning that adoption levels increased with increased BIM Observability levels within the Building Contractors.

A one-way ANOVA test was done on these two variables to see if there was variance between the various groups in these variables and how these variances affected levels of BIM Adoption. One-way ANOVA results for BIM Observability versus BIM adoption was as shown in table 4.42 below.

Table 4.42: One-Way ANOVA Test on BIM Observability vs BIM Adoption

Tests of Between-Subjects Effects						
Dependent Variable: Overall BIM Adoption Score						
Source	**Type III Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**	**Partial Eta Squared**
Corrected Model	97.358[a]	10	9.736	14.097	.000	.734
Intercept	259.396	1	259.396	375.601	.000	.880
BIM Observability Score	97.358	10	9.736	14.097	.000	.734
Error	35.221	51	.691			
Total	375.109	62				
Corrected Total	132.579	61				

a. R Squared = .734 (Adjusted R Squared = .682)

Source: Author (2019)

The ANOVA summary indicates that with $p < 0.05$, the null hypothesis that variances were equal amongst observability scores was rejected hence means of BIM adoption across the observability scores were different with 73% of the variance of BIM Adoption explained by BIM Observability and variance between groups was 14.1 times greater than variances within the groups.

Having established that there was a correlation, a bivariate regression model was generated between the BIM Adoption score and BIM Observability Score, having established that there was a correlation using the following hypothesis:

- H_o: None of the coefficients in BIM Observability Score predict BIM Adoption Score
- H_a: Most of the coefficients in BIM Observability Score predict BIM Adoption Score

Table 4.43: Bivariate Regression Model on BIM Observability vs BIM Adoption

Coefficients[a]								
Model		**Unstandardized Coefficients**		**Standardized Coefficients**	**t**	**Sig.**	**95.0% Confidence Interval for B**	
		B	**Std. Error**	**Beta**			**Lower Bound**	**Upper Bound**
1	(Constant)	.913	.169		5.402	.000	.575	1.251
	Overall BIM Observability Score	.725	.080	.762	9.115	.000	.566	.884

a. Dependent Variable: Overall BIM Adoption Score

Source: Author (2019)

As indicated in table 4.43 above, with sig (p) < 0.05, the null hypothesis was rejected, meaning that BIM Observability predicted BIM Adoption with the regression equation as shown and further articulated using the linear graph in figure 4.7 below.

BIM Adoption Score = 0.725 x BIM Observability Score + 0.913

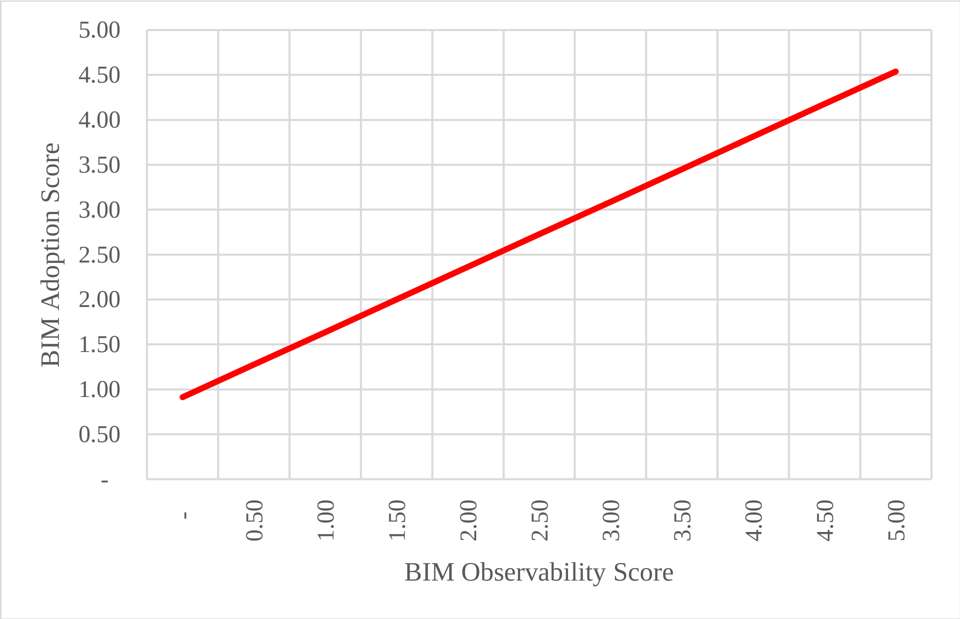


Figure 4.7: Bivariate Graph of BIM Observability Score vs BIM Adoption Score

Source: Author (2019)

4.3.2.4 BIM Social Organization

There was need to investigate the level of BIM Social Organisation amongst Building Contractors in Kenya. The null and alternate hypothesis for this stated that:

- H_o – The BIM Social Organization Level within Building Contractors in Kenya is low.
- H_a – The BIM Social Organization Level within Building Contractors in Kenya is not low meaning that either the BIM Social Organization Level within Building Contractors in Kenya is lower than the low score or the BIM Social

Organization Level within Building Contractors in Kenya is higher than the low score.

BIM Social Organization Level was tested using the averages of the values of indicators associated with BIM Social Organisation.

BIM Social Organization Score = (BIM Social System Score + Statutory Bodies and Professional Bodies Score + BIM Opinion Leaders and Social Shapers Score + Peer Pressure Score + ICT Skills Score)/5

The BIM Social Organisation Score was scaled from 1 (very low Social Organization score) 2 (low Social Organization score), 3 (neutral), 4 (high Social Organization score) to 5 (very high Social Organization score). One sample t test was used was used to check this hypothesis as shown in tables 4.44 and 4.45 below.

Table 4.44: One Sample Statistics for BIM Social Organization Score

One-Sample Statistics				
	N	**Mean**	**Std. Deviation**	**Std. Error Mean**
Overall BIM Social Organisation Score	62	2.4129	1.56556	.19883

Source: Author (2019)

Table 4.45: One Sample *t* Test for BIM Social Organisation Score

One-Sample Test						
	Test Value = 2 (Low BIM Social Organisation Score)					
	t	**df**	**Sig. (2-tailed)**	**Mean Difference**	**95% Confidence Interval of the Difference**	
					Lower	**Upper**
Overall BIM Social Organisation Score	2.077	61	.042	.41290	.0153	.8105

Source: Author (2019)

$t(61) = -2.077$, $\alpha < .05$. t at 61 degrees of freedom is 2.077. The probability that the observed difference between our sample mean and the population mean was due to mere chance rather than to a real difference in achievement is less than 5%.Our survey is significantly different from the null hypothesis and therefore, BIM Social

Organization score (M=2.41, SD=1.57) scored is significantly higher than the low BIM Social Organization Score (M=2).

This study narrowed into the individual BIM Social Organization Indicators to establish their respective level of performance as shown in tables 4.46 and 4.47 below.

Table 4.46: One Sample Statistics for Social Organisation Indicators

One-Sample Statistics				
	N	**Mean**	**Std. Deviation**	**Std. Error Mean**
BIM social system	62	1.94	1.608	.204
Statutory bodies and Professional Organisations	62	2.13	1.573	.200
BIM opinion leaders and Social Shapers	62	2.21	1.641	.208
Peer pressure	62	3.08	1.969	.250
ICT skills	62	2.71	1.885	.239

Source: Author (2019)

Table 4.47: One Sample *t* Test for Social Organisation indicators

One-Sample Test						
	Test Value = 2 (Low Social Organisation Score)					
	t	**df**	**Sig. (2-tailed)**	**Mean Difference**	**95% Confidence Interval of the Difference**	
					Lower	**Upper**
BIM social system	-.316	61	.753	-.065	-.47	.34
Statutory bodies and Professional Organisations	.646	61	.521	.129	-.27	.53
BIM opinion leaders and Social Shapers	1.006	61	.318	.210	-.21	.63
Peer pressure	4.321	61	.000	1.081	.58	1.58
ICT skills	2.964	61	.004	.710	.23	1.19

Source: Author (2019)

For BIM Social System, $t(61) = -0.316$, $\alpha > .05$ means that the BIM Social System is not significantly different from the null hypothesis that the BIM Social System is weak (M=2), and therefore at (M=1.94, SD=1.61) the BIM Social System is weak. For BIM Statutory bodies and Professional Organisations, $t(61) = 0.646$, $\alpha > .05$ means that these bodies are not significantly different from the null hypothesis that the BIM Statutory and Professional Organisations are weak (M=2), and therefore at (M=2.13, SD=1.57) these bodies are weak. For BIM Opinion Leaders and Social Shapers, $t(61) = 1.006$, $\alpha > .05$ means that these people are not significantly different from the null hypothesis that the BIM Opinion Leaders and Social Shapers are weak (M=2), and therefore at (M=2.21, SD=1.64) these people are weak. For peer pressure, t(61) = 4.321, $\alpha < .05$ means that the level of peer pressure is significantly different from the null hypothesis that peer pressure is low (M=2), and therefore at (M=3.08, SD=1.97) peer pressure is significantly higher than low BIM peer pressure (moderate). For ICT skills, t(61) = 2.964, $\alpha < .05$ means that the level of ICT skills is significantly different from the null hypothesis that ICT skills are poor (M=2), and therefore at (M=2.71, SD=1.89) ICT skills are significantly higher than poor BIM ICT Skills (moderate).

The study also looked at the correlations between BIM Adoption and BIM Social Organisation amongst Building Contractors as shown in table 4.48 below. Where $p < .05$, correlation was significant, with the extent of correlation varying from weak ($0.2 < r < 0.4$), moderate ($.4 < r < 0.6$) to strong ($0.6 < r$)

Table 4.48: Pearson Correlation between BIM Social Organisation and BIM Adoption

Correlations			
		Overall BIM Social Organisation	**Overall BIM Adoption Score**
Overall BIM Social Organisation Score	Pearson Correlation	1	.172
	Sig. (2-tailed)		.182
	N	62	62
Overall BIM Adoption Score	Pearson Correlation	.172	1
	Sig. (2-tailed)	.182	
	N	62	62

Source: Author (2019)

The results indicated that $p > .05$ showing that these variables were not significantly correlated. Based on this, there was no need of doing the ANOVA test and regression analysis. However, the study was interested in the correlation between the individual indicators to try flag which ones were major contributors to this lack of correlation.

As shown in table 4.49 below, the results indicated that while there were correlations amongst the indicators, they were not strong enough to create a significant correlation with the BIM adoption score.

Table 4.49: Pearson Correlation between BIM Social Organisation Indicators

Correlations							
		Overall BIM Adoption Score	**BIM social system**	**Statutory bodies and professional Organisations**	**BIM opinion leaders and Social Shapers**	**Peer pressure**	**ICT skills**
Overall BIM Adoption Score	Pearson	1	.132	.288*	.177	.146	.052
	Sig. (2-tailed)		.305	.023	.168	.257	.687
	N	62	62	62	62	62	62
BIM social system	Pearson	.132	1	.833**	.906**	.633**	.772**
	Sig. (2-tailed)	.305		.000	.000	.000	.000
	N	62	62	62	62	62	62
Statutory bodies and professional organizations	Pearson	.288*	.833**	1	.821**	.721**	.665**
	Sig. (2-tailed)	.023	.000		.000	.000	.000
	N	62	62	62	62	62	62
BIM opinion leaders and Social Shapers	Pearson	.177	.906**	.821**	1	.674**	.815**
	Sig. (2-tailed)	.168	.000	.000		.000	.000
	N	62	62	62	62	62	62
Peer pressure	Pearson	.146	.633**	.721**	.674**	1	.854**
	Sig. (2-tailed)	.257	.000	.000	.000		.000
	N	62	62	62	62	62	62
ICT skills	Pearson	.052	.772**	.665**	.815**	.854**	1
	Sig. (2-tailed)	.687	.000	.000	.000	.000	
	N	62	62	62	62	62	62

*. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).

Source: Author (2019)

4.3.2.5 BIM Essentials Score Summary.

After looking at all indicators influencing the essential score, there was need to study how they influenced the BIM Essential Score and how this score related to the BIM Adoption Score. For this, the null and alternate hypothesis for this stated that:

- H_o – The BIM Essentials Score for Building Contractors in Kenya is low.
- H_a – The BIM Essentials Score for Building Contractors in Kenya is not low meaning that either the BIM Essentials Score for Building Contractors in Kenya is lower than the low score or the BIM Essentials Score for Building Contractors in Kenya is higher than the low score.

BIM Essentials Score was tested using the averages of the indicators for BIM Essentials.

BIM Essentials Score = (BIM Trialability + BIM Observability + BIM Availability + BIM Social Organization)/4

The BIM Essentials Score was scaled from 1 (very low BIM Essentials score), 2 (low BIM Essentials score), 3 (moderate BIM Essentials score), 4 (high BIM Essentials score) to 5 (very high BIM Essentials). One sample t test was used was used to check this hypothesis as shown in tables 4.50 and 4.51 below.

Table 4.50: One Sample Statistics for BIM Essentials Score

One-Sample Statistics				
	N	**Mean**	**Std. Deviation**	**Std. Error Mean**
BIM Essentials Score	62	1.9841	1.14918	.14595

Source: Author (2019)

Table 4.51: One Sample t Test for BIM Essentials Score

One-Sample Test						
	Test Value = 2 (Low BIM Essentials Score)					
	t	**df**	**Sig. (2-tailed)**	**Mean Difference**	**95% Confidence Interval of the Difference**	
					Lower	**Upper**
BIM Essentials Score	-.109	61	.914	-.01589	-.3077	.2759

Source: Author (2019)

$t(61) = -0.109$, $\alpha > .05$. t at 61 degrees of freedom is -0.109. The probability that the observed difference between our sample mean and the population mean was due to mere chance rather than to a real difference in achievement is more than 5%.Our survey is not significantly different from the null hypothesis and therefore BIM Essentials score (M=1.98, SD=1.15) scored is not significantly lower than the low BIM Essentials Score (M=2).

4.3.2.7 BIM Essentials Score vs BIM Adoption Score

The study also looked at the correlations between BIM Adoption Score and BIM Essentials Score amongst Building Contractors as shown in table 4.52 below. Where $p < .05$, correlation was significant, with the extent of correlation varying from weak ($0.2 < r < 0.4$), moderate ($.4 < r < 0.6$) to strong ($0.6 < r$)

Table 4.52: Pearson Correlation between BIM Essentials Score and BIM Adoption

Correlations			
		BIM Essentials Score	Overall BIM Adoption Score
BIM Essentials Score	Pearson Correlation	1	.659**
	Sig. (2-tailed)		.000
	N	62	62
Overall BIM Adoption Score	Pearson Correlation	.659**	1
	Sig. (2-tailed)	.000	
	N	62	62

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

Source: Author (2019)

The results indicated that $p < .05$ showing that these variables were significantly correlated. The Pearson correlation indicated a strong positive correlation between BIM Essentials Score and BIM Adoption meaning that adoption levels increased with increased levels of BIM Essentials within the Building Contractors.

Having established that there was a correlation, a bivariate regression model was generated between the BIM Adoption score and BIM Essentials Score using the following hypothesis:

- H_o: None of the coefficients in BIM Essentials Score predict BIM Adoption Score.
- H_a: Most of the coefficients in BIM Essentials Score predict BIM Adoption Score.

Table 4.53: Bivariate Regression Model on BIM Essentials vs BIM Adoption)

Coefficients[a]								
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B	
		B	Std. Error	Beta			Lower Bound	Upper Bound
1	(Constant)	.301	.285		1.056	.295	-.269	.872
	BIM Essentials Score	.845	.125	.659	6.781	.000	.596	1.094

a. Dependent Variable: Overall BIM Adoption Score

Source: Author (2019

As indicated in table 4.53, with sig (p) < 0.05, the null hypothesis was rejected, meaning that BIM Essentials Score predicted BIM Adoption with the regression equation as shown below and further articulated using the linear graph in figure 4.8 below.

BIM Adoption Score = 0.845 x BIM Essentials Score + 0.301

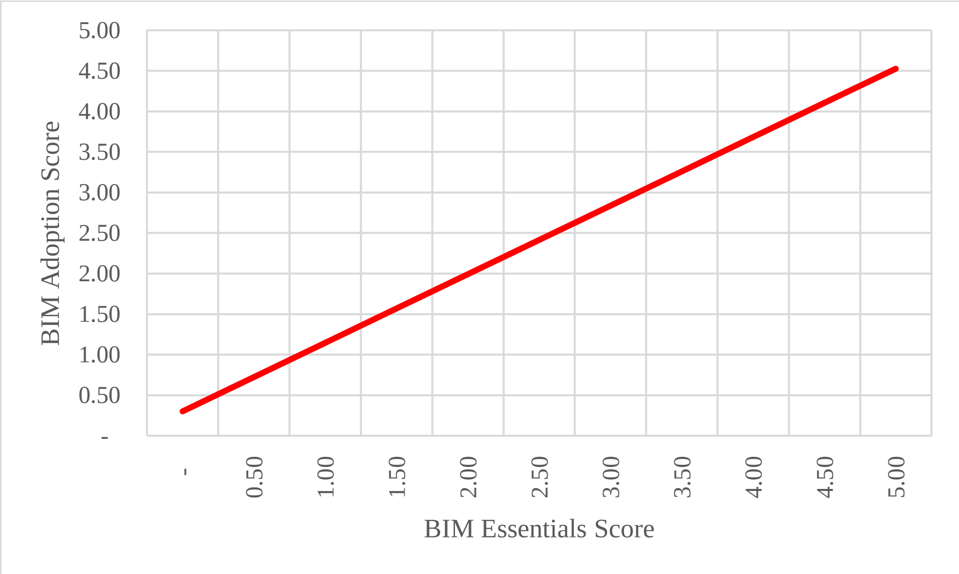


Figure 4.8: Bivariate graph of BIM Essentials Score vs BIM Adoption Score

Source: Author (2019)

To understand the relationship between BIM Adoption and the various indicators under BIM Essentials, a multivariate regression model was generated between the BIM Adoption score and the various indicators that make up the BIM Essentials Score using the following hypothesis:

- H_o: None of the indicators in BIM Essentials Score predict BIM Adoption Score
- H_a: Most of the indicators in BIM Essentials Score predict BIM Adoption Score

Table 4.54: Multivariate Regression Model on BIM Essentials Score Indicators vs BIM Adoption

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B	
		B	Std. Error	Beta			Lower Bound	Upper Bound
1	(Constant)	1.122	.283		3.972	.000	.557	1.688
	Overall BIM Trialability Score	.498	.155	.417	3.208	.002	.187	.808
	Overall BIM Availability Score	-.321	.106	-.349	-3.044	.004	-.533	-.110
	Overall BIM Observability Score	.708	.129	.744	5.482	.000	.450	.967
	Overall BIM Social Organisation	-.131	.082	-.139	-1.610	.113	-.295	.032

Coefficients[a]

a. Dependent Variable: Overall BIM Adoption Score

As indicated in table 4.54 above, all indicators with sig (p) < 0.05 had their null hypothesis rejected, meaning that they predicted BIM Adoption Score while all indicators with sig (p) > 0.05 had their null hypothesis accepted, meaning that they did not predict BIM Adoption Score. The regression equation is as shown below

BIM Adoption Score = 0.708 x BIM Observability Score + 0.498 x BIM Trialability Score -0.321 x BIM Availability Score + 1.122

4.3.3 Relationship between BIM Maturity Score and BIM Adoption.

The second secondary task of this study was to investigate the relationship between the BIM Maturity Score and BIM Adoption amongst Building Contractors in Kenya. The null and alternate hypothesis stated that:

- H_o – There is no relationship between the BIM Maturity Score and BIM Adoption amongst Building Contractors in Kenya.
- H_a – There is a relationship between the BIM Maturity Score and BIM Adoption amongst Building Contractors in Kenya.

Before testing these hypotheses, there was need to look at BIM Maturity and its associated constructs and indicators. BIM Maturity Score was generated by using the average of the highest scores for the various indicators in the context of the various BIM Capabilities which include BIM Simplicity, BIM Interoperability, BIM Demonstration and Training and BIM Government Policies while BIM Adoption level was a score generated using the average of the highest level of preference for the various BIM tools associated capabilities. It was there imperative that the various indicators for BIM Maturity be keenly looked at using the BIM Capabilities classifications.

4.3.3.1 BIM Simplicity.

There was need to investigate the level of BIM Complexity or Simplicity of various tasks amongst Building Contractors in Kenya. The null and alternate hypothesis for this stated that:

- H_o – The BIM Simplicity Level of BIM tasks by Building Contractors in Kenya is low.
- H_a – The BIM Simplicity Level of BIM tasks by Building Contractors in Kenya is not low meaning that either the BIM Simplicity Level of BIM tasks by Building Contractors in Kenya is lower than the low score or the Simplicity Level of BIM tasks by Building Contractors in Kenya is higher than the low score.

BIM Simplicity Level was tested using the averages of the values of simplicity indicators amongst the various BIM capabilities.

BIM Simplicity for 2DCAD Tasks (BS_1) = (2D-CAD Drafting+2D Documentation)/2

BIM Simplicity for 3DBIM Tasks (BS_2) = (3D-CAD Modelling+3D-Parametric Modelling+3D Printing+3D Fabrication+3D Mobile Interfacing+3D Augmented Reality)/6

BIM Simplicity for 4DBIM Tasks (BS_3) = (4D Manual Scheduling+4D Parametric Scheduling+4D-3D Scheduling)/3

BIM Simplicity for 5DBIM Tasks (BS_4) = (5D Manual QTO and Costing+5D Parametric QTO and Costing+5D Classification Systems)/3

BIM Simplicity for SAMBIM Tasks (BS_5) = (Structural Analysis and Simulation + Structural Modelling + Structural Documentation and QTO)/3

BIM Simplicity for MEPBIM Tasks (BS_6) = (P&D Analysis and Simulation + P&D Modelling + P&D Documentation and QTO+ Electrical Analysis and Simulation + Electrical Modelling + Electrical Documentation and QTO)/6

BIM Simplicity for IDCCBIM Tasks (BS_7) = (2D overlaying and trace referencing + 3D overlaying and trace referencing + 3D Design Collaboration + 3D Cloud Collaboration)/4

BIM Simplicity Score = (BS_1 + BS_2+ BS_3+ BS_4+ BS_5+ BS_6+ BS_7)/7

The BIM Simplicity Score was scaled from 1(very low simplicity score or very high complexity) 2 (low simplicity score or high complexity score), 3 (moderate simplicity score), 4 (high simplicity score or low complexity score) to 5 (very high simplicity score or very low complexity). One sample t test was used to check this hypothesis as shown in tables 4.55 and 4.56 below.

Table 4.55: One Sample Statistics for BIM Simplicity Score

One-Sample Statistics				
	N	**Mean**	**Std. Deviation**	**Std. Error Mean**
Overall BIM Simplicity Score	62	2.3533	1.71224	.21745

Source: Author (2019)

Table 4.56: One Sample t test for BIM Simplicity Score

One-Sample Test						
	Test Value = 2 (Low BIM Simplicity Score)					
	t	**df**	**Sig. (2-tailed)**	**Mean Difference**	**95% Confidence Interval of the Difference**	
					Lower	**Upper**
Overall BIM Simplicity Score	1.625	61	.109	.35330	-.0815	.7881

Source: Author (2019)

t(61) = 1.625, α > .05. t at 61 degrees of freedom is 1.625. The probability that the observed difference between our sample mean and the population mean was due to mere chance rather than to a real difference in achievement is more than 5%.Our survey is not significantly different from the null hypothesis and therefore BIM Simplicity score (M=2.35, SD=1.71) scored is not significantly higher than the low BIM Simplicity (M=2).

This study narrowed into the individual BIM capabilities to establish their respective levels of Simplicity as shown in tables 4.57 and 4.58 below.

Table 4.57: One Sample Statistics for Simplicity Score for Each Capability

One-Sample Statistics				
	N	**Mean**	**Std. Deviation**	**Std. Error Mean**
BIM Simplicity Score for 2DCAD	**62**	**2.6855**	**1.86036**	**.23627**
BIM Simplicity Score for 3DBIM	62	2.3118	1.74240	.22129
BIM Simplicity Score for 4DBIM	62	2.4301	1.96452	.24949
BIM Simplicity Score for 5DBIM	62	2.2473	1.84454	.23426
BIM Simplicity Score for SAMBIM	62	2.0430	2.00317	.25440
BIM Simplicity Score for MEPBIM	62	2.1263	1.97726	.25111
BIM Simplicity Score for IDCCBIM	62	2.6290	1.82859	.23223

Source: Author (2019)

Table 4.58: One Sample t Test for Simplicity Score for Each Capability

One-Sample Test						
	Test Value = 2 (Low Simplicity Score)					
	t	**df**	**Sig. (2-tailed)**	**Mean Difference**	**95% Confidence Interval of the Difference**	
					Lower	**Upper**
BIM Simplicity Score for 2DCAD	2.901	61	.005	.68548	.2130	1.1579
BIM Simplicity Score for 3DBIM	1.409	61	.164	.31183	-.1307	.7543
BIM Simplicity Score for 4DBIM	1.724	61	.090	.43011	-.0688	.9290
BIM Simplicity Score for 5DBIM	1.056	61	.295	.24731	-.2211	.7157
BIM Simplicity Score for SAMBIM	.169	61	.866	.04301	-.4657	.5517
BIM Simplicity Score for MEPBIM	.503	61	.617	.12634	-.3758	.6285
BIM Simplicity Score for IDCCBIM	2.709	61	.009	.62903	.1647	1.0934

Source: Author (2019)

For 2D-CAD Simplicity, t(61) = 2.901, α < .05 means that the level of simplicity is significantly different from the null hypothesis that the simplicity level is low (M=2), and therefore at (M=2.69, SD=1.86) the simplicity level is significantly higher than low BIM Simplicity level (moderate). For 3D-BIM Simplicity, $t(61) = .177$, $\alpha > .05$ means that the level of simplicity is not significantly different from the null hypothesis that the simplicity level is low (M=2), and therefore at (M=2.31, SD=1.74) the simplicity level is low. For 4D-BIM Simplicity, $t(61) = 1.724$, $\alpha > .05$ means that the level of simplicity is not significantly different from the null hypothesis that the simplicity level is low (M=2), and therefore at (M=2.43, SD=1.96) the simplicity level is low. For 5D-BIM simplicity, $t(61) = .918$, $\alpha > .05$ means that the level of simplicity is not significantly different from the null hypothesis that the simplicity level is low (M=2), and therefore at (M=2.25, SD=1.84) the simplicity level is low. For SAM-BIM Simplicity, $t(61) = 0.169$, $\alpha > .05$ means that the level of Simplicity is not significantly different from the null hypothesis that the simplicity level is low (M=2), and therefore at (M=2.04, SD=2.00) the simplicity level is low. For MEP-BIM simplicity, $t(61) = 0.503$, $\alpha > .05$ means that the level of simplicity is not significantly different from the null hypothesis that the simplicity level is low (M=2), and therefore at (M=2.13, SD=1.98) the simplicity level is low. For IDCC-BIM Simplicity, $t(61) = 2.709$, $\alpha < .05$ means that the level of simplicity is significantly different from the null hypothesis that the simplicity level is low (M=2), and therefore at (M=2.62, SD=1.82) the simplicity level is significantly higher than low BIM Simplicity level (moderate).

The study also looked at the correlations between BIM Adoption and BIM Simplicity amongst Building Contractors as shown in table 4.59 below. Where $p < .05$, correlation was significant, with the extent of correlation varying from weak ($0.2 < r < 0.4$), moderate ($.4 < r < 0.6$) to strong ($0.6 < r$)

Table 4.59: Pearson Correlation between BIM Simplicity and BIM Adoption

Correlations

		Overall BIM Simplicity Score	**Overall BIM Adoption Score**
	Pearson Correlation	1	.280*
Overall BIM Simplicity Score	Sig. (2-tailed)		.028
	N	62	62
	Pearson Correlation	.280*	1
Overall BIM Adoption Score	Sig. (2-tailed)	.028	
	N	62	62

*. Correlation is significant at the 0.05 level (2-tailed).

Source: Author (2019)

As indicated in table 4.59 above, the results indicated that $p < .05$ showing that these variables were significantly correlated. The Pearson correlation indicated a weak positive correlation between BIM Simplicity and BIM Adoption meaning that adoption levels increased with increased BIM Simplicity levels within the Building Contractors.

A one-way ANOVA test was done on these two variables to see if there was variance between the various groups in these variables and how these variances affected levels of BIM Adoption. One-way ANOVA results for BIM Simplicity versus BIM adoption was as shown in table 4.60 below.

Table 4.60: One-Way ANOVA Test on BIM Simplicity vs BIM Adoption

Tests of Between-Subjects Effects						
Dependent Variable: Overall BIM Adoption Score						
Source	**Type III Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**	**Partial Eta Squared**
Corrected Model	102.789[a]	21	4.895	6.572	.000	.775
Intercept	180.838	1	180.838	242.821	.000	.859
BIM Simplicity Score	102.789	21	4.895	6.572	.000	.775
Error	29.789	40	.745			
Total	375.109	62				
Corrected Total	132.579	61				

a. R Squared = .775 (Adjusted R Squared = .657)

Source: Author (2019)

The ANOVA summary indicates that with $p < 0.05$, the null hypothesis that variances were equal amongst simplicity scores was rejected hence means of BIM adoption across the simplicity scores were different with 78% of the variance of BIM Adoption explained by BIM Simplicity and variance between groups was 6.6 times greater than variances within the groups.

Having established that there was a correlation, a bivariate regression model was generated between the BIM Adoption score and BIM Simplicity Score using the following hypothesis:

- H_o: None of the coefficients in BIM Simplicity Score predict BIM Adoption Score

- H_a: Most of the coefficients in BIM Simplicity Score predict BIM Adoption Score

Table 4.61: Bivariate Regression Model on BIM Simplicity vs BIM Adoption

Coefficients[a]								
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B	
		B	Std. Error	Beta			Lower Bound	Upper Bound
1	(Constant)	2.298	.334		6.891	.000	1.628	2.968
	Overall BIM Simplicity Score	.027	.108	.035	.246	.807	-.190	.243

a. Dependent Variable: Overall BIM Adoption Score - CORRECT

Source: Author (2019)

As indicated in table 4.61 above, with sig (p) > 0.05, the null hypothesis was accepted, meaning that BIM Simplicity did not predict BIM Adoption hence regression equation could not be generated.

4.3.3.2 BIM Interoperability.

There was need to investigate the level of BIM Interoperability amongst Building Contractors in Kenya. The null and alternate hypothesis for this stated that:

- H_o – The BIM Interoperability Level by Building Contractors in Kenya is low.
- H_a – The BIM Interoperability Level by Building Contractors in Kenya is not low meaning that either the BIM Interoperability Level by Building Contractors in Kenya is lower than the low score or the Interoperability Level by Building Contractors in Kenya is higher than the low score

BIM Interoperability Level was tested using the averages of the values of interoperability indicators.

BIM Interoperability (BI) = (Open BIM Standards + Use of Native Models + Use of Federated Models + Hard Clash Detection + Soft Clash Detection)/5

The BIM Interoperability Score was scaled from 1 (very low Interoperability score), 2 (low Interoperability score), 3 (moderate Interoperability score), 4 (high Interoperability score) to 5 (very high Interoperability score). One sample t test was used to check this hypothesis as shown in tables 4.62 and 4.63 below.

Table 4.62: One Sample Statistics for BIM Interoperability Score

One-Sample Statistics				
	N	**Mean**	**Std. Deviation**	**Std. Error Mean**
Overall BIM Interoperability Score	62	2.2452	1.78203	.22632

Source: Author (2019)

Table 4.63: One Sample t test for BIM Interoperability Score

One-Sample Test						
	Test Value = 2 (Low Interoperability Score)					
	t	**df**	**Sig. (2-tailed)**	**Mean Difference**	**95% Confidence Interval of the Difference**	
					Lower	**Upper**
Overall BIM Interoperability Score	1.083	61	.283	.24516	-.2074	.6977

Source: Author (2019)

t(61) = 1.083, $\alpha > .05$. t at 61 degrees of freedom is 1.083. The probability that the observed difference between our sample mean and the population mean was due to mere chance rather than to a real difference in achievement is more than 5%. Our survey is not significantly different from the null hypothesis and therefore BIM Interoperability score (M=2.24, SD=1.78) scored is not significantly higher than the low BIM Interoperability (M=2).

This study narrowed into the individual tasks to establish their respective levels of Interoperability as indicated in tables 4.64 and 4.65 below.

Table 4.64: One Sample Statistics for Interoperability Score for Each Task

One-Sample Statistics				
	N	**Mean**	**Std. Deviation**	**Std. Error Mean**
Generate open BIM Standards	62	2.23	2.044	.260
Create and use native models	62	1.90	1.905	.242
Create and use federated models.	62	2.26	2.016	.256
Hard Clash detection	62	2.42	1.788	.227
Soft Clash Detection	62	2.42	1.788	.227

Source: Author (2019)

Table 4.65: One Sample t test for Interoperability Score for Each Task

One-Sample Test						
	Test Value = 2					
	t	**df**	**Sig. (2-tailed)**	**Mean Difference**	**95% Confidence Interval of the Difference**	
					Lower	**Upper**
Generate open BIM Standards	.870	61	.388	.226	-.29	.74
Create and use native models	-.400	61	.691	-.097	-.58	.39
Create and use federated models.	1.008	61	.317	.258	-.25	.77
Hard Clash detection	1.846	61	.070	.419	-.03	.87
Soft Clash Detection	1.846	61	.070	.419	-.03	.87

Source: Author (2019)

For generating open BIM Standards, $t(61) = .870$, $\alpha > .05$ means that the level of interoperability is not significantly different from the null hypothesis that the interoperability level is low (M=2), and therefore at (M=2.23, SD=2.04) the interoperability level is low. For using and creating native models, $t(61) = -.400$, $\alpha > .05$ means that the level of interoperability is not significantly different from the null hypothesis that the interoperability level is low (M=2), and therefore at (M=1.90, SD=1.91) the interoperability level is low. For using and creating federated models, $t(61) = 1.008$, $\alpha > .05$ means that the level of interoperability is not significantly different from the null hypothesis that the interoperability level is low (M=2), and therefore at (M=2.26, SD=2.02) the interoperability level is low. For using hard and soft clash detection, $t(61) = 1.846$, $\alpha > .05$ means that the level of interoperability is not significantly different from the null hypothesis that the interoperability level is low (M=2), and therefore at (M=2.42, SD=1.79) the interoperability level is low.

The study also looked at the correlations between BIM Adoption and BIM Interoperability amongst Building Contractors as shown in table 4.66 below. Where $p < .05$, correlation was significant, with the extent of correlation varying from weak ($0.2 < r < 0.4$), moderate ($.4 < r < 0.6$) to strong ($0.6 < r$)

Table 4.66: Pearson Correlation between BIM Interoperability and BIM Adoption

Correlations			
		Overall BIM Interoperability	**Overall BIM Adoption Score**
Overall BIM Interoperability Score	Pearson Correlation	1	.190
	Sig. (2-tailed)		.139
	N	62	62
Overall BIM Adoption Score	Pearson Correlation	.190	1
	Sig. (2-tailed)	.139	
	N	62	62

Source: Author (2019)

The results indicated that $p > .05$ showing that these variables were not significantly correlated. The Pearson correlation indicated no correlation between BIM Interoperability and BIM Adoption meaning that adoption levels increase was not influenced by increased BIM Interoperability levels within the Building Contractors. Based on this, there was no need of doing the ANOVA test and regression analysis. However, the study was interested in the correlation between the individual indicators as shown in table 4.67 below to try flag which ones were major contributors to this lack of correlation.

Table 4.67: Pearson Correlation between BIM Interoperability Indicators and BIM Adoption

Correlations							
		Overall BIM Adoption Score	**Open BIM Standard**	**Create and use native models**	**Create and use federated models.**	**Hard Clash detection**	**Soft Clash Detection**
Overall BIM Adoption Score	Pearson Correlation	1	.140	.320*	.185	.119	.119
	Sig. (2-tailed)		.276	.011	.151	.355	.355
	N	62	62	62	62	62	62
Open BIM Standard	Pearson Correlation	.140	1	.822**	.933**	.772**	.772**
	Sig. (2-tailed)	.276		.000	.000	.000	.000
	N	62	62	62	62	62	62
Create and use native models	Pearson Correlation	.320*	.822**	1	.869**	.782**	.782**
	Sig. (2-tailed)	.011	.000		.000	.000	.000
	N	62	62	62	62	62	62
Create and use federated models.	Pearson Correlation	.185	.933**	.869**	1	.833**	.833**
	Sig. (2-tailed)	.151	.000	.000		.000	.000
	N	62	62	62	62	62	62
Hard Clash detection	Pearson Correlation	.119	.772**	.782**	.833**	1	1.000**
	Sig. (2-tailed)	.355	.000	.000	.000		.000
	N	62	62	62	62	62	62
Soft Clash Detection	Pearson Correlation	.119	.772**	.782**	.833**	1.000**	1
	Sig. (2-tailed)	.355	.000	.000	.000	.000	
	N	62	62	62	62	62	62

*. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).

Source: Author (2019)

The results confirmed that there were no correlations amongst these indicators and BIM adoption with use of native models the only indicator having a weak positive correlation.

4.3.3.3 BIM Demonstration and Training.

There was need to investigate the level of BIM Demonstration and Training amongst Building Contractors in Kenya. The null and alternate hypothesis for this stated that:

- H_o – The BIM Demonstration and Training Level within Building Contractors in Kenya is low.
- H_a – The BIM Demonstration and Training Level within Building Contractors in Kenya is not low meaning that either the BIM Demonstration and Training Level within Building Contractors in Kenya is lower than the low score or the

Demonstration and Training Level within Building Contractors in Kenya is higher than the low score.

BIM Demonstration and Training Level was tested using the averages of the sentiments of Demonstration and Training indicators.

BIM Demonstration and Training (BDT) = (Government Contribution to BIM Research + BIM Laboratories + BIM Boot camps + Collaboration between innovators, resellers, and educational institutions + Hardware upgrades + Software upgrades + BIM Curriculum + BIM Specialized CPD seminars)/8

The BDT Score was scaled from 1(very low BDT score), 2(low BDT score), 3(moderate BDT score), 4(high BDT score) to 5 (very high BDT score). One sample t test was used to check this hypothesis as shown in tables 4.68 and 4.69 below.

Table 4.68: One Sample Statistics for BIM Demonstration and Training Score

One-Sample Statistics				
	N	**Mean**	**Std. Deviation**	**Std. Error Mean**
Overall BIM Demonstration and Training Score	62	2.2702	1.66605	.21159

Source: Author (2019)

Table 4.69: One Sample *t* test for BIM Demonstration and Training Score

One-Sample Test						
	Test Value = 2 (Low BDT Score)					
	t	**df**	**Sig. (2-tailed)**	**Mean Difference**	**95% Confidence Interval of the Difference**	
					Lower	**Upper**
Overall BIM Demonstration and Training Score	1.277	61	.207	.27016	-.1529	.6933

Source: Author (2019)

t(61) = 1.277, α > .05. t at 61 degrees of freedom is 1.277. The probability that the observed difference between our sample mean and the population mean was due to mere chance rather than to a real difference in achievement is more than 5%.Our survey is not significantly different from the null hypothesis and therefore, BDT score (M=2.27, SD=1.67) scored is not significantly higher than the low BDT (M=2).

This study narrowed into the individual BIM Demonstration and Training indicators to establish their respective levels of performance as shown in table 4.70 and 4.71 below.

Table 4.70: One Sample Statistics for BIM Demonstration and Training Indicators

One-Sample Statistics				
	N	**Mean**	**Std.**	**Std. Error Mean**
Government contribution to BIM research	62	2.03	1.609	.204
Institutional based BIM laboratories	62	1.90	1.647	.209
Short term boot camps	62	1.92	1.540	.196
Collaboration between BIM innovators, resellers and educational institutions	62	2.00	1.660	.211
Frequent upgrading of computer hardware	62	2.81	2.055	.261
Frequent upgrading of computer software	62	2.82	2.154	.274
BIM Curriculum	62	2.48	1.897	.241
BIM specialized CPD seminars	62	2.19	1.763	.224

Source: Author (2019)

Table 4.71: One Sample *t* Test for BIM Demonstration and Training Indicators

One-Sample Test						
	Test Value = 2					
	t	**df**	**Sig. (2-tailed)**	**Mean Difference**	**95% Confidence Interval of the**	
					Lower	**Upper**
Government contribution to BIM research	.158	61	.875	.032	-.38	.44
Institutional based BIM laboratories	-.463	61	.645	-.097	-.51	.32
Short term boot camps	-.412	61	.681	-.081	-.47	.31
Collaboration between BIM innovators, resellers and educational institutions	.000	61	1.000	.000	-.42	.42
Frequent upgrading of computer hardware	3.090	61	.003	.806	.28	1.33
Frequent upgrading of computer software	3.007	61	.004	.823	.28	1.37
BIM Curriculum	2.009	61	.049	.484	.00	.97
BIM specialized CPD seminars	.864	61	.391	.194	-.25	.64

Source: Author (2019)

For Government Contribution to BIM Research, $t(61) = .158$, $\alpha > .05$ means that the level of BDT score is not significantly different from the null hypothesis that the Government contribution is low (M=2), and therefore at (M=2.03, SD=1.61) the BDT level is low. For Institutional based BIM Laboratories, $t(61) = -.463$, $\alpha > .05$ means that the level of BDT score is not significantly different from the null hypothesis that the availability of Institutional based BIM Laboratories is low (M=2), and therefore at

(M=1.90, SD=1.65) the BDT level is low. For Short Term boot camps, $t(61) = -.412$, $\alpha > .05$ means that the level of BDT score is not significantly different from the null hypothesis that the frequency of short term boot camps is low (M=2), and therefore at (M=1.92, SD=1.54) the BDT level is low. For Collaboration between Innovators, resellers and institutions, $t(61) = 0.000$, $\alpha > .05$ means that the level of BDT score is not significantly different from the null hypothesis that collaboration between these three parties is low (M=2), and therefore at (M=2.00, SD=1.67) the BDT level is low. For frequency of upgrading computer hardware, $t(61) = 3.090$, $\alpha < .05$ means that the level of BDT score is significantly different from the null hypothesis that frequency of upgrading computer hardware is low (M=2), and therefore at (M=2.81, SD=2.06) the BDT level is significantly higher than low BDT level (moderate). For frequency of upgrading computer software, $t(61) = 3.007$, $\alpha < .05$ means that the level of BDT score is significantly different from the null hypothesis that the frequency of upgrading software is low (M=2), and therefore at (M=2.82, SD=2.15) the BDT level is significantly higher than low BDT level (moderate). For availability and use of BIM Curriculum, $t(61) = 2.009$, $\alpha < .05$ means that the level of BDT score is significantly different from the null hypothesis that frequency of availability and use of BIM curriculum is low (M=2), and therefore at (M=2.48, SD=1.90) the BDT level is significantly higher than low BDT level (moderate). For BIM specialized CPD seminars, $t(61) = .864$, $\alpha > .05$ means that the level of BDT score is not significantly different from the null hypothesis that the frequency of holding BIM specialised seminars is low (M=2), and therefore at (M=2.19, SD=1.76) the BDT level is low.

The study also looked at the correlations between BIM Adoption and BIM Demonstration and Training amongst Building Contractors as shown in table 4.72 below. Where $p < .05$, correlation was significant, with the extent of correlation varying from weak ($0.2 < r < 0.4$), moderate ($.4 < r < 0.6$) to strong ($0.6 < r$)

Table 4.72: Pearson Correlation between BIM Demonstration and Training and BIM Adoption

Correlations			
		Overall BIM Demonstration	**Overall BIM Adoption Score**
Overall BIM Adoption Score	Pearson Correlation	.337**	1
	Sig. (2-tailed)	.007	
	N	62	62
Overall BIM Demonstration and Training Score	Pearson Correlation	1	.337**
	Sig. (2-tailed)		.007
	N	62	62

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

Source: Author (2019)

The results indicated that p<.05 showing that these variables were significantly correlated. The Pearson correlation indicated a weak positive correlation between BIM Demonstration and Training and BIM Adoption meaning that adoption levels weakly increased with increased BIM Demonstration and Training levels within the Building Contractors.

A one-way ANOVA test was done on these two variables to see if there was variance between the various groups in these variables and how these variances affected levels of BIM Adoption. One-way ANOVA results for BIM Demonstration and Training versus BIM adoption was as shown in table 4.73 below.

Table 4.73: One-way ANOVA Test on BIM Demonstration and Training vs BIM Adoption

Tests of Between-Subjects Effects Dependent Variable: Overall BIM Adoption Score						
Source	**Type III Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**	**Partial Eta Squared**
Corrected Model	53.008[a]	10	5.301	3.397	.002	.400
Intercept	141.202	1	141.202	90.501	.000	.640
BIM Demonstration and Training Score	53.008	10	5.301	3.397	.002	.400
Error	79.571	51	1.560			
Total	375.109	62				
Corrected Total	132.579	61				

a. R Squared = .400 (Adjusted R Squared = .282)

Source: Author (2019)

The ANOVA summary indicates that with $p < 0.05$, the null hypothesis that variances were equal amongst simplicity scores was rejected hence means of BIM adoption across the demonstration and training scores were different with 40% of the variance of BIM Adoption explained by BIM Demonstration and Training and variance between groups was 3.4 times greater than variances within the groups.

Having established that there was a correlation, a bivariate regression model was generated between the BIM Adoption score and BIM Demonstration and Training Score using the following hypothesis:

- H_o: None of the coefficients in BIM Demonstration and Training Score predict BIM Adoption Score.
- H_a: Most of the coefficients in BIM Demonstration and Training Score predict BIM Adoption Score.

Table 4.74: Bivariate Regression Model on BIM Simplicity vs BIM Adoption

Coefficients[a]								
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B	
		B	Std. Error	Beta			Lower Bound	Upper Bound
1	(Constant)	1.300	.302		4.305	.000	.696	1.904
	Overall BIM Demonstration and Training Score	.299	.108	.337	2.777	.007	.083	.514

a. Dependent Variable: Overall BIM Adoption Score

Source: Author (2019)

As indicated in table 4.74 above, with sig (p) < 0.05, the null hypothesis was rejected, meaning that BIM Demonstration and Training Score predicted BIM Adoption with the regression equation as shown below and further articulated using the linear graph in figure 4.9 below.

BIM Adoption Score = 0.299 x BIM Demonstration and Training Score + 1.300

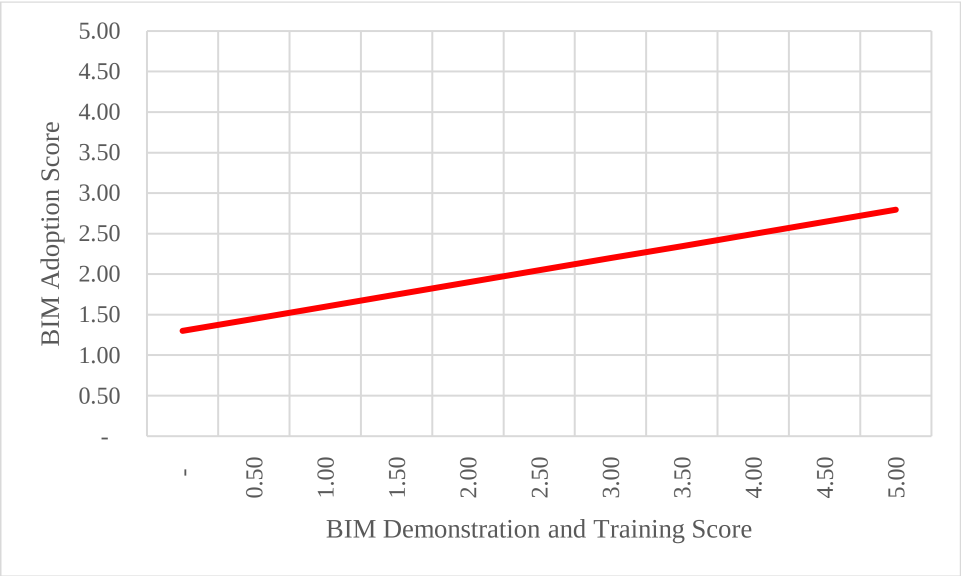


Figure 4.9: Bivariate Graph of BIM Demonstration and Training Score vs BIM Adoption

Score Source: Author (2019)

4.3.3.4 BIM Government Policies.

There was need to investigate the level of BIM Government Policies on Building Contractors in Kenya. The null and alternate hypothesis for this stated that:

- H_o-The BIM Government Policies on Building Contractors in Kenya is weak.
- H_a-The BIM Government Policies on Building Contractors in Kenya is not weak meaning that either the BIM Government Policies on Building Contractors in Kenya is lower than the weak score or the BIM Government Policies on Building Contractors in Kenya is higher than the weak score

BIM Government Policies Score was tested using the averages of the sentiments of Government Policies indicators.

BIM Government Policies Score (BGP) = (Government Mandate on BIM + Government Regulation on BIM + Government Funding on BIM + Specific Government Policies + Government backed taskforce)/5

The BIM Government Policy Score was scaled from 1(very weak BGP score), 2(weak BGP score), 3(moderate BGP score), 4(strong BGP score) to 5 (very strong BGP score). One sample t test was used to check this hypothesis as shown in tables 4.75 and 4.76 below.

Table 4.75: One Sample Statistics for BIM Government Policies

One-Sample Statistics				
	N	**Mean**	**Std. Deviation**	**Std. Error Mean**
Overall BIM Government Policy Score	62	2.0500	1.65287	.20991

Source: Author (2019)

Table 4.76: One Sample t test for BIM Government Policies

One-Sample Test						
	Test Value = 2 (Weak Government Policy)					
	t	**df**	**Sig. (2-tailed)**	**Mean Difference**	**95% Confidence Interval of the Difference**	
					Lower	**Upper**
Overall BIM Government Policy Score	.238	61	.813	.05000	-.3697	.4697

Source: Author (2019)

t(61) = 0.238, $\alpha > .05$. t at 61 degrees of freedom is 0.238. The probability that the observed difference between our sample mean and the population mean was due to mere chance rather than to a real difference in achievement is more than 5%.Our survey is not significantly different from the null hypothesis and therefore BIM Government Policy score (M=2.05, SD=1.66) scored is not significantly higher than the low BIM Government Policy Score (M=2).

This study narrowed into the individual indicators to establish their respective levels of score as indicated in tables 4.77 and 4.78 below.

Table 4.77: One Sample Statistics for BIM Government Policy Indicators

One-Sample Statistics				
	N	Mean	Std. Deviation	Std. Error Mean
Government mandate on BIM	62	1.84	1.661	.211
Government regulation on BIM	62	1.87	1.769	.225
Government funding on BIM	62	2.00	1.699	.216
Specific Government Policies	62	2.22	1.896	.241
Government backed taskgroups on BIM	62	2.32	1.906	.242

Source: Author (2019)

Table 4.78: One Sample t test for BIM Government Policy Indicators

One-Sample Test						
	Test Value = 2 (Weak Government Policies)					
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
Government mandate on BIM	-.764	61	.448	-.161	-.58	.26
Government regulation on BIM	-.574	61	.568	-.129	-.58	.32
Government funding on BIM	.000	61	1.000	.000	-.43	.43
Specific Government Policies	.904	61	.369	.218	-.26	.70
Government backed taskgroups on BIM	1.333	61	.188	.323	-.16	.81

Source: Author (2019)

For Government Mandate on BIM, $t(61) = -0.764$, $\alpha > .05$ means that the level of Government Mandate is not significantly different from the null hypothesis that the Government Mandate is weak (M=2), and therefore at (M=1.84, SD=1.66) the Government Policy is weak. For Government Regulation on BIM, $t(61) = -0.574$, $\alpha > .05$ means that the level of Government Regulation is not significantly different from the null hypothesis that the Government Regulation is weak (M=2), and therefore at (M=1.87, SD=1.77) the Government Policy is weak. For Government Funding of BIM Activities, $t(61) = 0.000$, $\alpha > .05$ means that the level of Government Funding is not significantly different from the null hypothesis that the Government Funding is low (M=2), and therefore at (M=2.00, SD=1.70) the Government Policy is weak. For Specific Government policies on Interoperability, e-Building Permits, Open BIM and BIM software certification, $t(61) = 0.904$, $\alpha > .05$ means that the level of these specific Government Policies are not significantly different from the null hypothesis that these specific Government policies are weak (M=2), and therefore at (M=2.22, SD=1.90) the Government Policy is weak. For Government Backed Taskgroups, t(61) = 1.333, $\alpha > .05$ means that the use of Government backed Taskgroups is not significantly different from the null hypothesis that the use of Government backed Taskforce is weak (M=2), and therefore at (M=2.32, SD=1.91) the Government Policy is weak.

The study also looked at the correlations between BIM Adoption and BIM Government Policies on Building Contractors as shown in table 4.79 below. Where $p < .05$, correlation was significant, with the extent of correlation varying from weak ($0.2 < r < 0.4$), moderate ($.4 < r < 0.6$) to strong ($0.6 < r$)

Table 4.79: Pearson Correlation between BIM Government Policies and BIM Adoption

Correlations			
		Overall BIM Government	**Overall BIM Adoption Score**
Overall BIM Government Policy Score	Pearson Correlation	1	.094
	Sig. (2-tailed)		.468
	N	62	62
Overall BIM Adoption Score	Pearson Correlation	.094	1
	Sig. (2-tailed)	.468	
	N	62	62

Source: Author (2019)

The results indicated that $p > .05$ showing that these variables were not significantly correlated. The Pearson correlation indicated no correlation between BIM Government Policies and BIM Adoption meaning that adoption levels increase was not influenced by improved BIM Government Policies within the Building Contractors. Based on this, there was no need of doing the ANOVA test and regression analysis. However, the study was interested in the correlation between the individual indicators as shown in table 4.80 below to try flag which ones were major contributors to this lack of correlation.

Table 4.80: Pearson Correlation between BIM Government Policy Indicators and BIM Adoption

Correlations							
		Strong government mandate on BIM	**Strong government regulation on BIM**	**Strong government funding on BIM**	**Specific Government Policies**	**Strong government backed taskgroups**	**Overall BIM Adoption Score**
Strong government mandate on BIM	Pearson Correlation	1	.974**	.755**	.818**	.752**	.160
	Sig. (2-tailed)		.000	.000	.000	.000	.214
	N	62	62	62	62	62	62
Strong government regulation on BIM	Pearson Correlation	.974**	1	.785**	.815**	.742**	.245
	Sig. (2-tailed)	.000		.000	.000	.000	.055
	N	62	62	62	62	62	62
Strong government funding on BIM	Pearson Correlation	.755**	.785**	1	.789**	.810**	.133
	Sig. (2-tailed)	.000	.000		.000	.000	.304
	N	62	62	62	62	62	62
Specific Government Policies	Pearson Correlation	.818**	.815**	.789**	1	.951**	-.001
	Sig. (2-tailed)	.000	.000	.000		.000	.995
	N	62	62	62	62	62	62
Strong government backed BIM task groups	Pearson Correlation	.752**	.742**	.810**	.951**	1	-.077
	Sig. (2-tailed)	.000	.000	.000	.000		.552
	N	62	62	62	62	62	62
Overall BIM Adoption Score	Pearson Correlation	.160	.245	.133	-.001	-.077	1
	Sig. (2-tailed)	.214	.055	.304	.995	.552	
	N	62	62	62	62	62	62

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

Source: Author (2019)

The results confirmed that there were no correlations amongst these indicators and BIM adoption.

4.3.3.5 BIM Maturity Score Summary.

After looking at all indicators influencing maturity, there was need to study how they influenced the BIM Maturity Score and how this score related to the BIM Adoption Score. For this, the null and alternate hypothesis stated that:

- H_o – The BIM Maturity Score for Building Contractors in Kenya is low.
- H_a – The BIM Maturity Score for Building Contractors in Kenya is not low meaning that either the BIM Maturity Score for Building Contractors in Kenya

is lower than the low score or the BIM Maturity Score for Building Contractors in Kenya is higher than the low score

BIM Maturity Score was tested using the averages of the indicators for BIM Maturity.

BIM Maturity Score = (BIM Simplicity + BIM Interoperability + BIM Demonstration and Training + BIM Government Policies)/4

The BIM Maturity Score was scaled from 1(very low BIM Maturity score), 2(low BIM Maturity score), 1(moderate BIM Maturity score), 4(high BIM Maturity score) to 5 (very high BIM Maturity score). One sample t test was used was used to check this hypothesis as shown in tables 4.81 and 4.82 below.

Table 4.81: One Sample Statistics for BIM Maturity Score

One-Sample Statistics				
	N	**Mean**	**Std. Deviation**	**Std. Error Mean**
Overall BIM Maturity Score	62	2.2297	1.48897	.18910

Source: Author (2019)

Table 4.82: One Sample *t* Test for BIM Maturity Score

One-Sample Test						
	Test Value = 2 (Low BIM Maturity Score)					
	t	**df**	**Sig. (2-tailed)**	**Mean Difference**	**95% Confidence Interval of the Difference**	
					Lower	**Upper**
Overall BIM Maturity Score	1.214	61	.229	.22966	-.1485	.6078

Source: Author (2019)

$t(61) = 1.214$, $\alpha > .05$. t at 61 degrees of freedom is 1.214. The probability that the observed difference between our sample mean and the population mean was due to mere chance rather than to a real difference in achievement is more than 5%.Our survey is not significantly different from the null hypothesis and BIM Maturity score (M=2.23, SD=1.49) scored is not significantly higher than low BIM Maturity Score (M=2).

4.3.3.6 BIM Maturity Score vs BIM Adoption Score

The study also looked at the correlations between BIM Adoption Score and BIM Maturity Score amongst Building Contractors as shown in table 4.83 below. Where $p < .05$, correlation was significant, with the extent of correlation varying from weak $(0.2 < r < 0.4)$, moderate $(.4 < r < 0.6)$ to strong $(0.6 < r)$

Table 4.83: Pearson Correlation between BIM Maturity Score and BIM Adoption

Correlations			
		Overall BIM Maturity Score	**Overall BIM Adoption Score**
Overall BIM Maturity Score	Pearson Correlation	1	.261*
	Sig. (2-tailed)		.040
	N	62	62
Overall BIM Adoption Score	Pearson Correlation	.261*	1
	Sig. (2-tailed)	.040	
	N	62	62

*. Correlation is significant at the 0.05 level (2-tailed).

Source: Author (2019)

The results indicated that $p<.05$ showing that these variables were significantly correlated. The Pearson correlation indicated a weak positive correlation between BIM Maturity Score and BIM Adoption meaning that adoption levels increased with increased levels of BIM Maturity within the Building Contractors.

A bivariate regression model was generated between the BIM Adoption score and BIM Maturity Score, having established that there was a correlation using the following hypothesis:

- H_o: None of the coefficients in BIM Maturity Score predict BIM Adoption Score
- H_a: Most of the coefficients in BIM Maturity Score predict BIM Adoption Score

Table 4.84: Bivariate Regression Model on BIM Maturity Score vs BIM Adoption

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.	95.0% Confidence Interval for B Lower Bound	95.0% Confidence Interval for B Upper Bound
1	(Constant)	1.401	.330		4.246	.000	.741	2.061
	Overall BIM Maturity Score	.259	.123	.261	2.096	.040	.012	.505

Coefficients[a]

a. Dependent Variable: Overall BIM Adoption Score

Source: Author (2019)

As indicated in table 4.84 above, with sig (p) < 0.05, the null hypothesis was rejected, meaning that BIM Maturity Score predicted BIM Adoption with the regression equation as shown below and further articulated using the linear graph in figure 4.10 below.

BIM Adoption Score = 0.259 x BIM Maturity Score + 1.401

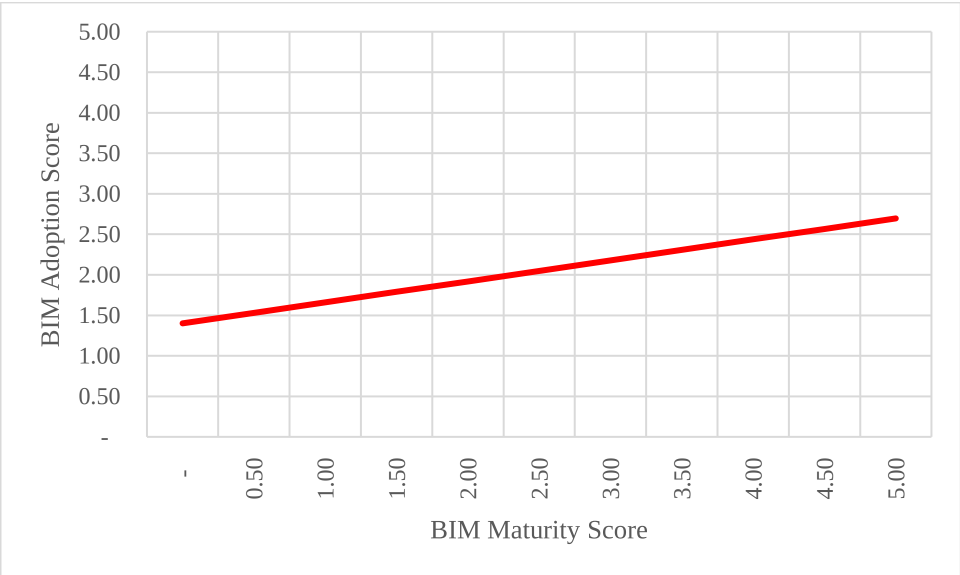


Figure 4.10: Bivariate Graph of BIM Maturity Score vs BIM Adoption Score

Source: Author (2019)

To understand the relationship between BIM Adoption and the various indicators under BIM Maturity, a multivariate regression model was generated between the BIM

Adoption score and the various indicators that make up the BIM Maturity Score using the following hypothesis:

- H_o: None of the indicators in BIM Maturity Score predict BIM Adoption Score
- H_a: Most of the indicators in BIM Maturity Score predict BIM Adoption Score

Table 4.85: Multivariate Regression Model on BIM Maturity Score vs BIM Adoption

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B	
		B	Std. Error	Beta			Lower Bound	Upper Bound
1	(Constant)	1.274	.321		3.964	.000	.630	1.917
	Overall BIM Simplicity	.801	.385	.930	2.080	.042	.030	1.571
	Overall BIM Interoperability Score	-.746	.343	-.901	-2.173	.034	-1.433	-.058
	Overall BIM Demonstration and	.337	.201	.380	1.678	.099	-.065	.738
	Overall BIM Government Policy	-.132	.150	-.148	-.879	.383	-.432	.168

a. Dependent Variable: Overall BIM Adoption Score

Source: Author (2019)

As indicated in 4.85 above, with sig (p) < 0.05, the null hypothesis was rejected, meaning that these specific indicators predicted BIM Adoption with the regression equation as shown below:

BIM Adoption Score = 0.801 x BIM Simplicity Score - 0.746 x BIM Interoperability Score + 1.274

4.3.4 Relationship between BIM Risk Tolerance Score and BIM Adoption.

The third secondary task of this study was to investigate the relationship between the BIM Risk Tolerance Score and BIM Adoption amongst Building Contractors in Kenya. The null and alternate hypothesis stated that:

- H_o – There is no relationship between the BIM Risk Tolerance Score and BIM Adoption amongst Building Contractors in Kenya.

- H_a – There is a relationship between the BIM Risk Tolerance Score and BIM Adoption amongst Building Contractors in Kenya.

Before testing these hypotheses, there was need to look at BIM Risk Tolerance and its associated constructs and indicators. BIM Risk Tolerance Score was generated by using the average scores for the various indicators which include BIM Relative Advantage, Intellectual Property, Liability and Experience while BIM Adoption level was a score generated using the average of the highest level of preference for the various BIM tools associated capabilities.

4.3.4.1 BIM Relative Advantage.

There was need to investigate the level of BIM Relative Advantage amongst Building Contractors in Kenya. The null and alternate hypothesis for this stated that:

- H_o – The BIM Relative Advantage of BIM by Building Contractors is low.
- H_a – The BIM Relative Advantage of BIM by Building Contractors is not low meaning that either the BIM Relative Advantage of BIM by Building Contractors in Kenya is lower than the low score or the BIM Relative Advantage of BIM by Building Contractors in Kenya is higher than the low score.

BIM Relative Advantage was tested using the difference of averages of the values of benefits and challenges amongst the various BIM capabilities.

BIM Benefits Score (BBS) = (Reduced Office Operations + Improved Productivity + Reduced ROI + Improved Change Management + Improved coordination and collaboration + Improved Design Integration + Reduced errors omissions and reworks + improved control cost and predictability + reduced cycle time + reduced litigation)/10

BIM Challenges Score (BCS) = (Cost of upgrading hardware + cost of upgrading software + cost of retraining staff + cost of creating workflows + low client demand + low model sharing)/6

BIM Relative Advantage = BIM Benefit Score – BIM Challenges Score

The BIM Benefit Score was scaled from 1(very low benefit score), 2(low benefit score), 3(moderate benefit score), 4(high benefit score) to 5 (very high benefit score). The BIM Challenges Score was scaled from 1(very low challenges score), 2(low challenges score),3(moderate challenges score),4(high challenges score) to 5 (very high challenges score).The BIM Relative Advantage was scaled from -2(very low Relative Advantage score), -1(low Relative Advantage score), 0 (moderate Relative Advantage score),1(high Relative Advantage score) to 2(very high Relative score).One sample t test was used to check this hypothesis as shown in tables 4.86 and 4.87 below.

Table 4.86: One Sample Statistics for BIM Relative Advantage Score

One-Sample Statistics				
	N	**Mean**	**Std. Deviation**	**Std. Error Mean**
BIM Relative Advantage	62	.4306	1.57760	.20036

Source: Author (2019)

Table 4.87: One Sample t Test for BIM Relative Advantage Score

One-Sample Test						
	Test Value = -1 (Low Relative Advantage Score)					
	t	**df**	**Sig. (2-tailed)**	**Mean Difference**	**95% Confidence Interval of the Difference**	
					Lower	**Upper**
BIM Relative Advantage Score	7.141	61	.000	1.43065	1.0300	1.8313

Source: Author (2019)

$t(61) = 7.141$, $\alpha < .05$. t at 61 degrees of freedom is 7.141. The probability that the observed difference between our sample mean and the population mean was due to mere chance rather than to a real difference in achievement is less than 5%. Our survey is significantly different from the null hypothesis and therefore BIM Relative Advantage score (M=0.43, SD=1.58) scored is significantly higher than the low BIM Relative Advantage (M=-1).

This study compared the BIM benefit score, and BIM challenges score as shown in tables 4.88 and 4.89 below.

Table 4.88: One Sample Statistics for BIM Benefit and Challenges Scores

One-Sample Statistics				
	N	**Mean**	**Std. Deviation**	**Std. Error Mean**
BIM Benefits Score	62	2.4790	2.13374	.27098
BIM Challenges Score	62	2.0484	1.89919	.24120

Source: Author (2019)

Table 4.89: One Sample *t* Test for BIM Benefit and Challenges Scores

One-Sample Test						
	Test Value = 2					
	t	**df**	**Sig. (2-tailed)**	**Mean Difference**	**95% Confidence Interval of the Difference**	
					Lower	**Upper**
BIM Benefits Score	1.768	61	.082	.47903	-.0628	1.0209
BIM Challenges Score	.201	61	.842	.04839	-.4339	.5307

Source: Author (2019)

For BIM Benefits Score, t(61) = 1.768, α > .05 means that BIM Benefits Score is not significantly different from the null hypothesis that the benefits level is low (M=2), and therefore at (M=2.48, SD=2.13) the BIM Benefits Score low. For BIM Challenges Score, t(61) = 0.201, α > .05 means that BIM Challenges Score is not significantly different from the null hypothesis that the challenges level is low (M=2), and therefore at (M=2.05, SD=1.90) the BIM Challenges Score is low. Though both indicated low scores, benefits outweighed challenges thereby having a relative advantage as shown in tables 87 and 88 above.

The study also looked at the correlations between BIM Adoption and BIM Relative Advantage amongst Building Contractors as shown in table 4.90 below. Where p < .05, correlation was significant, with the extent of correlation varying from weak (0.2 < r < 0.4), moderate (.4 < r < 0.6) to strong (0.6 < r)

Table 4.90: Pearson Correlation between BIM Relative Advantage and BIM Adoption

Correlations			
		Overall BIM Adoption Score	**BIM Relative Advantage Score**
Overall BIM Adoption Score	Pearson Correlation	1	.469**
	Sig. (2-tailed)		.000
	N	62	62
BIM Relative Advantage Score	Pearson Correlation	.469**	1
	Sig. (2-tailed)	.000	
	N	62	62

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

Source: Author (2019)

The results indicated that p < .05 showing that these variables were significantly correlated. The Pearson correlation indicated a moderate positive correlation between BIM Relative Advantage and BIM Adoption meaning that adoption levels increased with increased BIM Relative Advantage levels within the Building Contractors.

A one-way ANOVA test was done on these two variables to see if there was variance between the various groups in these variables and how these variances affected levels of BIM Adoption. One-way ANOVA results for BIM Relative Advantage versus BIM adoption was as shown in table 4.91 below.

Table 4.91: One-way ANOVA Test on BIM Relative Advantage vs BIM Adoption

Tests of Between-Subjects Effects Dependent Variable: Overall BIM Adoption Score						
Source	**Type III Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**	**Partial Eta Squared**
Corrected Model	73.268[a]	14	5.233	4.147	.000	.553
Intercept	168.044	1	168.044	133.165	.000	.739
BIM Relative Advantage Score	73.268	14	5.233	4.147	.000	.553
Error	59.310	47	1.262			
Total	375.109	62				
Corrected Total	132.579	61				

a. R Squared = .553 (Adjusted R Squared = .419)

Source: Author (2019)

The ANOVA summary indicates that with p < 0.05, the null hypothesis that variances were equal amongst simplicity scores was rejected hence means of BIM Relative

Advantage across the simplicity scores were different with 55% of the variance of BIM Adoption explained by BIM Simplicity and variance between groups was 4.1 times greater than variances within the groups.

Having established that there was a correlation, a bivariate regression model was generated between the BIM Adoption score and BIM Relative Advantage Score using the following hypothesis:

- H_o: None of the coefficients in BIM Relative Advantage Score predict BIM Adoption Score
- H_a: Most of the coefficients in BIM Relative Advantage Score predict BIM Adoption Score

Table 4.92: Bivariate Regression Model on BIM Relative Advantage vs BIM Adoption

Coefficients[a]								
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B	
		B	Std. Error	Beta			Lower Bound	Upper Bound
1	(Constant)	1.789	.173		10.344	.000	1.443	2.135
	BIM Relative Advantage	.438	.107	.469	4.108	.000	.225	.651

a. Dependent Variable: Overall BIM Adoption Score

Source: Author (2019)

As indicated in table 4.92 above, with sig (p) < 0.05, the null hypothesis was rejected, meaning that BIM Relative Advantage predicted BIM Adoption with the regression equation as shown below and further articulated using the linear graph in figure 4.11 below.

BIM Adoption Score = 0.438 x BIM Relative Advantage Score + 1.789

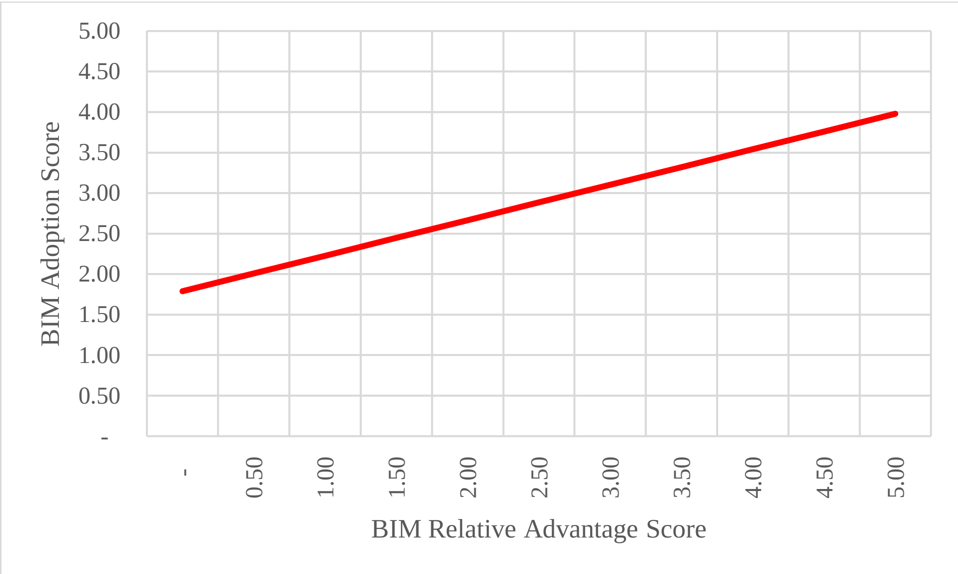


Figure 4.11: Bivariate Graph of BIM Relative Advantage Score vs BIM Adoption Score

Source: Author (2019)

4.3.4.2 Intellectual Property

There was need to investigate the Intellectual Property amongst Building Contractors in Kenya. The null and alternate hypothesis for this stated that:

- H_o – The Intellectual Property Level by Building Contractors in Kenya is low.
- H_a – The Intellectual Property Level by Building Contractors in Kenya is not low meaning that either the Intellectual Property Level by Building Contractors in Kenya is lower than the low score or the Intellectual Property Level by Building Contractors in Kenya is higher than the low score.

BIM Intellectual Property Level was tested using the averages of the values of Intellectual Property indicators.

BIM Intellectual Property Level = (Recognition of Copyrights + Recognition of Federated Models)/2

The BIM Intellectual Property Score was scaled from 1(very low Intellectual Property Level score), 2(low Intellectual Property Level score), 3(moderate Intellectual Property Level score), 4(high Intellectual Property Level score) to 5 (very high Intellectual Property Level score). One sample t test was used to check this hypothesis as shown in tables 4.93 and 4.94 below.

Table 4.93: One Sample Statistics for BIM Intellectual Property Score

One-Sample Statistics				
	N	**Mean**	**Std. Deviation**	**Std. Error Mean**
BIM Intellectual Property Score	62	1.6774	1.53937	.19550

Source: Author (2019)

$t(61) = -1.650$, $\alpha > .05$. *t* at 61 degrees of freedom is -1.650. The probability that the observed difference between our sample mean and the population mean was due to mere chance rather than to a real difference in achievement is more than 5%. Our survey is not significantly different from the null hypothesis and therefore BIM Intellectual Property score (M=1.68, SD=1.54) scored is not significantly lower than the low BIM Intellectual Property Level (M=2).

Table 4.94: One Sample *t* Test for BIM Intellectual Property Score

One-Sample Test						
	Test Value = 2 (Low BIM Intellectual Property Score)					
	t	**df**	**Sig. (2-tailed)**	**Mean Difference**	**95% Confidence Interval of the Difference**	
					Lower	**Upper**
BIM Intellectual Property Score	-1.650	61	.104	-.32258	-.7135	.0683

Source: Author (2019)

This study narrowed into the individual indicators to establish their respective levels of score as indicated in tables 4.95 and 4.96 below.

Table 4.95: One Sample Statistics for BIM Intellectual Property Indicators

One-Sample Statistics				
	N	Mean	Std. Deviation	Std. Error Mean
Copyright Recognition	62	1.65	1.590	.202
Federated Models Recognition	62	1.71	1.683	.214

Source: Author (2019)

Table 4.96: One Sample *t* Test for BIM Intellectual Property Indicators

One-Sample Test						
	Test Value = 2					
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
Copyright Recognition	-1.757	61	.084	-.355	-.76	.05
Federated Models Recognition	-1.358	61	.179	-.290	-.72	.14

Source: Author (2019)

For copyright recognition, $t(61) = -1.757$, $\alpha > .05$ means that the level of copyright recognition is not significantly different from the null hypothesis that the copyright recognition is low (M=2), and therefore at (M=1.65, SD=1.59), copyright recognition is low. For federated model recognition, $t(61) = -1.358$, $\alpha > .05$ means that the level of federated models recognition is not significantly different from the null hypothesis that federated model recognition is low (M=2), and therefore at (M=1.71, SD=1.69) federated model recognition is low.

The study also looked at the correlations between BIM Adoption and BIM Intellectual Property amongst Building Contractors as shown in table 4.97 below. Where $p < .05$, correlation was significant, with the extent of correlation varying from weak ($0.2 < r < 0.4$), moderate ($.4 < r < 0.6$) to strong ($0.6 < r$)

The results indicated that $p<.05$ showing that these variables were significantly correlated. The Pearson correlation indicated a moderate positive correlation between BIM Intellectual Property and BIM Adoption meaning that adoption levels increased with increased BIM Intellectual Property levels within the Building Contractors.

Table 4.97: Pearson Correlation between BIM Intellectual Properties and BIM Adoption

Correlations			
		BIM Intellectual Property Score	Overall BIM Adoption Score
BIM Intellectual Property Score	Pearson Correlation	1	.533**
	Sig. (2-tailed)		.000
	N	62	62
Overall BIM Adoption Score	Pearson Correlation	.533**	1
	Sig. (2-tailed)	.000	
	N	62	62

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

Source: Author (2019)

A one-way ANOVA test was done on these two variables to see if there was variance between the various groups in these variables and how these variances affected levels of BIM Adoption. One-way ANOVA results for BIM Intellectual Property versus BIM adoption was as shown in table 4.98 below.

Table 4.98: One-Way ANOVA Test on BIM Intellectual Property vs BIM Adoption

Tests of Between-Subjects Effects						
Dependent Variable: Overall BIM Adoption Score						
Source	**Type III Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**	**Partial Eta Squared**
Corrected Model	68.710[a]	8	8.589	7.127	.000	.518
Intercept	120.639	1	120.639	100.110	.000	.654
BIM Intellectual Property	68.710	8	8.589	7.127	.000	.518
Error	63.869	53	1.205			
Total	375.109	62				
Corrected Total	132.579	61				

a. R Squared = .518 (Adjusted R Squared = .446)

The ANOVA summary indicates that with $p<0.05$, the null hypothesis that variances were equal amongst Intellectual Property Scores was rejected hence means of BIM adoption across the Intellectual Property Scores were different with 52% of the variance of BIM Adoption explained by BIM Demonstration and Training and variance between groups was 7.1 times greater than variances within the groups.

Having established that there was a correlation, a bivariate regression model was generated between the BIM Adoption score and BIM Intellectual Property Score, using the following hypothesis:

- H_o: None of the coefficients in BIM Intellectual Property Score predict BIM Adoption Score
- H_a: Most of the coefficients in BIM Intellectual Property Score predict BIM Adoption Score

Table 4.99: Bivariate Regression Model on BIM Intellectual Property vs BIM Adoption

Coefficients[a]								
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B	
		B	Std. Error	Beta			Lower Bound	Upper Bound
1	(Constant)	1.121	.237		4.72	.000	.647	1.596
	BIM Intellectual Property Score	.511	.105	.533	4.881	.000	.301	.720

a. Dependent Variable: Overall BIM Adoption Score

Source: Author (2019)

As indicated in table 4.99 above, with sig (p) < 0.05, the null hypothesis was rejected, meaning that BIM Intellectual Property Score predicted BIM Adoption with the regression equation as shown below and further articulated using the linear graph in figure 4.12 below.

BIM Adoption Score = 0.511 x BIM Intellectual Property Score + 1.121

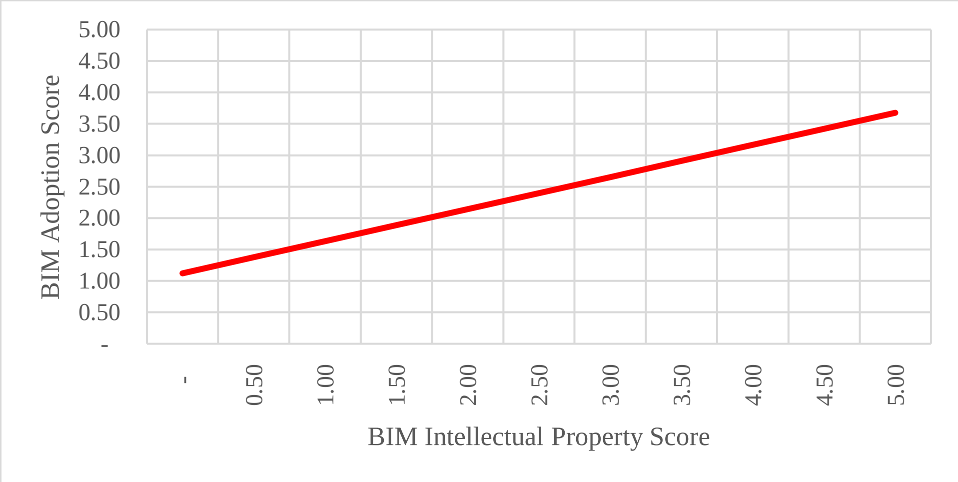


Figure 4.12: Bivariate Graph of BIM Intellectual Property Score vs BIM Adoption Score

Source: Author (2019)

4.3.4.3 Insurance Liability

There was need to investigate the Insurance Liability Cover amongst Building Contractors in Kenya. The null and alternate hypothesis for this stated that:

- H_o – The Insurance Liability Cover by Building Contractors in Kenya is low.
- H_a – The Insurance Liability Cover by Building Contractors in Kenya is not low meaning that either the Insurance Liability Cover by Building Contractors in Kenya is lower than the low score or the Insurance Liability Cover by Building Contractors in Kenya is higher than the low score

BIM Insurance Liability Cover was tested using the averages of the values of Insurance Liability Cover indicators.

BIM Insurance Liability Cover = (Recognition of BIM by insurers + Reduced cost of insurance)/2

The BIM Insurance Liability Cover was scaled from 1(very low Insurance Liability Cover), 2(low Insurance Liability Cover), 3(moderate Insurance Liability Cover), 4(high Insurance Liability Cover) to 5 (very high Insurance Liability Cover). One sample t test was used to check this hypothesis as shown in tables 4.100 and 4.101 below.

Table 4.100: One Sample Statistics for BIM Insurance Liability Cover)

One-Sample Statistics				
	N	Mean	Std. Deviation	Std. Error Mean
BIM Liability Cover Score	62	2.2177	1.99922	.25390

Source: Author (2019

Table 4.101: One Sample *t* Test for BIM Insurance Liability Cover

One-Sample Test						
	Test Value = 2 (Low BIM Insurance Liability Cover)					
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
BIM Liability Cover Score	.858	61	.394	.21774	-.2900	.7254

Source: Author (2019)

$t(61) = 0.858$, $\alpha > .05$. t at 61 degrees of freedom 0.858. The probability that the observed difference between our sample mean and the population mean was due to mere chance rather than to a real difference in achievement is more than 5%.Our survey is not significantly different from the null hypothesis and therefore BIM Liability Cover (M=2.21, SD=2.00) scored is not significantly higher than the low Liability Cover Score (M=2). This study narrowed into the individual indicators to establish their respective levels of score as indicated in tables 4.102 and 4.103 below.

Table 4.102: One Sample Statistics for BIM Insurance Liability Cover Indicators

One-Sample Statistics				
	N	Mean	Std. Deviation	Std. Error Mean
BIM Recognition by insurers	62	2.26	2.048	.260
Reduced indemnity due to using BIM	62	2.18	2.146	.273

Source: Author (2019)

Table 4.103: One Sample t Test for BIM Insurance Liability Cover Indicators

	One-Sample Test					
	Test Value = 2(Low BIM Insurance Liability Cover)					
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the	
					Lower	Upper
BIM Recognition by insurers	.992	61	.325	.258	-.26	.78
Reduced indemnity due to using BIM	.651	61	.518	.177	-.37	.72

Source: Author (2019)

For recognition of BIM by Insurers, $t(61) = 0.992$, $\alpha > .05$ means that the level of BIM recognition by insurers is not significantly different from the null hypothesis that the BIM recognition by insurers is low (M=2), and therefore at (M=2.26, SD=2.05), BIM recognition by insurers is low. For reduced Insurance cost, $t(61) = 0.651$, $\alpha >$ .05 means that the level of reduced Insurance cost is not significantly different from the null hypothesis that the level of reduced Insurance cost is low (M=2), and therefore at (M=2.18, SD=2.15) level of reduced Insurance cost is low.

The study also looked at the correlations between BIM Adoption and BIM Liability Cover amongst Building Contractors as shown in table 4.104 below. Where $p < .05$, correlation was significant, with the extent of correlation varying from weak ($0.2 < r < 0.4$), moderate ($.4 < r < 0.6$) to strong ($0.6 < r$)

Table 4.104: Pearson Correlation between BIM Liability Cover and BIM Adoption

Correlations			
		BIM Liability Cover Score	Overall BIM Adoption Score
BIM Liability Cover Score	Pearson Correlation	1	.184
	Sig. (2-tailed)		.152
	N	62	62
Overall BIM Adoption Score	Pearson Correlation	.184	1
	Sig. (2-tailed)	.152	
	N	62	62

Source: Author (2019)

The results indicated that $p > .05$ showing that these variables were not significantly correlated. The Pearson correlation indicated no correlation between BIM Liability

Cover and BIM Adoption meaning that adoption levels increased was not influenced by increased BIM Liability cover levels within the Building Contractors. Based on this, there was no need of doing the ANOVA test and regression analysis.

4.3.4.4 BIM Risk Tolerance Score Summary.

After looking at all indicators influencing risk tolerance, there was need to study how they influenced the BIM Risk Tolerance Score and how this score related to the BIM Adoption Score. For this, the null and alternate hypothesis stated that:

- H_o – The BIM Risk Tolerance Score for Building Contractors in Kenya is low.
- H_a – The BIM Risk Tolerance Score for Building Contractors in Kenya is not low meaning that either the BIM Risk Tolerance Score for Building Contractors in Kenya is lower than the low score or the BIM Risk Tolerance Score for Building Contractors in Kenya is higher than the low score

BIM Risk Tolerance Score was tested using the averages of the indicators for BIM Risk Tolerance.

BIM Risk Tolerance Score = (BIM Relative Advantage + BIM Intellectual Property Score + BIM Liability Cover Score)/3

The BIM Risk Tolerance Score was scaled from 1(very low BIM Risk Tolerance score), 2(low BIM Risk Tolerance score), 1(moderate BIM Risk Tolerance score), 4(high BIM Risk Tolerance score) to 5 (very high BIM Risk Tolerance score). One sample t test was used was used to check this hypothesis as shown in tables 4.105 and 4.106 below.

Table 4.105: One Sample Statistics for BIM Risk Tolerance Score

One-Sample Statistics				
	N	**Mean**	**Std. Deviation**	**Std. Error Mean**
BIM Risk Tolerance Score	62	2.1056	1.69077	.21473

Source: Author (2019)

Table 4.106: One Sample *t* Test for BIM Risk Tolerance Score

One-Sample Test						
	Test Value = 2(Low BIM Risk Tolerance Score)					
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
BIM Risk Tolerance Score	.492	61	.624	.10565	-.3237	.5350

Source: Author (2019)

$t(61) = 0.492$, $\alpha > .05$. t at 61 degrees of freedom is 0.492. The probability that the observed difference between our sample mean and the population mean was due to mere chance rather than to a real difference in achievement is more than 5%.Our survey is not significantly different from the null hypothesis and therefore BIM Risk Tolerance score (M=2.11, SD=1.69) scored is not significantly higher than the low BIM Risk Tolerance Score (M=2).

4.3.4.5 BIM Risk Tolerance vs BIM Adoption Score.

The study also looked at the correlations between BIM Adoption Score and BIM Risk Tolerance Score amongst Building Contractors as shown in table 4.107 below. Where $p < .05$, correlation was significant, with the extent of correlation varying from weak ($0.2 < r < 0.4$), moderate ($.4 < r < 0.6$) to strong ($0.6 < r$)

Table 4.107: Pearson Correlation between BIM Risk Tolerance Score and BIM Adoption)

Correlations			
		Overall BIM Risk Tolerance Score	Overall BIM Adoption Score
BIM Risk Tolerance Score	Pearson Correlation	1	.305*
	Sig. (2-tailed)		.016
	N	62	62
Overall BIM Adoption Score	Pearson Correlation	.305*	1
	Sig. (2-tailed)	.016	
	N	62	62

*. Correlation is significant at the 0.05 level (2-tailed).

Source: Author (2019)

The results indicated that p<.05 showing that these variables were significantly correlated. The Pearson correlation indicated a weak positive correlation between BIM Risk Tolerance Score and BIM Adoption meaning that adoption levels increased with increased levels of BIM Risk Tolerance within the Building Contractors.

A bivariate regression model was generated between the BIM Adoption score and BIM Risk Tolerance Score, having established that there was a correlation using the following hypothesis:

- H_o: None of the coefficients in BIM Risk Tolerance Score predict BIM Adoption Score
- H_a: Most of the coefficients in BIM Risk Tolerance Score predict BIM Adoption Score

Table 4.108: Bivariate Regression Model on BIM Risk Tolerance Score vs BIM Adoption

Coefficients[a]								
Model		**Unstandardized Coefficients**		**Standardized Coefficients**	**t**	**Sig.**	**95.0% Confidence Interval for B**	
		B	**Std.**	**Beta**			**Lower Bound**	**Upper Bound**
1	(Constant)	1.418	.289		4.913	.000	.840	1.995
	BIM Risk Tolerance Score	.266	.107	.305	2.482	.016	.052	.480

a. Dependent Variable: Overall BIM Adoption Score

Source: Author (2019)

As indicated in table 4.108 above, with sig (p) < 0.05, the null hypothesis was rejected, meaning that BIM Risk Tolerance Score predicted BIM Adoption with the regression equation as shown below and further articulated using the linear graph in figure 4.13 below.

BIM Adoption Score = 0.266 x BIM Risk Tolerance Score + 1.418

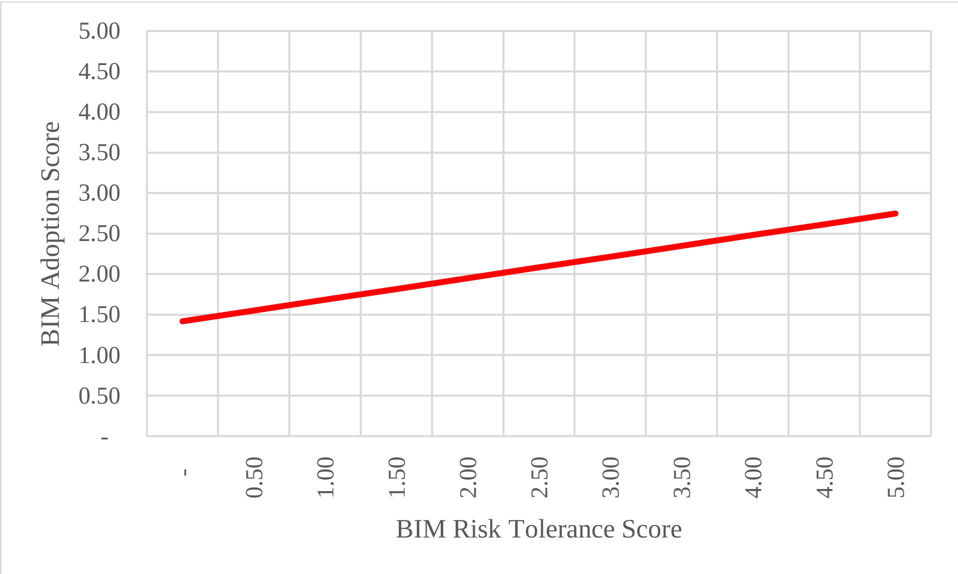


Figure 4.13: Bivariate graph of BIM Trialability Score vs BIM Adoption Score

Source: Author (2019)

To understand the relationship between BIM Adoption and the various indicators under BIM Risk Tolerance, a multivariate regression model was generated between the BIM Adoption score and the various indicators that make up the BIM Essentials Score using the following hypothesis:

- H_o: None of the indicators in BIM Risk Tolerance Score predict BIM Adoption Score
- H_a: Most of the indicators in BIM Risk Tolerance Score predict BIM Adoption Score

As indicated in table 4.109 below, where sig (p) < 0.05, the null hypothesis was rejected, meaning that these specific indicators predicted BIM Adoption with the regression equation as shown below:

BIM Adoption Score = 0.502 x BIM Intellectual Property + 1.279

Table 4.109: Multivariate Regression Model on BIM Risk Tolerance Score vs BIM Adoption

Coefficients[a]								
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B	
		B	Std. Error	Beta			Lower Bound	Upper Bound
1	(Constant)	1.279	.243		5.266	.000	.793	1.766
	BIM Relative Advantage Score	.209	.128	.224	1.633	.108	-.047	.465
	BIM Liability Cover Score	-.106	.118	-.143	-.895	.374	-.342	.131
	BIM Intellectual Property Score	.502	.172	.525	2.927	.005	.159	.846

a. Dependent Variable: Overall BIM Adoption Score

Source: Author (2019)

4.3.5 Factors that Influence BIM Adoption by Building Contractors in Kenya

A primary multivariate regression model was generated between the BIM Adoption score and the three main factors using the following hypothesis:

- H_o: None of the main factors predict BIM Adoption Score
- H_a: Most of the main factors predict BIM Adoption Score

Table 4.110: Multivariate Regression Model on main factors affecting BIM vs BIM Adoption

Coefficients[a]								
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B	
		B	Std. Error	Beta			Lower Bound	Upper Bound
1	(Constant)	.438	.294		1.490	.142	-.150	1.026
	BIM Risk Tolerance Score	.064	.120	.073	.533	.596	-.176	.304
	BIM Maturity Score	-.250	.144	-.253	-1.731	.089	-.539	.039
	BIM Essentials Score	.989	.157	.771	6.304	.000	.675	1.303

a. Dependent Variable: Overall BIM Adoption Score

Source: Author (2019)

As indicated in table 4.110 above, where sig $(p)<0.05$, the null hypothesis was rejected, meaning that these specific factors predicted BIM Adoption with the regression equation as shown below:

BIM Adoption Score = 0.989 x BIM Essentials Score + 0.438

A secondary multivariate regression model was generated between the BIM Adoption score and the respective factors within the three main factors using the following hypothesis:

- H_o: None of the factors predict BIM Adoption Score
- H_a: Most of the factors predict BIM Adoption Score

As indicated in table 4.111 below, where sig (p)<0.05, the null hypothesis was rejected, meaning that these specific factors predicted BIM Adoption with the regression equation as shown below:

BIM Adoption Score = 0.592 x BIM Trialability Score - 0.442 x BIM Availability Score + 0.703 x BIM Observability Score + 0.365 x BIM Intellectual Property Score + 1.438.

Table 4.111: Multivariate Regression Model on secondary factors affecting BIM vs BIM Adoption

Coefficients[a]								
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B	
		B	Std. Error	Beta			Lower Bound	Upper Bound
1	(Constant)	1.438	.280		5.130	.000	.875	2.001
	Overall BIM Trialability	.592	.169	.496	3.496	.001	.252	.932
	Overall BIM Availability Score	-.442	.120	-.480	-3.675	.001	-.684	-.200
	Overall BIM Observability Score	.703	.135	.738	5.206	.000	.431	.974
	Overall BIM Social Organisation Score	.046	.142	.049	.322	.749	-.240	.332
	Overall BIM Simplicity Score	-.538	.320	-.625	-1.683	.099	-1.180	.104
	Overall BIM Interoperability Score	.469	.305	.568	1.539	.130	-.143	1.082
	Overall BIM Demonstration and Training Score	-.360	.227	-.407	-1.588	.119	-.816	.095
	Overall BIM Government Policy Score	-.133	.126	-.149	-1.061	.294	-.385	.119
	BIM Relative Advantage Score	.124	.124	.132	.998	.323	-.125	.372
	BIM Liability Cover Score	.004	.119	.005	.034	.973	-.235	.243
	BIM Intellectual Property Score	.365	.161	.381	2.264	.028	.041	.689

a. Dependent Variable: Overall BIM Adoption Score

Source: Author (2019)

Figure 4.14 below summarises these performance trends of key indicators with regards to BIM adoption amongst Building Contractors in Kenya. Overall BIM adoption level amongst Building Contractors was low. With regards to usage of various capabilities, usage of 2D, 3D and 5D were low towards moderate, usage of 4D was low while use of SAM and MEPAM was very low. Owing to the sensitive nature of costs during construction, the contractor does a lot of 5D related activities. During the bid stage, the contractor engages like filling in Bills of Quantities while during construction, the contractor prepares valuations for payment and generates schedules and costs of variation. These 5D related activities can only be done if the contractor has some basic knowledge in handling various 2D and 3D capabilities. With regards to simplicity of various capabilities, all capabilities were considered moderately complex to complex. This inferred that all these BIM capabilities are regarded as difficult to understand which may be as a result of low or no training of these capabilities during the studying phase of the workers. With regards to interoperability of various tools and capabilities, all indicators showed a low level of interoperability. This inferred that most Building Contractors were working alone, using standalone BIM tools.

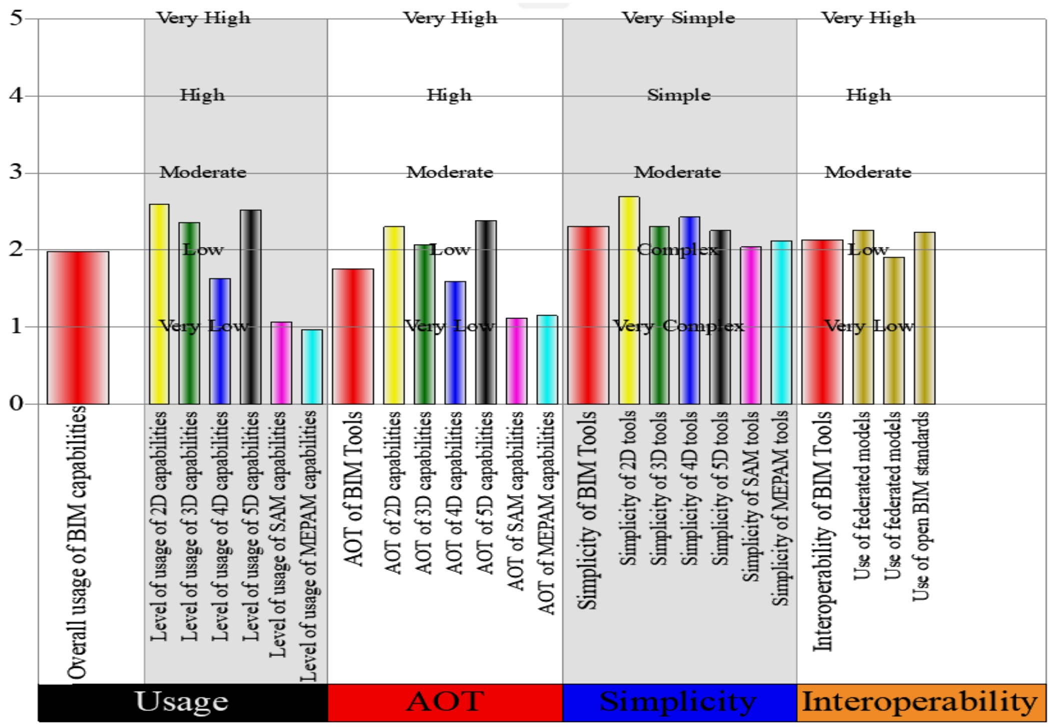


Figure 4.14: Performance Levels of Various Factors And Variables

Source: Author (2019)

4.4 Summary of BIM Adoption by Building Contractors in Kenya

Compared to global standards, the level of BIM adoption by Building Contractors in Kenya is low at 39.6% as established by this study, compared to 79% in USA by 2013 (McGraw Hill Construction, 2014) and 67% in UK by 2016 (Waterhouse & Philp, 2016). This study looked in detail at the research questions, comparing patterns in Kenya with USA and UK and corroborating information extracted from interviewing representatives of organizations that are stakeholders in the construction Industry.

4.4.1 Level of BIM Adoption amongst Building Contractors in Kenya.

The overall level of BIM Adoption is low. When this is narrowed down to individual BIM capabilities, levels of adoption vary. Adoption of 2DCAD, 3DBIM and 5DBIM tools was higher at 51.6%, 47.1% and 50.3% respectively compared to 4DBIM, SAM-BIM and MEPAM-BIM tools whose adoption levels were 32.6%, 21.3% and 19.4% respectively. This is attributed to the Design-Bid-Build being the predominant Construction Delivery Method in Kenya. This method results into specialisation of each group broadly creating the design team led by Construction Project Manager or Architect and the construction team led by Building Contractors. The mandate of the Building Contractor in this context is to implement designs through construction and is therefore not involved in the design process. As a result, Building Contractors would concentrate on their scope which includes controlling and documenting construction cost for any variations or deviations. This is done using 5DBIM tools hence the higher level of adoption. Besides costing, Building Contractors from time to time asked for shop drawings for specialised works before they are approved by the design team for implantation. These shop drawings are done using 2DCAD tools and when 3D documentation is needed, then 3DBIM tools are used. The low adoption of 4DBIM tools points to aspects of time in the Iron Triangle being neglected.

From the analysis, the relationship between BIM Adoption and the four independent variables gave various inferences. With regards to age, younger Building Contractors adopted BIM more than older Building Contractors. According to BIM resellers, this is attributed to higher exposure to BIM Educational training for younger members since the BIM curricula were integrated into university programmes less than 15 years ago and at the same time, the country lacks a strong professional training of BIM through specialised CPDs for Building Contractors. With regards to years of practice, years of using BIM and number of projects using BIM, BIM adoption reduced with increase of these variables indicating that practitioners were not getting Relative Advantage of using BIM as they continued practicing. According to NCA, this is attributed to lack of a legal framework on BIM usage compounded with the low client demand for BIM. As a result, Building Contractors are not able to offset costs incurred in implementing BIM hence no motivation to continue using BIM. From the multivariate regression analysis of these 4 variables, years of practice stood out as a negative influencer of BIM adoption, while the other variables were not strong enough to influence BIM adoption.

4.4.2 Relationship between BIM Essentials and BIM Adoption.

The success of BIM Essentials with regards to influencing BIM adoption is influenced by the success of Availability, Observability and Trialability of the BIM tools and the BIM Social organisation. Availability of BIM tools amongst Building Contractors was low at 46%. This indicated that either Building Contractors are not aware about the BIM tools or do not know how to get them. When this is narrowed down to individual BIM availability, levels of availability varied. Availability of 2DCAD, 3DBIM and 5DBIM tools was higher at 53.6%, 50.3% and 58.8% respectively compared to 4DBIM, SAM-BIM and MEPAM-BIM tools whose availability levels were 47.7%, 26.5% and 31.0% respectively. Observability of BIM tools amongst Building Contractors was low at 29.4%. This indicated that either Building Contractors were not interested to observe these BIM tools hence would ignore opportunities like unveiling of new BIM tools or organised specialised seminars, or an opportunity to observe did not exist in the first place. When this is narrowed down to individual BIM observability, the levels varied. Observability of 2DCAD, 3DBIM and 5DBIM tools was higher at 36.1%, 32.9% and 40.0% respectively compared to 4DBIM, SAM-BIM and MEPAM-BIM tools whose observability levels were 18.7%, 21.6% and 19.7% respectively. Trialability of BIM tools amongst Building Contractors was low at 35.1%. This indicated that Building Contractors did not know how to access these BIM tools for trial purposes before deciding on adoption. When this is narrowed down to individual BIM trialability, the levels varied. Trialability of 2DCAD, 3DBIM and 5DBIM tools was higher at 48.0%, 40.9% and 44.0% respectively compared to 4DBIM, SAM-BIM and MEPAM-BIM tools whose trialability levels were 23.0%, 19.4% and 18.3% respectively.

According to BIM resellers, AOT of BIM tools is low because some practitioners are not using genuine licences hence lack of interest in attending seminars where BIM tools are showcased. As a result, the resellers saw no need of investing so much in professional training since most Building Contractors were giving these training a wide berth as there are not embedded on the CPD trainings by NCA therefore creating a vicious cycle leading to low AOT of BIM. NCA and KABCEC acknowledged this but attributed it to high costs of these BIM licences, compounded by the lack of a client demand because there was no proper framework of implementing BIM in Kenya making Building Contractors not interested since they are not getting value for time and money. The trend of 2DCAD, 3DBIM and 5DBIM tools performing better compared to 4DBIM, SAM-BIM and MEPAM-BIM tools in all aspects of AOT of BIM is attributed to the CDM used in Kenya as explained in 4.4.1 above. With regards to BIM Social Organisation, high levels of peer pressure to use BIM amongst Building Contractors, coupled with the high level of ICT skills amongst Building Contractors creates an enabling environment that encouraged BIM adoption. However, low influence of statutory bodies and professional organisations, and there being no outstanding BIM opinion leaders and social shapers amongst Building Contractors inhibited BIM adoption

From the multivariate regression analysis of these four variables, BIM observability and BIM trialability stood out as positive influencers of BIM adoption, BIM Availability stood out as a negative influencer of BIM Adoption, while BIM Social Organisation was not strong enough to influence BIM adoption. According to BIM resellers, the negative influence is due to availability of illegal BIM licences while for KABCEC, the high cost of BIM licences was causing this negative influence. NCA and KABCEC acknowledged a lack of a strong BIM social Organisation amongst Building Contractors to influence BIM adoption due to lack of a proper legal BIM framework.

4.4.3 Relationship between BIM Maturity and BIM Adoption.

The success of BIM Maturity with regards to influencing BIM adoption is influenced by the Simplicity and Interoperability of BIM tools, Demonstration and Training of BIM and Government Policies on BIM. Simplicity of BIM tools amongst Building Contractors was moderate with BIM tools frequently used, that is 2DCAD, 3DBIM and 5DBIM tools being perceived as simpler to use compared to 4DBIM, SAM-BIM and MEPAM-BIM.

Interoperability of BIM Tools amongst Building Contractors was moderate though generation of native models seemed to be a difficult task for Building Contractors. According to KABCEC and NCA, there were three causes to this. The Design-Bid-Build form of Construction Delivery Method predominantly used in Kenya resulted into the Building Contractor not being an information generator, making it difficult for Building Contractors to generate these BIM models to the levels of accuracy required. With modelling not being their core scope, it becomes a major cost should a Building Contractor decide to do the modelling alone after getting the 2D documents and drawings from the design actors since in the current Bills of Quantities, cost of Building Information Modelling is not catered for. Since there is no proper framework that regulates copyrights and insurance with regards to BIM in Kenya, design actors are not comfortable sharing detailed Building Information models with bidders and Building Contractors since they may be misused. This compels the Building Contractors to do model by themselves.

BIM Demonstration and Training on BIM is low amongst Building Contractors in Kenya. According to BIM Resellers, this is because the critical mass needed to mount these activities without incurring major losses has not yet been achieved. According to NCA, mainstreaming of BIM training at both the educational and professional levels is still not possible since there was no clear government policies, mandates and BIM legal framework that would compel stakeholders to do demonstration and training. For KABCEC, the bottom line is the expensive BIM licences that make ownership of licences a nightmare hence training still being a dream rather than a reality

From the multivariate regression analysis of these four variables, BIM Simplicity stood out as a positive influencer of BIM adoption, BIM Interoperability stood out as a negative influencer of BIM Adoption, while BIM Demonstration and Training and Government Policies were not strong enough to influence BIM adoption. According to KABCEC, the negative influence is due to the inability of design actors to freely share native models to assist Building Contractors create federated models due to the reasons discussed above. The lack of influence is due to lack of clear government policies and guidelines on issues relating to BIM besides BIM resellers being overwhelmed to independently run BIM Demonstration and Training without the government intervention.

4.4.4 The Success of Relationship between BIM Risk Tolerance and BIM Adoption

BIM Risk Tolerance with regards to influencing BIM adoption is influenced by Relative Advantage, Intellectual Property and Liability Cover. With regards to Relative Advantage, according to the analysis, there is no doubt that BIM has brought a lot of benefit to the Building Contractor especially on issues of cost management. At the same time, the Building Contractors experiences challenges when using these BIM tools, with the outstanding ones being cost of BIM licences and low client demand. Intellectual Property is low amongst Building Contractors which is manifested by high usage of illegal BIM licences according to the BIM Resellers and low sharing of native models by design actors. According to the analysis, though Building Contractors claim to have a favourable insurance regime due to BIM usage, the local insurance industry does not know about the existence of BIM in the Construction Industry

From the multivariate regression analysis of these three variables, BIM Intellectual Property stood out as a positive influencer of BIM adoption while BIM Relative Advantage and Liability Cover were not strong enough to influence BIM adoption. According to KABCEC, the lack of influence due to the exorbitant BIM licences which eliminates all benefit accrued from using BIM Tools. With regards to liability cover, there is no existing insurance policy that is pegged on use of BIM hence it not being an influence whatsoever to BIM adoption

4.4.5 Relationship between BIM Essentials, BIM Maturity, BIM Risk Tolerance and BIM Adoption.

From the multivariate regression analysis of these three variables, BIM Essentials stood out as a positive influencer of BIM adoption while BIM Maturity and BIM Risk Tolerance were not strong enough to influence BIM adoption. This infers that BIM amongst Building Contractors in Kenya is still at a low level in terms of development, maturity, and use. Positive influence of BIM Essentials indicates there is strong individual efforts amongst Building Contractors, BIM Innovators, and resellers to advance the cause of BIM while other major stakeholders like the government, statutory bodies, professional organisations, copyright bodies and insurers are yet to fully embrace BIM. This research demonstrates that there is a gap with regards to BIM macro-adoption which affect BIM micro-adoption amongst the Building Contractors. Creation of a BIM mandate by the National Government will in turn improve government involvement on BIM through mandates, regulations, policies, funding, and creation of special taskforces thereby improving the environment for BIM macro-adoption, which in turn positively improves BIM adoption by Building Contractors.

4.5 Comparative Analysis of Kenya and Other Global Actors on BIM.

Table 4.112 below compares the performance of the factors in influencing BIM usage in USA, UK and Kenya. It goes further to highlight localised variables that act as catalysts or barriers towards BIM usage. This study concludes by noting that several localised variables influence BIM usage, and these variables do not necessarily behave the same from country to country. As a result, researchers and policy makers need to identify these localised variables especially ones that act as barriers to come up with policies that thaw them up.

Table 4.112: Comparative Analysis

	Correlation	Aspects	USA	UK	Kenya
1	Status of BIM usage		High	High	Low
2	AOT in BIM vs BIM usage	Type of correlation	Positive	Positive	Strong Positive
		Status of AOT	High	High	Low
		Enablers of AOT	IPD method. Economies of Scale	Opportunity to understudy USA. Availability of National Standards Presence of UK BIM framework Collaboration between public and private entities	Availability of trial licences. Availability of student licences. Improved demonstrations through webinars Collaboration between public and private entities

	Correlation	Aspects	USA	UK	Kenya
		Barriers towards AOT	Lack of National Standards. Being a pioneer user	Infrequent webinars. Lack of professional training. Low software training during undergraduate studies	High software costs. Lack of National standards. Lack of localised BIM templates. Low government involvement. No specialised educational bootcamps. Lack of specialised CPD training.
3	Simplicity in BIM vs BIM usage	Type of correlation	No information available	No information available	Weak positive
		Status of Simplicity	N/A	N/A	Low
		Enablers of Simplicity	N/A	N/A	High level of ICT skills
		Barriers towards Simplicity	N/A	N/A	Infrequent BIM training Perceived complexity of BIM tools
4	Relative Advantage in BIM vs BIM usage	Type of correlation	Positive	Positive	Moderate positive
		Status of RA	High	High	Low
		Enablers of RA	IPD method. Economies of Scale	Economies of Scale for large companies	Reduced operation costs. Improved productivity. Reduced request for information. Improved process of change management. Improved coordination, and collaboration. Reduced errors, omissions, and reworks.
		Barriers towards RA		High software cost. Low accrued benefits. Low client demand	High indemnity despite reduced risks. Cost of frequent upgrading software. High cost of retraining staff Low client demand

	Correlation	Aspects	USA	UK	Kenya
5	Interoperability in BIM vs BIM usage	Type of correlation	No correlation	Positive	No correlation
		Status of Interoperability	Low	High	Low
		Enablers of Interoperability		National templates and standards. Emphasis of Common Data Environment. Creation of specific interoperable formats like COBie, IFC, uniclass, NBS Chorus and NBS Source. Improved cloud technologies	
		Barriers towards Interoperability	Emphasis on company standards, not national standards.	Enhancement and use of individual company standards	Discomfort by design actors to share their models. DBB nature of construction delivery. Lack of government policies on CDE. Lack of localised templates. Lack of clear policies on copyrights

Source: Author (2019)

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS.

5.1 Introduction

This study gave us an opportunity to understand the correct status of BIM adoption amongst Building Contractors in Kenya. Few studies have been done on BIM Adoption in Kenya, with the only notable one being BIM adoption amongst Construction Project Managers (Mumbua, 2016). This study therefore becomes a building block towards the study of BIM adoption amongst various actors in the Kenyan Construction Industry. This study sought to establish the main factor that influence BIM Adoption at a micro-level, that is for a Building Contractor. This has created a basis for replication of the same research on various design actors in Kenya, namely Planners, Architects, Interior Designers, Landscape Architects, Quantity Surveyors, Civil Structural Engineers, Building Service Engineers, Mechanical Subcontractor and Electrical Subcontractors with an aim of understanding their respective BIM Adoption levels.

5.2 Theoretical Implications

This study was underpinned on two theories namely Theory of Diffusion and Hype Cycle Theory of Technology Adoption. This study has shown that the process of adopting new technologies, regardless of the type of innovation, follows a specific pattern. This study has identified four main factors that are enablers of innovation, namely hype, time, communication channels and social system. Innovation as used in this study is the result of continuous desire to improve qualities of current technologies in a bid to make them easier to use and have a higher relative advantage. A successful innovation results into higher levels of adoption. At the same time, higher levels of adoption results into frequent feedback to the innovators thus resulting into highly improved innovations. These two aspects create a viscious cycle of sustaining innovation. Hype as used in this study is the typical progression of an emerging technology from over-enthusiasm, through disillusionment to eventual understanding of the technology. Hype can be generated at a micro level through peer pressure in a social organisation or at a macro level through demonstration and training. Therefore, the level of success in terms of innovation influences the extent of hype, which also influences the form of diffusion, whether natural or intervened.

5.3 Methodological Implications

Owing to the sensitive nature of the construction industry due to lack of clear framework, methodologies, and jurisdictions of various institutions during site inspections, performance of data collection especially on active sites is normally affected. Apathy of Building Contractors towards strangers on active construction sites make it difficult to have an interaction with these Building Contractors thereby making data collection difficult. A researcher therefore must develop tools and techniques that would minimise this apathy in a bid to improve the response rate by respondents. One way of achieving this is by avoiding direct sensitive questions that would discourage interaction of Building Contractors when collecting data.

Owing to the lower levels of exposure to BIM by Building Contractors, they tend to misinterpret questions asked in the questionnaires. This is a methodological problem experienced by most BIM researchers since the measurable degree of perception towards certain facets of BIM can be easily misinterpreted in environments where several practitioners have not been exposed to BIM. The research fraternity needs to come up with a system of synchronising data collection with the CPD's for Building Contractors that are normally organised by the NCA. These opportunities would give the researcher a chance to quickly explain the questions before respondents give their feedback. For this to thrive, online surveys need to be encouraged and embraced by both the researchers and Building Contractors

5.4 General Conclusion

This study focused on BIM Adoption amongst Building Contractors in Kenya. Through this study, it can be concluded that BIM Adoption level is low amongst Building Contractors in Kenya. This has been occasioned by micro factors generated by the Building Contractors and the macro factors generated by other stakeholders other than the Building Contractors. Licensing system of BIM tools in Kenya comes out as a major inhibitor of BIM Adoption amongst Building Contractors since these licenses are expensive compared to a low client demand for these BIM Tools. Low or no government involvement in terms of mandates, regulations and funding also results into low BIM adoption amongst Buildings Contractors. Compared to other jurisdictions like UK and USA, adoption might not fully take off in Kenya unless the government makes deliberate interventions, decisions, and policies regarding BIM.

5.5 Recommendations

This study has identified several gaps within the BIM ecosystem of Building Contractor in Kenya and makes recommendations that would improve BIM adoption. BIM thrives where there is proper collaboration amongst all disciplines. To achieve this, laws on copyrights need to be enforced to enable design actors comfortably share BIM models with Building Contractors. This can be well achieved through the creation of a BIM mandate by the National Government which creates the necessary legal framework for BIM adoption to thrive.

There is need to have a comprehensive National BIM Training guide that would help in improving BIM skills and knowledge for all stakeholders in the construction industry. This training guide needs to incorporate educational BIM training and professional BIM training. Educational BIM training would involve generating a consistent BIM curriculum to be used by all Universities and TVET institutions in Kenya. The curriculum should lay emphasis on interoperability and use of open BIM to enable complete training regardless of the BIM tool used. The training system should have a certification system that synchronises itself with the Competence Based Education and Training being currently rolled out by CDACC so that the certification clearly shows the capability of the holder with regards to the various BIM capabilities.

There is need for BIM innovators and resellers to rethink their licensing models to enhance BIM Adoption. Perpetual licences tend to be too expensive for ordinary Building Contractors to comfortably pay. Since they know the benefits of these BIM tools, many of them resort to using counterfeit BIM tools. This makes it difficult to operate within a legal framework. Most software developers are moving away from perpetual licences to pay as you use, daily, weekly, monthly, or annual licences like the office 365 by Microsoft which would substantially reduce use of counterfeit BIM licences. Improving licencing method shall result into higher availability, observability and trialability of these BIM tools which eventually improves BIM adoption. There is need for the government of enforce respect of copyrights. This will reduce the use of counterfeit tools thus encouraging BIM innovators and resellers to improve their availability thereby improving observability and trialability of BIM tools. This will also encourage design actors to comfortably share their BIM files for federation.

5.6 BIM Implementation Framework

Based on the recommendations above, this study proposes a cross-disciplinary BIM Implementation Framework that will enhance BIM Adoption in Kenya as shown in the figure 5.1 below.

To improve the government's role in BIM adoption and as shown in the implementation framework in figure 18 below, this study recommends that all BIM related stakeholders - Professional organisations, statutory bodies, educational institutions and BIM resellers representing BIM Innovators - lobby for specific legislation created through statutory instruments conforming with various parent laws like Architect and Quantity Surveyors Act 525, Board of Engineer's Act 2011, National Construction Act 2011 to create a BIM law that gives the government mandate in guiding BIM growth in Kenya. The law shall create a legally recognised body – the BIM Implementation Board of Kenya (BIMIBK) – drawing membership from all the stakeholder to guide all issues involving BIM. The mandate of this body shall be secondary to the mandates of BORAQS, EBK and NCA which manages Building Contractors in Kenya and therefore BIMIBK shall act as a vessel to enable all stakeholders have a common place to discuss issues of BIM, generate and implement budgets relating to BIM implementation in the country, create secondary legislation to enhance enforcement of specific and strategic BIM policies and create specific taskgroups or committees to achieve specific deliverables like BIM licencing, BIM training and BIM virtual depository.

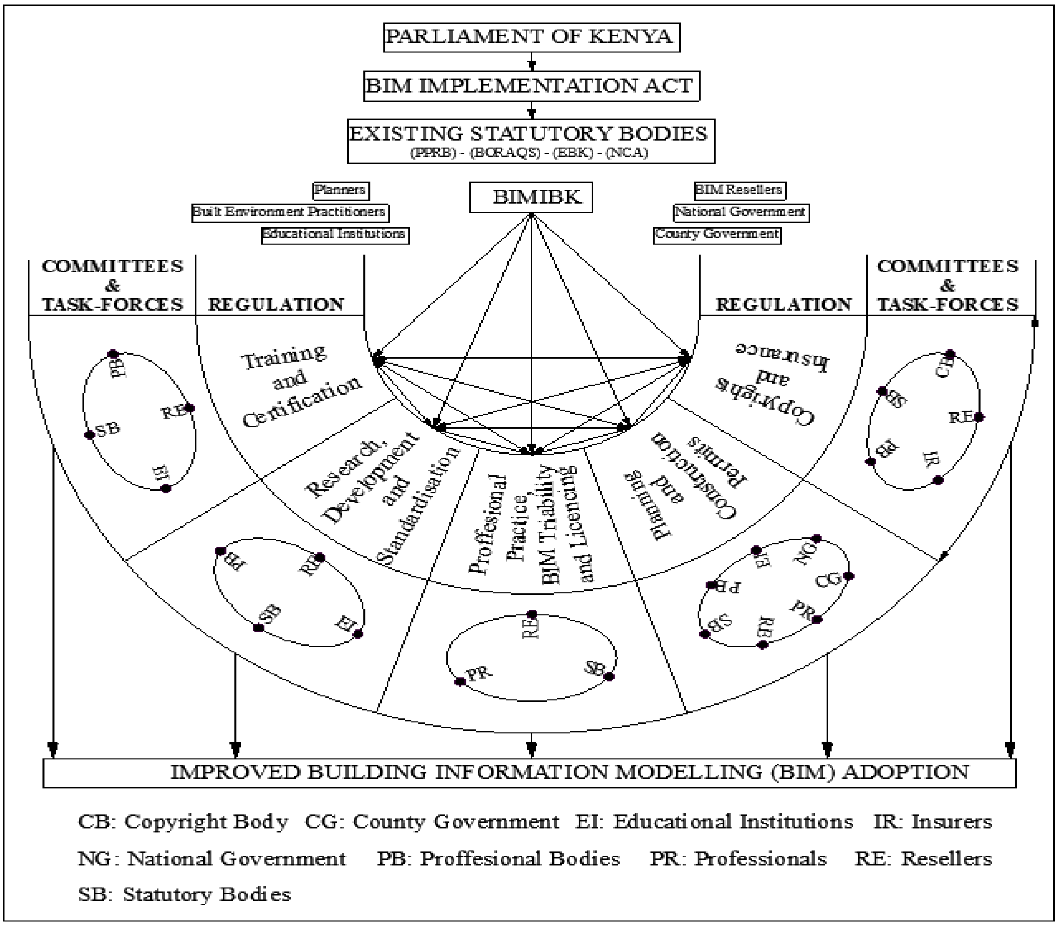


Figure 5.1: Proposed BIM Implementation Framework.

Source: Author (2019).

To improve the BIM licensing structure and as shown in the implementation framework in figure 30 above, this study recommends the creation of the BIM Professional practise, BIM Trialability and Licensing tripartite committee between the statutory bodies, BIM resellers and professional bodies with an aim of negotiating a better licencing structure and system that will be beneficial to both BIM resellers and other actors including Building Contractors in the Kenyan Construction Industry. To improve issues of training and certification and as shown in the Implementation framework in figure 30 above, this study recommends the creation of the BIM Training and Certification quadripartite committee between the statutory bodies, professional organisations, BIM resellers and educational institutions with an aim of collaborating with CUE, TVETA and CDACC to reconcile and rationalise course outlines of all BIM related units taught in all educational institutions in Kenya, generating rules for the minimum infrastructural requirements for educational BIM laboratory facilities for them to be able to run BIM related units, organising focussed continuous professional development training which accumulate CPD points for the professionals including Building Contractors, maintaining a publicly accessed register of all institutions licensed to offer BIM training, giving exemptions to educational institutions with diploma and undergraduate programmes that train in a manner that matches capability certification from BIMIBK and maintaining a publicly accessed register of all professionals with certification on specific BIM capabilities.

To improve and localise research and development on issues of BIM within the Kenyan Construction Industry and as shown in the implementation framework in figure 30 above, this study recommends the creation of a BIM Research and Development quadripartite committee between the statutory bodies , professional organisations, BIM resellers and educational Institutions with an aim of generating, maintaining and frequently improving training guides and codes, generating local BIM standard templates and data formats that are compatible with international standards, creating and maintaining a virtual depository for all BIM based application for planning and construction permits, ensuring that BIM files are embedded on virtual maps like google earth and zoom.earth to ensure that the national government, county governments and all other relevant stakeholders have access to these meta BIM models and data for planning and resource management.

To improve the legal and insurance environment to improve uptake of BIM and as shown in the implementation framework in figure 18 above, this study recommends creation of the BIM Legal and Insurance multipartite committee between the statutory bodies, professional bodies, BIM resellers, Insurers and Copyright Board with an aim of assisting professional bodies to update their respective contract documents to recognise BIM files and models as instruments of contract, assisting county governments to update all construction permit related laws to make it compulsory to submit BIM models based on BIMIBK templates for submission and approval, assisting the insurance industry to come up with a risk calculation tool for professionals in the built industry which include the Building Contractors, that uses ownership of legitimate BIM licences, BIM certification and BIM experience as a basis of reducing cost of Indemnity for professionals who conform to these requirements. To improve the submission of construction permits using BIM to improve uptake of BIM and as shown in the implementation framework in figure 18 above, this study recommends the creation of the Planning and BIM multipartite committee that consist of all relevant stakeholders like national government, county governments, statutory bodies and professional organisations with an aim of assisting county governments to build capacity on issues regarding to submission and approval of construction permits using BIMIBK sanctioned templates and files.

5.7 Areas for Further Research

This study gives a basis for further research on the various aspects of BIM, for example BIM Licensing, Government Policies on BIM, BIM Training, BIM Copyright Management and BIM Insurance Management.

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APPENDICES

Appendix I: Questionnaire

Dear Respondent.

My name is Architect Joel Odhiambo Oyuga, and I am a graduate student at Jomo Kenyatta University of Agriculture and Technology (JKUAT), Department of Construction Management. For my research, I am examining the level of adoption of Building Information Modelling (BIM) by Building Contractors within the Kenyan Construction Industry. Because you are a one of them, I am inviting you to participate in this research by completing the attached questionnaire.

The attached questionnaire will take you approximately 40 minutes to complete. There is no compensation for responding, neither is there any risk exposure. To ensure confidentiality, please do not write your name or that of the company. If you choose to participate in this exercise, kindly answer all questions as honestly as possible. The person named ___________________________________of ID number __________________ who dropped the questionnaire to you is assisting me handle this exercise. The said person shall pass by after 7 days to collect the filled-up questionnaire. Participation is strictly voluntary.

The attached questionnaire has 4 sections. The first section is general information on demographics. The second section has specific questions about BIM Essentials. The third section has specific questions about BIM Maturity. The fourth section asks for your general views about adoption of BIM by Building Contractors in Kenya. In all the sections, kindly ignore the boxes or cells that have been blanked off.

Thank you for taking your time to assist me in my research endeavour. The data collected shall provide useful insights with regards to BIM adoption by Building Contractors in Kenya. Should you require any clarification or additional information, do not hesitate to contact me using the information given below.

Yours sincerely,

Arch Joel Odhiambo Oyuga,

SECTION 1.

General Information on demographics for Building Contractors. Tick one box only for each row.

1	Age	21-25	26-30	31-35	36-40	41-45	46-50	51-55	56-60	Above 60
2	Years of practice after Under-graduate Studies	0-5	6-10	11-15	16-20	21-25	26-30	31-35	36-40	Above 40
3	Years of using Building Information Modelling (BIM) in your practise	0-2	3-4	5-6	7-8	9-10	11-12	13-14	15-16	Above 16
4	Number of projects that you have handled using BIM	0-5	6-10	11-15	16-20	21-25	26-30	31-35	36-40	Above 40

SECTION 2.

Tick one box only for each row. Ignore the shaded boxes

Objective: To establish the level of BIM Essentials by Building Contractors actors in the Kenyan Industry.

BIM Trialability							
A	Based on my experience, this is the level of your preference of use for the following BIM Tools	I do not use	1 (Least preferable)	2	3	4	5 (Most Preferable)
	a. Archicad.						
	b. Autocad.						
	c. Blue Beam.						
	d. Cost X.						
	e. MEP Modeller.						
	f. MS Project.						
	g. Primavera						
	h. Prokon						
	i. Revit						
	j. SAP						
	k. Sketchup						
	l. WinQs						
	Other 1(write the name)						
	Other 2(write the name)						
	Other 3(write the name)						

B	Trial Versions for these BIM tools are readily available for us to explore and decide on use.	I do not know	I strongly disagree	I disagree	I am undecided	I agree	I strongly agree
	a. Archicad.		1	2	3	4	5
	b. Autocad.		1	2	3	4	5
	c. Blue Beam.		1	2	3	4	5
	d. Cost X.		1	2	3	4	5

	e. MEP Modeller.		1	2	3	4	5
	f. MS Project.		1	2	3	4	5
	g. Primavera		1	2	3	4	5
	h. Prokon		1	2	3	4	5
	i. Revit		1	2	3	4	5
	j. SAP		1	2	3	4	5
	k. Sketchup		1	2	3	4	5
	l. WinQs		1	2	3	4	5
	Other 1(write the name)		1	2	3	4	5
	Other 2(write the name)		1	2	3	4	5
	Other 3(write the name)		1	2	3	4	5

C	Trial periods for the trial versions are long enough for me to explore and decide on use.	I do not know	I strongly disagree	I disagree	I am undecided	I agree	I strongly agree
	a. Archicad.		1	2	3	4	5
	b. Autocad.		1	2	3	4	5
	c. Blue Beam.		1	2	3	4	5
	d. Cost X.		1	2	3	4	5
	e. MEP Modeller.		1	2	3	4	5
	f. MS Project.		1	2	3	4	5
	g. Primavera		1	2	3	4	5
	h. Prokon		1	2	3	4	5
	i. Revit		1	2	3	4	5
	j. SAP		1	2	3	4	5
	k. Sketchup		1	2	3	4	5
	l. WinQs		1	2	3	4	5
	Other 1(write the name)		1	2	3	4	5
	Other 2(write the name)		1	2	3	4	5
	Other 3(write the name)		1	2	3	4	5

D	During my graduate studies, Student Licences for the following BIM tools were readily available to us for exploration and use.	I do not know	I strongly disagree	I disagree	I am undecided	I agree	I strongly agree

	a. Archicad.		1	2	3	4	5
	b. Autocad.		1	2	3	4	5
	c. Blue Beam.		1	2	3	4	5
	d. Cost X.		1	2	3	4	5
	e. MEP Modeller.		1	2	3	4	5
	f. MS Project.		1	2	3	4	5
	g. Primavera		1	2	3	4	5
	h. Prokon		1	2	3	4	5
	i. Revit		1	2	3	4	5
	j. SAP		1	2	3	4	5
	k. Sketchup		1	2	3	4	5
	l. WinQs		1	2	3	4	5
	Other 1(write the name)		1	2	3	4	5
	Other 2(write the name)		1	2	3	4	5
	Other 3(write the name)		1	2	3	4	5

BIM Observability							
A	Focused continuous training by BIM innovators and resellers of the following BIM tools especially during launches of new versions or upgrades are readily available and frequently done	I do not use	1 (Least preferable)	2	3	4	5 (Most Preferable)
	a. Archicad.						
	b. Autocad.						
	c. Blue Beam.						
	d. Cost X.						
	e. MEP Modeller.						
	f. MS Project.						
	g. Primavera						
	h. Prokon						
	i. Revit						
	j. SAP						
	k. Sketchup						
	l. WinQs						
	Other 1(write the name)						
	Other 2(write the name)						
	Other 3(write the name)						

BIM Availability					
A	The following BIM Tools are readily availed to me through this method	I download and purchase a key	A DVD is shipped to me after purchase	A reseller installs for me the software after	Any other method (explain)
	a. Archicad.				
	b. Autocad.				
	c. Blue Beam.				
	d. Cost X.				
	e. MEP Modeller.				
	f. MS Project.				
	g. Primavera				
	h. Prokon				
	i. Revit				
	j. SAP				
	k. Sketchup				
	l. WinQs				
	Other 1(write the name)				
	Other 2(write the name)				
	Other 3(write the name)				

Social Organisation								
A	New BIM related information frequently is disseminated to me through:	**Subscribed emails**	**Facebook posts**	**Linked In Posts**	**Twitter Posts**	**Continuous Professional Development Training**	**BIM website**	**Any other method (Please State)**
	a. Archicad.							
	b. Autocad.							
	c. Blue Beam.							
	d. Cost X.							
	e. MEP Modeller.							
	f. MS Project.							
	g. Primavera							
	h. Prokon							
	i. Revit							

	j. SAP							
	k. Sketchup							
	l. WinQs							
	Other 1(write the name)							
	Other 2(write the name)							
	Other 3(write the name)							

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		I strongly disagree	I disagree	I am undecided	I agree	I strongly agree
B	There exists a strong BIM social system within the practitioners in the Kenyan construction industry that	1	2	3	4	5
C	The statutory bodies and professional organisations within the construction industry are very instrumental	1	2	3	4	5
D	There is a strong presence of BIM opinion leaders in the construction industry, leaders that guide and	1	2	3	4	5
E	There is a strong presence of peer pressure amongst practitioners within the BIM social system that	1	2	3	4	5
F	The level of ICT skills for the practitioners is high thus creating an enabling environment for BIM adoption	1	2	3	4	5

SECTION 3.

Tick one box only for each row. Ignore the shaded boxes

Objective: To establish the level of BIM Maturity amongst Building Contractors in the Kenyan Industry.

Government Policies						
		I strongly disagree	**I disagree**	**I am undecided**	**I agree**	**I strongly agree**
A	There is a strong presence of government mandate and regulation on BIM in the Kenyan construction industry.	1	2	3	4	5
B	There is a strong presence of government funding on BIM in the Kenyan construction industry.	1	2	3	4	5
C	There is a strong presence of the following specific government policies on BIM in the Kenyan construction					
	a Interoperability of BIM tools	1	2	3	4	5
	b e-Building submission and permits	1	2	3	4	5
	c Open BIM	1	2	3	4	5
	d BIM software certification	1	2	3	4	5
D	There is a strong presence of government backed task groups on BIM implementation in the Kenyan construction industry.	1	2	3	4	5

Demonstration and Training						
		I strongly disagree	**I disagree**	**I am undecided**	**I agree**	**I strongly agree**
A	During my undergraduate studies there was a strong presence of government contribution on BIM research in the Kenyan construction industry through research funds and scholarship	1	2	3	4	5
B	During my undergraduate studies there was a strong presence of educational institution-based BIM laboratories that help in testing and improving BIM tools.	1	2	3	4	5
C	During my undergraduate studies there was a strong presence of educational institution based short term BIM training boot camps	1	2	3	4	5
D	During my undergraduate studies, there was a high level of collaboration between BIM innovators, BIM resellers and educational institutions to offer focussed in-house training.	1	2	3	4	5

E	During our undergraduate studies, there was frequent upgrading of computer hardware to match improved BIM tools.	1	2	3	4	5
F	During our undergraduate studies, there was frequent upgrading of computer software to match improved BIM tools.	1	2	3	4	5
G	In my professional practice, there is a strong presence and availability of BIM training guides and codes.	1	2	3	4	5
H	There is a strong presence of BIM specialized Continuous Professional Development seminars and workshops for apprentices and registered professionals	1	2	3	4	5

BIM Interoperability						
		I strongly disagree	**I disagree**	**I am undecided**	**I agree**	**I strongly agree**
A	There is a strong presence of localised BIM standard templates and data formats equivalent to CoBie and uniformat	1	2	3	4	5
B	There is a lot of ease in generating open BIM standards like .ifc, and .bcf.					
C	There is a lot of ease in creation and use of native models.	1	2	3	4	5
D	There is a lot of ease in creation and use of federated models.	1	2	3	4	5
E	There is a lot of ease in running Hard Clash Detection	1	2	3	4	5
F	There is a lot of ease in running Soft Clash Detection	1	2	3	4	5

BIM Simplicity							
			Very Difficult	**Difficult**	**I am undecided**	**Easy**	**Very Easy**
A	This is the level of ease in doing the following tasks using BIM tools at my disposal						
	a	2D - CAD Drafting	1	2	3	4	5

	b	2D documentation and producing files in the form of .dwg, .pdf or their equivalents.	1	2	3	4	5
	c	3D – CAD modelling	1	2	3	4	5
	d	3D – Parametric modelling.	1	2	3	4	5
	e	3D Printing.	1	2	3	4	5
	f	3D Fabrication.	1	2	3	4	5
	g	3D Mobile Interfacing.	1	2	3	4	5
	h	3D Augmented Reality.	1	2	3	4	5
	i	4D Manual Scheduling.	1	2	3	4	5
	j	4D Parametric Scheduling.	1	2	3	4	5
	k	4D -3D Scheduling.	1	2	3	4	5
	l	5D Manual Quantity Take Off and costing	1	2	3	4	5
	m	5D Parametric Quantity Take Off and costing	1	2	3	4	5
	n	Interchangeably using various classification systems like CAWS, RICS, NRM and Uniclass	1	2	3	4	5
	o	2D overlaying and trace referencing during design coordination with professional colleagues	1	2	3	4	5
	p	3D overlaying and trace referencing during design coordination with professional colleagues	1	2	3	4	5
	q	BIM design collaboration with professional colleagues	1	2	3	4	5
	r	BIM virtual design collaboration with professional colleagues through cloud computing	1	2	3	4	5
	s	Structural analysis and simulation	1	2	3	4	5
	t	Structural modelling	1	2	3	4	5
	u	Structural documentation and Quantity Take Off	1	2	3	4	5
	v	Plumbing and drainage analysis and simulation	1	2	3	4	5
	w	Plumbing and Drainage modelling	1	2	3	4	5
	x	Plumbing and Drainage documentation and Quantity Take Off	1	2	3	4	5
	y	Electrical analysis and simulation	1	2	3	4	5
	z	Electrical modelling	1	2	3	4	5
	aa	Electrical documentation and Quantity Take Off	1	2	3	4	5
	ab	Any other capability 1 (write the name)					
	ac	Any other capability 2 (write the name)					
	ad	Any other capability 3 (write the name)					

SECTION 4.

Tick one box only for each row. Ignore the shaded boxes

Objective: To establish the level of BIM Risk Tolerance within the Building Contractors in the Kenyan Construction Industry.

Intellectual Property

			I strongly disagree	I disagree	I am undecided	I agree	I strongly agree
A	The current legal framework recognises copyrights for native models and federated models generated using the BIM tools at my disposal.		1	2	3	4	5
B	The current contract documents in the construction industry recognises federated models made using the BIM tools at my disposal as part of the contract instruments.		1	2	3	4	5
C	I have interacted with the BIM tools at my disposal, and I am thereby knowledgeable about their strengths, weaknesses, and extent of capabilities.		1	2	3	4	5
D	The following benefits are accrued when using BIM tools at my disposal						
	a	Reduced office operation costs.	1	2	3	4	5
	b	Improved productivity.	1	2	3	4	5
	c	Reduced Request for Information from professional colleagues	1	2	3	4	5
	d	Improved process of change management.	1	2	3	4	5
	e	Improved coordination and collaboration of projects with professional colleagues.	1	2	3	4	5
	f	Improved design integration of projects with my professional colleagues	1	2	3	4	5
	g	Reduced errors, omissions, and reworks	1	2	3	4	5
	h	Improved cost control and predictability.	1	2	3	4	5
	i	Reduced cycle time for workflows.	1	2	3	4	5
	j	Reduced claims and litigations	1	2	3	4	5

Relative Advantage (Cost Benefit Analysis)						
		I strongly disagree	**I disagree**	**I am undecided**	**I agree**	**I strongly agree**
A	I have interacted with the BIM tools at my disposal, and I am thereby knowledgeable about their strengths, weaknesses, and extent of capabilities.	1	2	3	4	5

B	The following benefits are accrued when using BIM tools at my disposal						
	a	Reduced office operation costs.	1	2	3	4	5
	b	Improved productivity.	1	2	3	4	5
	c	Reduced Request for Information from professional colleagues	1	2	3	4	5
	d	Improved process of change management.	1	2	3	4	5
	e	Improved coordination and collaboration of projects with professional colleagues.	1	2	3	4	5
	f	Improved design integration of projects with my professional colleagues	1	2	3	4	5
	g	Reduced errors, omissions, and reworks	1	2	3	4	5
	h	Improved cost control and predictability.	1	2	3	4	5
	i	Reduced cycle time for workflows.	1	2	3	4	5
	j	Reduced claims and litigations	1	2	3	4	5

			I strongly disagree	**I disagree**	**I am undecided**	**I agree**	**I strongly agree**
C	The following challenges are experienced when using BIM tools at my disposal						
	a	High cost of continuously upgrading computer hardwares	1	2	3	4	5
	b	High cost of continuously upgrading computer softwares	1	2	3	4	5
	c	High cost of continuously retraining staff	1	2	3	4	5
	d	High cost of Continuously creating and improving internal workflows	1	2	3	4	5
	e	Low level of client demand	1	2	3	4	5
	f	Low level of model sharing	1	2	3	4	5

Liability Cover

		I strongly disagree	I disagree	I am undecided	I agree	I strongly agree
A	BIM models and documentation made using the BIM tools at my disposal are legally recognised by Insurers within the construction Industry.	1	2	3	4	5
B	Using BIM models and documentation made using the BIM tools at my disposal generally reduces the cost of professional indemnity and general insurance.	1	2	3	4	5

SECTION 5.

General views about adoption and use of BIM by Building Contractors in Kenya. Kindly give your answer in summary form

1. What are your views about the BIM softwares that you use? ___________________________________ ___________________________________ ___________________________________ ___________________________________	2. What are your views about the BIM training at educational level? ___________________________________ ___________________________________ ___________________________________ ___________________________________
3. What are your views about the BIM training at professional level? ___________________________________ ___________________________________ ___________________________________ ___________________________________	4. What are your views about the Government policy on BIM? ___________________________________ ___________________________________ ___________________________________ ___________________________________

5. What are your views about NCA's Policy on BIM? ___________________________________ ___________________________________ ___________________________________ ___________________________________	6. What are your views about the ease and difficulty of using BIM? ___________________________________ ___________________________________ ___________________________________ ___________________________________
7. What are the challenges that you experience when using BIM?______________________________ ___________________________________ ___________________________________ ___________________________________ _____	8. What are the benefits that you accrue when using BIM?____________________ ___________________________________ ___________________________________ ___________________________________ _

END OF THE QUESTIONNAIRE

Thank you for your participation..

Appendix II: Available BIM Tools and Their Capabilities.

Table 1: Outstanding BIM tools currently in use globally

	BIM Tool	Capabilities									BIM Innovator	Version as of 31st December 2019,	Source of information
		2D Drafting	3D CAD Modelling	3D Parametric Modelling	4D Scheduling	5D Costing	IDCC	Clash Detection and Interoperability	Structural Analysis and Modelling	MEP Analysis and Modelling			
1	Affinity	x	x	x							Trelligence		(Hergunsel, 2011)
2	Archicad	x	x	x		x	x	x	x	x	Graphisoft	22	(Underwood & Isikdag, 2010)
3	AutoCAD	x									Autodesk		(Migilinskas et al., 2013)
4	Autodesk QTO					x							
5	Bentley	x	x	x									
6	Bluebeam					x							
7	CAD Direct									x	Micro Applent		(Arayici, 2015)
8	Cad Pipe									x	AEC Design Group		(Hergunsel, 2011)
9	Cost X					x							
10	Cype CAD								x		Inter-VCAD		(Arayici, 2015)
11	D Profiler	x	x	x		x					Beak Technology		(Logothetis et al., 2017)
12	DELMA				x								
13	Diamonds								x		Buildsoft		(Eastman et al., 2011)
14	Digital Project	x	x	x						x	Gehry Technologies		(Arayici, 2015)
15	Fastrak								x		CSC (UK)		(Hergunsel, 2011)
16	FEM Design								x		Strusoft		(Arayici, 2015)

	BIM Tool	**Capabilities**									**BIM Innovator**	**Version as of 31st December 2019,**	**Source of information**
		2D Drafting	**3D CAD Modelling**	**3D Parametric Modelling**	**4D Scheduling**	**5D Costing**	**IDCC**	**Clash Detection and Interoperability**	**Structural Analysis and Modelling**	**MEP Analysis and Modelling**			
17	Innovaya					x							
18	iTWO					x							
19	MEP Modeller									x			
20	Micro station	x	x	x		x			x	x	Bentley Systems		(Arayici, 2015; Khosrowshahi & Arayici, 2012; Mehran, 2016)
21	Midas Gen								x		MIDAS		(Arayici, 2015)
22	Ms Project				x							2016	
23	Primavera				x								
24	Prokon								x				
25	Navis Work				x								
26	Planet				x								
27	Revit	x	x	x					x	x	Autodesk.		(Bopalgni, 2013)
28	RISA								x		Risa Technologies		(Hergunsel, 2011)
29	Robot								x		Autodesk		(Logothetis et al., 2017)
30	SAP					x							
31	SCIA								x		Nemetschek		(Migilinskas et al., 2013)
32	SDS/2								x	x	Design Data		(Arayici, 2015; Logothetis et al., 2017)
33	Sketchup	x	x	x							Trimble Building		(Graphisoft, 2015)

	BIM Tool	**Capabilities**									**BIM Innovator**	**Version as of 31st December 2019,**	**Source of information**
		2D Drafting	**3D CAD Modelling**	**3D Parametric Modelling**	**4D Scheduling**	**5D Costing**	**IDCC**	**Clash Detection and Interoperability**	**Structural Analysis and Modelling**	**MEP Analysis and Modelling**			
34	Solibri							x			Solibri		(Logothetis et al., 2017)
35	STAAD								x				(Hardin & McCool, 2015)
36	Synchro 4D				x								
37	Tekla							x	x		Trimble Building		(Arayici, 2015; Khosrowshahi & Arayici, 2012; Logothetis et al., 2017)
38	Vector works	x	x	x							Nemetschek		(Arayici, 2015; Logothetis et al., 2017)
39	VICO				x	x			x		Trimble Building		(Hergunsel, 2011)
40	WinQs					x							

Source: Author (2017)

Appendix III: Status of BIM Capabilities Based on Diffusion of Innovation Theory

Table 2: Status of various BIM capabilities based on the Diffusion of Innovation Theory Source

Capability of BIM	Phase in Diffusion of Innovation Curve	Explanation
3D CAD Modelling	Laggard Phase	Even the laggards have appreciated that 3D CAD is manual and taxing(Eastman et al., 2011). 3D CAD was automatically phased out with the advent of parametric modelling as early as mid-1990's. (Nyberg & Kullven, 2014).In some jurisdictions like Singapore have phased out 3D CAD models and are only allowing BIM models for Local Authority approval(Cheng & Lu, 2015).
3D Parametric modelling	Late majority phase	This capability has gone through cycles of improvement through sustainable innovation and is thus regarded having matured (Hergunsel, 2011; King & Baatartogtokh, 2015). A bulk of architectural and design modellers joined the bandwagon. In the UK, the level of adoption stands at 62%
4D Scheduling	Early Adopter's Phase	This capability is currently used mainly in large scale or specialised projects (Boton et al., 2015). It is still a young technology and currently the cost is prohibitive
5D Costing	Late Majority Adopter's Phase	Over 60% of Quantity Surveyors in certain jurisdictions like Australia and Ireland have already adopted 5D (Smith, 2014a; Society of Chartered Surveyors Ireland, 2017).
6D and 7D	Innovator's Phase	This is still a new phenomenon in the BIM world and therefore at an early stage of diffusion(Enynon, 2016)
Integrated Design Coordination and Collaboration	Early Majority Adopter's Phase	Improvement of collaborative BIM processes has built confidence on potential users.(McGraw Hill Construction, 2012)
Interoperability and Clash detection	Early Majority Adopter's Phase	Improved interoperability of various BIM tools has built confidence on potential users(McGraw Hill Construction, 2012)

Capability of BIM	Phase in Diffusion of Innovation Curve	Explanation
Structural Analysis and Modelling	Early Majority Adopter's Phase	Though regarded as one of the most difficult BIM tasks, its usage and adoption is increasing(McGraw Hill Construction, 2012).
MEP Analysis and Modelling	Early Majority Adopter's Phase	Regarded equally as another difficult BIM tasks, its usage and adoption is also increasing(Azhar & Cochran, 2009)
BEM	Innovator's Phase	This capability is still a new phenomenon. Potential innovators are still evaluating it.

Source: Author (2017)

Appendix IV: Status of BIM Capabilities Based on Hype-Cycle Theory

Table 3: Status of various BIM capabilities based on the Hype-Cycle Theory.

Capability of BIM	Phase in Hype-Cycle	Explanation
3D CAD Modelling	Post - Plateau Phase	This broadly involved basic 2D documentation and 3D modelling that is not parametric. This has progressively been replaced with interactive, parametric and intelligent models(Azhar et al., 2012; Eastman et al., 2011; Grzyl et al., 2017)
3D Parametric modelling	Slope of Enlightenment Phase	This capability currently stands at parametric modelling(Czmoch & Pękala, 2014). New opportunities surrounding 3D modelling, for example 3D printing, prefabrication and mobile accessibility of 3D models are being explored.
4D Scheduling	Slope of Enlightenment Phase	Tedious manual scheduling (1st generation product) gave way parametric scheduling (2nd generation product)(Czmoch & Pękala, 2014). Parametric scheduling gave way to parametric 3D scheduling and Virtual Prototyping(Huang et al., 2007; Tse, 2009)
5D Costing	Slope of Enlightenment Phase	Tedious QTO (1st generation product) gave way to LoD compatible QTO tools (Hijazi & Omar, 2017)This gave way to parametric QTO and costing tools(Smith, 2016)
6D and 7D	Technology Trigger Phase	Most of the available tools are at their innovation stage and have not been rolled out or exposed to media hype. This is why there is still a lot of confusion on what they represent. For 6d, confusion still reigns on whether it represents a facilities management tool (Enynon, 2016),sustainability tool (Abanda et al., 2017) or a procurement tool(Kapogiannis et al., 2015). For 7D, confusion still reigns on whether it represents a sustainability tool(Kapogiannis et al., 2015) or a life-cycle tool(Enynon, 2016)

Capability of BIM	Phase in Hype-Cycle	Explanation
Integrated Design Coordination and Collaboration	Slope of Enlightenment Phase	After much hyping of this BIM capability, most design actors went back to their standalone BIM tools that they were comfortable with. However, it must be noted that the early collaborators are still soldiering on led by BSI in a bid to get a universal solution to this issue. Other secondary issues are favouring its comeback, for example the advent of cloud computing(Royal Institute of Chartered Surveyors, 2015), favourable government policies, improved legal framework improving aspects of professional liability and ownership
Interoperability and Clash detection	Slope of Enlightenment Phase	There has been a noticeable continuous improvement of interoperability and clash detection in BIM tools currently in the market through the improvement of Common Data Environment(Ashurst Australia, 2014)
Structural Analysis and Modelling	Slope of Enlightenment Phase	A number of BIM tools for structural analysis are at their third or fourth generation(Hassinen, 2017)
MEP Analysis and Modelling	Slope of Enlightenment Phase	With all the hype gone, there is a slow but sure improvement of MEP tools in the market(Arayici, 2015)
BEM	On the Rise Phase	Still at its formative stage, a lot of hyping is going on especially when tagged to topics like sustainability and climate change. 1st generation of BEM tools have been availed to the market, a number of challenges concerning these tools have been noticed e.g. poor data transfer, incompatible BIM environments, BEM tools not being interoperable(Sarkar, 1998)

Source: Author (2017)

Appendix V: Levels of BIM Adoption in Various Jurisdictions

Table 4: Level of BIM adoption on a global level

Country	Code on the Map	Adoption Level	Year in question	Source
Australia	18	58% 61% 77%	2013 2014 2016	(McAuley et al., 2017; McGraw Hill Construction, 2014)
Brazil	3	45% 73%	2013 2015	(Gerges et al., 2017; McGraw Hill Construction, 2014)
Canada	2	62% 67%	2013 2015	(McGraw Hill Construction, 2014; NBS, 2016)
Chile	4	53%	2016	(University of Chile, 2016)
France	6	55% 71%	2013 2015	(Gerges et al., 2017; McGraw Hill Construction, 2014)
Germany	7	50% 72%	2013 2015	(Gerges et al., 2017; McGraw Hill Construction, 2014)
Japan	17	73%	2013	(McGraw Hill Construction, 2014)
Jordan	12	5%	2016	(Matarneh & Hamed, 2017)
Kenya	10	No clear-cut figures though studies how some level of adoption	2016	(Manza, 2016; Mumbua, 2016)
Malaysia	14	20%	2016	(Zainon et al., 2016)
Nigeria	8	3%	2016	(James et al., 2016)
Singapore	15	80%	2015	(Zakaria et al., 2013)
South Africa	11	54%	2016	(Harris, 2016)
South Korea	16	52%	2013	(McGraw Hill Construction, 2014)

Country	Code on the Map	Adoption Level	Year in question	Source
Sudan	9	No clear-cut figures though studies how some level of adoption	2016	(Ahmed, 2016)
United Arab Emirates	13	40%	2017	(Mehran, 2016)
United Kingdom	5	13% 31% 39% 46% 48% 54% 62%	2010 2011 2012 2013 2014 2015 2016	(McGraw Hill Construction, 2014; National Building Specifications, 2017)
United States of America	1	71% 79%	2012 2013	(Edirisinghe & London, 2015; McGraw Hill Construction, 2014)

Source: Author (2017)

Appendix VI: Geographical Scope of the Study

Table 5: Planning Zones selected for Data Collection

zone number	minimum size (sqm) of land parcel	average plot ratio	predominant development type	minimum plinth area	rate	minimum cost (42,000/- per sqm)	zone selected?
1	500.00	600	Commercial	3,000.0	61,167.	183,501,000.	Ye
2	500.00	250 %	Commercial / Residential	1,250.0 0	43,343. 00	54,178,750.0 0	No
3	500.00	240	Commercial	1,200.0	61,167.	73,400,400.0	Ye
4	500.00	300 %	Residential Apartments	1,500.0 0	49,650. 00	74,475,000.0 0	Ye s
5	2,000.0 0	75%	One Family Dwelling House	1,500.0 0	45,600. 00	68,400,000.0 0	No
6	2,000.0 0	25%	One Family Dwelling House	500.00	45,600. 00	22,800,000.0 0	No
7	500.00	75%	High Density Residential Flats	375.00	37,250. 00	13,968,750.0 0	No
8	500.00	150 %	High Density Residential Flats	750.00	37,250. 00	27,937,500.0 0	No
9	500.00	300	Industrial	1,500.0	56,650.	84,975,000.0	Ye
10	500.00	300 %	Mixed Residential/ Industrial	1,500.0 0	56,650. 00	84,975,000.0 0	Ye s
10 E	500.00	75%	High Density Residential Flats	375.00	56,650. 00	21,243,750.0 0	No
11	500.00	75%	Comprehensive Residential Schemes	375.00	43,343. 00	16,253,625.0 0	No
12	2,000.0 0	25%	One Family Dwelling House	500.00	45,600. 00	22,800,000.0 0	No
13	2,000.0 0	25%	One Family Dwelling House	500.00	45,600. 00	22,800,000.0 0	No
14	2,000.0 0	25%	One Family Dwelling House	500.00	38,500. 00	19,250,000.0 0	No
15	500.00	75%	Residential Mix	375.00	37,250.	13,968,750.0	No
16	500.00	300	Industrial	1,500.0	56,250.	84,375,000.0	Ye

zone number	minimum size (sqm) of land parcel	average plot ratio	predominant development type	minimum plinth area	rate	minimum cost (42,000/- per sqm)	zone selected?
17	500.00	200	Residential Mix	1,000.0	37,250.	37,250,000.0	No
18	500.00	200	Residential Mix	1,000.0	37,250.	37,250,000.0	No
19			Outside Nairobi County				No
20			Public/Reserved Areas				No
20 G			Recreational and Forests				No

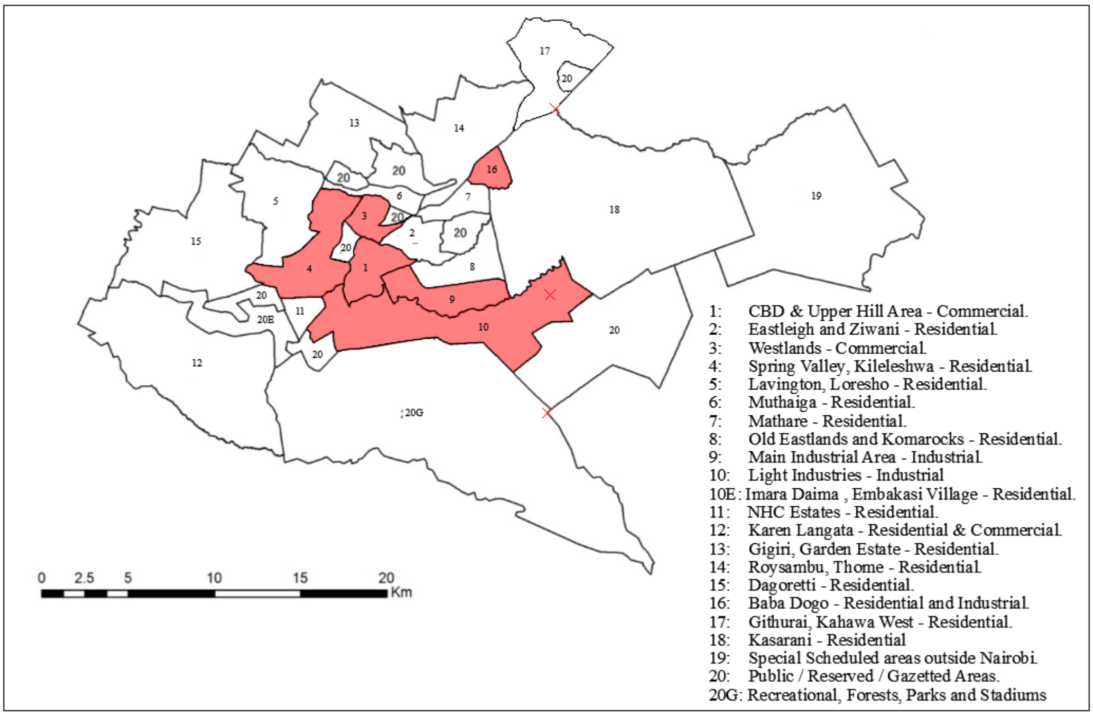

Figure 1: Planning Zones selected for Data Collection

Source: Author (2018)

Appendix VII: Sample Size for Continuous and Categorical Data

Table 1: Table for Determining Minimum Returned Sample Size for a Given Population Size for Continuous and Categorical Data

	Sample size					
	Continuous data (margin of error=.03)			Categorical data (margin of error=.05)		
Population size	alpha=.10 t=1.65	alpha=.05 t=1.96	alpha=.01 t=2.58	p=.50 t=1.65	p=.50 t=1.96	p=.50 t=2.58
100	46	55	68	74	80	87
200	59	75	102	116	132	154
300	65	85	123	143	169	207
400	69	92	137	162	196	250
500	72	96	147	176	218	286
600	73	100	155	187	235	316
700	75	102	161	196	249	341
800	76	104	166	203	260	363
900	76	105	170	209	270	382
1,000	77	106	173	213	278	399
1,500	79	110	183	230	306	461
2,000	83	112	189	239	323	499
4,000	83	119	198	254	351	570
6,000	83	119	209	259	362	598
8,000	83	119	209	262	367	613
10,000	83	119	209	264	370	623

NOTE: The margins of error used in the table were .03 for continuous data and .05 for categorical data. Researchers may use this table if the margin of error shown is appropriate for their study; however, the appropriate sample size must be calculated if these error rates are not appropriate. Table developed by Bartlett, Kotrlik, & Higgins.

Figure 2: Table determining minimum returned sample size

Source: (Bartlett et al., 2001)