INFLUENCE OF BUILDING INFORMATION MODELLING ADOPTION ON COMPLETION OF CONSTRUCTION PROJECTS: A CASE OF NAIROBI COUNTY, KENYA

BY

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DECLARATION

This research project report is my original work and has not been presented for academic award in any University.

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L50/62331/2013

This research project report has been submitted for examination with my approval as the university supervisor

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DEDICATION

This research project report is dedicated to My Parents Mr. & Mrs. Gideon Manza for their unfathomable support, May God bless them.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABBREVIATIONS AND ACRONYMS

AEC	Architecture, Engineering and Construction
BIM	Building Information Modeling
CAD	Computer Aided Design
HVAC	Heating, Ventilation, and Air Conditioning
IAI	International Alliance for Interoperability
IPD	Integrated Project Delivery
NBS	National Building Specification
PMBOK	Project Management Body of Knowledge
RFI	Request for Information
TQM	Total Quality Management

ABSTRACT

The Architectural, Engineering and Construction (AEC) industry is characterized by its fragmented, complex and multidisciplinary nature. Hence, the project completion is heavily pivoted on its effective collaboration among the stakeholders during various project phases. The exchange and management of massive project information under various project delivery methods are cumbersome in modern day's projects. Information Technology applications are playing a vital role in overcoming this difficulty; however the technological adoption and its full utilization has always been slow in the emerging economies. Among these technologies, Building Information Modelling (BIM) dominates the AEC sector. The main purpose of this research was to establish the influence of Building Information Modeling adoption on completion of construction projects a case of Nairobi County. Specifically, the research sought to achieve the following objectives: to establish the influence of Building Information Modelling budget estimation on completion of construction projects; to determine the influence of Building Information Modelling error minimization on completion of construction projects; to assess the influence of Building Information Modelling time estimation on completion of construction project and to establish the influence of Building Information Modelling quality improvement on completion of construction projects. A descriptive survey research design was adopted in this study so as to enable the researcher to use quantitative techniques to measure and describe the influence of Building Information Modeling adoption on completion of construction projects. Both open-ended and close-ended questions were used. The study had a total population of 30 elements. The researcher sampled out 28 AEC firms out of the target population using purposive sampling. Primary data was collected using personally administered questionnaires. The researcher sought the assistance of the supervisors in reviewing the instruments for validity and used the Cronbach Alpha test to confirm reliability. The Cronbach Alpha score was generated from SPSS to give a score of 0.75 which was within the recommendable range. The data was analyzed using descriptive statistics like frequencies, percentages and mean aided by SPSS. The data is presented in frequency and percentage distribution tables. The findings revealed that 85% of the respondents strongly agreed that BIM budget estimation enhances completion of projects. 94% strongly agreed BIM time estimation ensures completion of projects. On the aspect of BIM error elimination, 85% agreed that error elimination promotes completion of projects. 74% strongly agreed that BIM quality improvements ensures completion of construction projects. The study recommends that the government and key players in the construction industry need to develop institutional framework on BIM adoption in the various projects increase the awareness of the BIM adoption benefits so more firms will be able to adopt and reap its benefits. It is suggested that further research may be done on related areas including the interoperability standards, programs and legal framework of the BIM.

CHAPTER ONE: INTRODUCTION

1.1 Background of the Study

Construction is a labor intensive industry that has remained relatively unchanged for hundreds of years. Traditionally, a construction project, consisting of drawings and specifications, is delivered by architects and engineers to the owners/clients of the proposed project, with a warranty that the design is complete and free of any defects. Owners then put the project up for bid among a selected list of contractors; the lowest bid typically being awarded the job. Once the construction documents are in the possession of the general contractor and construction begins, the relationship between general contractors, architects and engineers also begins. This relationship tends to be typically limited and distant. Any changes or discrepancies that occur in the drawings are corrected, typically, by a long trail of paperwork, for a contractual period of time per each request for information (RFI). This can stifle productivity on the job site because of trades waiting for pertinent information, and it can decrease morale among crew members, which also decreases productivity.

The construction industry experiences many changes concerning how to increase the efficiency on its processes. Building information modeling (BIM) promotes a modern collaborative method of working in the Architectural, Engineering and Construction (ACE) areas where each participant that have assigned an individual task, should adopt a new behaviour based on the interchange of knowledge and information, with the aim of overcoming new challenges and increment the common benefits of the group. The new trend is partially motivated by the necessity of being successful on the development of complex projects, which create the necessity of collaboration between designers, owners, stakeholders, financial firms, administrations, contractors and subcontractors. As a result information and communication technology has grown up really past in the last years trying to offer precise tools to satisfy these new requirements (Bryde et al.2013).

Design/Build firms can be extremely efficient because they house both the designers (Architects and Engineers) and the Construction Management professionals; however they still operate with the same flawed system of designers generating construction drawings and the construction team erecting the building. More advancements can be made to increase productivity in construction, reduce requests for information, eliminate coordination problems, decrease construction time, and increase quality. The BIM Software is the gateway to solving these issues. With dynamically linked on demand modeling, changes can be made by Designers in a remote location that would update digital construction drawings at the jobsite. Project managers on site can propose changes to the design team with no delay time. Means of construction can be displayed in 4-Dimensions for an increased understanding of construction sequencing by the contractor on site. Any and all questions can then be answered immediately and virtually from any location (Mosca, 2007)

The research study focuses on the influence of BIM Budget estimation, minimization of errors, time estimation and quality improvement on completion of construction projects.

1.1.1 Building Information Modeling

This technological advancement is being heavily promoted by Autodesk® with the program Revit, which is used to develop Building Information Models. Building Information Modeling (BIM) approach is a dynamically linked interface designed to take the place of redundant computer aided drafting (CAD) work. Idea being, architects are free to design, and the software generates the plans, sections, and elevations. Any changes to the documents change any other instance of it throughout the drawings, to improve coordination. Reduction in coordination issues will reduce RFIs, which will increase productivity. Knowledge of the program is essential for the general contractor on site to make suggestions to the architects and engineers who address unanticipated field conditions, this will reduce non-productive time on a jobsite and increase construction job efficiency and productivity (Azhar, 2011).

Building Information Modeling (BIM) is being adopted by the Architecture, Engineering, and Construction (AEC) industry in various regions in the world: In the UK, 2011 was the start of the BIM journey. At the time, around 40% of those we surveyed were not even aware of BIM, let alone implementing it in their projects. Four years later, we have very different picture. Driven by the UK Government’s construction strategy, we’re now at a point where only 6% are unaware of BIM and 39% are actively using BIM on their projects. The UK Government as a client has recognised the benefits of BIM deliverables and therefore in the Government Construction Strategy 2011 specified the requirement for public sector projects to use fully collaborative BIM level 2 by 2016. The detailed benefits provided by BIM deliverables and the requisite for the application of BIM level 2 processes on public sector projects signifies the importance and urgency required for BIM adoption in the UK quantity surveying profession. (Cabinet Office, 2011).

One of the surveys, conducted by McGraw Hill Construction in partnership with Autodesk and Skanska, revealed that: 38 % of UK business owners expect that more than 75 % of their projects will involve BIM within two years, 67% of UK owners report that the central government mandate has a high impact on their use of BIM, UK owners are more aware of BIM use by the core project team members (general contractors and architects) than their US counterparts, most UK owners (88%) are formally measuring the impact of BIM and more UK owners agree that they have experienced key BIM benefits like enhanced visualization, fewer problems due to design errors, coordination issues or construction errors, and beneficial impacts on project schedule and the control of construction costs(McGraw-Hill Construction

Report,2012). The UK government estimates that it saved £1.7 billion (2 billion Euro) on major public building projects since 2012 and that 66 per cent of the UK's Major Project Authority portfolio is now being delivered on time and within budget, a substantial improvement on the 33 per cent seen in 2010. (Construction News, 2013).

According to a recent McGraw-Hill Construction Report (2012), BIM adoption in the USA expanded from 49% in 2009 to over 71% in 2012. In 2003 in the United States the General Services Administration (GSA), through its Public Buildings Service (PBS) Office of Chief Architect (OCA), established the National 3D-4D-BIM Program. In 2006 the GSA mandated that new buildings designed through its Public Buildings Service use building information modeling in the design stage. At that time GSA had an inventory of more than 342 million square feet of office space. GSA owns about half of that space, in 1,500 buildings, and leases the rest. For all major projects receiving design funding in Fiscal Year 2007 and beyond, GSA requires spatial program BIMs be the minimum requirements for submission to OCA for Final Concept approvals by the PBS Commissioner and the Chief Architect. Since 2008, the U.S. Army Corps of Engineers requires the use of BIM for all military construction projects to improve construction time and costs (NIBS, 2006).

Singapore's goal is simple, to implement the fastest building permitting in the world. The Building and Construction Authority (BCA) led a multi-agency effort in 2008 to implement the world's first BIM electronic submission (e-submission). The BIM e-submission system streamlines the process for regulatory submission. Project teams only need to submit one building model, which contains all of the information needed to meet the requirements of a regulatory agency. In 2010, nine regulatory agencies accepted architectural BIM 3D models for approval through e-submission. This was followed by the acceptance of mechanical, electrical and plumbing (MEP) and structural BIM models in 2011. To date, more than 200 projects have made BIM e-submissions. In 2010 the BCA implemented the BIM Roadmap with the aim that 80% of the construction industry will use BIM by 2015. This is part of the government's plan to improve the construction industry's productivity by up to 25% over the next decade. The government provides BIM funds to promote a broader usage of BIM technology (Singapore Government, 2013). Out of $250 million Construction Productivity and Capability Fund (CPCF), $5.7 million was reserved as BIM fund for adopting BIM (Keung, 2011b). This BIM fund covers cost for BIM supporting software and hardware as well training and consultancy. BCA launched Construction Productivity Centre and Centre for Construction IT (CCIT) which have been guiding and funding on training, technology adoption and improving the way things work in the construction sector (BCA, 2011b).

The International BIM Survey 2013, carried out by construction information provider NBS found out that 57% of the respondents in New Zealand were currently using BIM.

Table 1.1: Awareness and use of BIM in New Zealand (International BIM Survey 2013)

Awareness and use of BIM	Percentage (%)
Aware and currently using BIM approach	57
Neither aware nor using BIM approach	2
Just aware of BIM approach	41

Finland is a pioneer in BIM and has progressed beyond the pilot phase (TEKLA, 2009). According to Hartmann & Fischer (2007), Finnish AEC industry is leading the use of BIM worldwide. The Finish government support the use BIM through Senate properties firm. It has given almost half of its responsibility to senate properties to manage almost the Finnish state`s property assets. Senate Properties is Finland`s largest and most comprehensive provider of property services in Finland. Since 2001, Senate Properties has carried out a number of pilot projects to develop and study the use of building information models and the company decided on October 2007 to require models meeting the Industry Foundation Classes (IFC) standard in its projects and has provided the BIM requirement document. This document contains general operation procedures in BIM projects and specifies the detailed general requirements of building information models. (Kiviniemi, 2007)The International BIM Survey 2013, carried out by construction information provider NBS found out that 67% of the respondents in Finland were currently using BIM (NBS National BIM Report, 2014)

The South African building industry traditionally is an early adopter of technology, propelled by independent thinkers and doers who can make IT work to suit their needs. An open regulatory process encourages investigating new approaches for building design. The country's dynamic political and social environment creates a can-do atmosphere that energizes the business sector, freeing it from the constraints of established and perhaps outdated ways of doing things. Many firms in South Africa already use AutoCAD, so they saw little risk in trying out Revit, which integrates with AutoCAD, on a working project. As a result, designers elected to use Revit on sizable projects right out of the gate, foregoing the traditional approach of proving the technology on a small, trial project. Enough projects are being developed by consultants to allow BIM to move into the construction phase (Autodesk, 2007).

The move to adopt Building Information Modeling in Nigeria’s private and public sector (Client side) and amongst different building professionals (Architects, Quantity Surveyors, Civil Engineers etc) has been very slow. Architects have adopted but mainly for enhancing the visual quality of their presentation. This is unfortunate because of its enormous potentials to enhance efficiency, reduce disputes, save costs and curb corruption. The first step in promoting adoption will be to increase awareness of the technique, the tools employed and their benefits. Software vendors and training institutions have a role and commercial opportunity in promoting the awareness. Another critical step is for professional institutions such as the Nigerian Institute of Quantity Surveyors and the Nigerian Society of Engineers to organize training for their members and clients, including or perhaps especially public sector institutions. As this awareness grow, the construction press and other informed opinion such as analysts will join in the promotion of the critical cost management tool that the BIM represents. Egypt is engaged in intensive BIM outsourcing services that help to communicate work together and create design information related models to all involved in the process of design and execution (Journal of Environmental Sciences and Policy Evaluation, 2012).

In Kenya BIM adoption is at its infancy stage however gaining momentum due to increased awareness through conferences by Autodesk Kenya, complexity of construction projects and foreign investors who have realized the influence of BIM in the project cycle

1.2 Statement of the Problem

Some of the problems in the AEC sector is there are so many different professionals working on different parts of the project (Structure, services, design, distribution among others) following a fragmented method of management. Each of this parts must be based on a common idea and follow the same criteria of others, they are key parts of information that all together allow to create the project. If information is not accurate and enough next stages will be affected. Building Information Modelling could make more efficient these stages in order to avoid many of the most typical mistakes when they work separately.

Through the use of Building Information Modeling in both design and construction process problems associated with the traditional methods and project changes; uncoordinated drawings, drawings with errors, delays in construction, late project completion, omissions among others are minimized. BIM enables virtue construction of the project before actual construction commences thus providing room for any amendments and finalization of drawings. Failure to adopt Building Information Modeling in the ACE industry will perpetuate problems associate with traditional methods like uncoordinated drawings, drawings with errors, delays in construction, late project completion, omissions, more RFIs from contactors, more defects at completion of projects, poor documentation, and stretched project budget among others (Eastman, 2008)

1.3 Purpose of the Study

The purpose of the study was to establish the influence of Building Information Modeling adoption on completion of construction projects: a case of Nairobi County, Kenya.

1.4 Objectives of the Study

This study was be guided by the following research objectives:

(i) To establish the influence of Building Information Modelling budget estimation on completion of construction projects;

(ii) To assess the influence of Building Information Modelling time estimation on completion of construction projects;

(iii) To determine the influence of Building Information Modelling error minimization on completion of construction projects;

(iv) To establish the influence of Building Information Modelling quality improvement on completion of construction projects.

1.5 Research Questions

The study was be guided by the following research questions:

(i) To what extent do Building Information Modeling budget estimation influence completion of construction project?

(ii) How do Building Information Modeling error minimization influence completion of construction project?

(iii) To what extent do Building Information Modeling time estimation influence completion of construction project?

(iv) How do Building Information Modeling quality improvement influence completion of construction project?

1.6 Significance of the Study

The findings of the study will hopefully enlighten the players in the construction industry (Architect, Engineers, Contractor, and clients) on the influence of BIM and the role it plays in ensuring completion of construction projects with reference to cost, time, accuracy and quality. The study also hopes to encourage both stakeholders in the private and public to adopt BIM in their construction projects and enact legal framework to ensure better and sustainable utilization of resources.

1.7 Delimitation of the Study

The study was carried out in Nairobi County. The target population will be key construction players; project managers, Architects, Engineers, contractors and clients based in Nairobi, Kenya who have adopted BIM approach in their projects. Adoption of Building Information Modeling by the target population influences completion of construction which is the research interest thus they have been selected. The research will be conducted in Nairobi because only firms within Nairobi meet the criteria of selection and convenience for the researcher.

1.8 Limitations of the Study

The study envisaged a limitation of access of local historical data that is not readily available due to the fact that the software is still in its infancy stage of implementation in the AEC industry in Kenya, the change over by architects, engineers, project managers and contractors is very slow although most experts consider BIM to be the future of the construction industry.

However information will be derived from data collected from the study respondents, web pages, books, journals that cover topics focused on Building Information Modeling and interoperability.

1.9 Assumptions of the Study

The study assumed that the participants targeted were available and willing to participate. It further assumes that participants will give accurate feedback to enquiries presented to them by the researcher. It further assumes that they will have and provide the right information required for the study. The researcher will be granted access to relevant research data throughout the study.

1.10 Definitions of Significant Terms used in the study

Building Information modeling (BIM). It is the creation and use of computer models and collaborative work between architects, engineers, client, project managers and contractors to improve design and construction of facilities and other infrastructure.

Completion of construction projects. This refers to completion of a unique undertaking aimed at achieving specific predefined goals and objectives that are inherent with risk within a predetermined budget, time and to acceptable quality standards.

Architecture, Engineering and Construction industry. The sector of the construction industry that provides the services on the architectural design, engineering design and construction services.

Request for information (RFI). It refers a partnering tool to resolve these gaps, conflicts, or subtle ambiguities during the bidding process or early in the construction process to eliminate the need for costly corrective measures.

Quality. It is defined as the level to which product or service meets its specification or meets the expectations of the users

1.11 Organization of the study

The study is organized into five chapters. Chapter one gives background of the study, statement of the problem, purpose, research objectives, research questions, justification and significance of the study, limitations, and delimitations of the study, basic assumptions of the study and definition of key terms. Chapter two reviews the literature based on the objectives of the study. It reviews the literature on the concept Building Information Modeling and the influence of the Building Information modeling budget estimation, minimization of errors, time estimation and quality improvement on completion of construction projects. It further looks at the conceptual framework and the variables used in the study. Chapter three looks at the research methodology of the study and has the following sections; research design, target population, sampling procedure, methods of data collection, validity and reliability of the research instrument, operational definition of variables and ethical consideration. Chapter four involves analyses of the data, presentation of the data and interpretation of the findings. It also provides the major findings and results of the study as directed by the objectives of the study. Chapter five presents the discussion of key data findings, conclusion drawn from the findings highlighted and recommendation made there-to. The conclusions and recommendations drawn addresses the objectives of the study.

CHAPTER TWO: LITERATURE REVIEW

2.1 Introduction

With the rapid adoption of BIM in the construction industry, and its gradual implementation in the design industry, careful considerations have to be taken when making the change over from the traditional method of creating construction documents towards a BIM approach. There are plenty of positives, negatives, and unknowns that have to be considered when implementing BIM. This chapter will discuss research that was done about the concept of BIM, its perceived influence on completion of construction projects, the theoretical and conceptual framework

Archer (2006) defines project Completion as “Controlling process that ensures that project objectives are met within the specified time and budget by monitoring and measuring progress regularly to identify variances from plan, so that corrective action can be taken when necessary” and further identifies controlling process to have links with planning and executing process.

2.2 The concept of Building Information Modeling and completion of construction projects

BIM is not merely a 3D graphic representation of design intent; rather, it is a comprehensive information management tool based on the simulation of design and construction. BIM has its roots in Computer Aided Design (CAD) development from decades ago, yet still has no single, widely-accepted definition in the AEC industry. However, the most comprehensive definition of building information modeling has been defined by Associated General Contractors of America (AGC) which states “BIM is the development and use of a computer software model to simulate the construction and operation of a facility.” The resulting model, a building information model, is a data-rich, object-oriented, intelligent and parametric digital representation of the facility, from which views and data appropriate to various users' needs can be extracted and analyzed to generate information that can be used to make decisions and improve the process of delivering the facility (Associated General Contractors of America, 2006). This "Model Based "process where buildings will be built virtually before they get built in the field is also referred to as Virtual Design and Construction (VDC).

M. A. Mortenson Company (Mortenson) thinks of BIM as "an intelligent simulation of architecture," that must exhibit six (6) key characteristics; digital – enabling simulation of design and construction, spatial – 3D, to better represent complex construction conditions than 2D drawings, measurable – data is quantifiable, dimension-able, and query-able more than visual, comprehensive – encapsulating and communicating design intent, building performance, constructability, and sequential and financial aspects of means and methods, accessible – data made available to the entire project team through interoperable and intuitive interface, including architects, engineers, contractors, fabricators, owners, facility maintenance, and users, and durable – data that reflects as-built conditions and remains usable through all phases of a facility's life, including design and planning, fabrication and construction, and operations and maintenance (Campbell, 2007).

BIM incorporates the use of 3D visualization techniques with real-time, data driven, object-based imaging as a tool by all facets of the industries (Holness, 2006). This is a change from the current practice of; designs being manifested and put to paper with engineers then designing the structure and other supporting elements of the building. After completion of the design documents, a 3D model can be generated for the owner showing digital walkthroughs and to provide 3D renderings of spatial relationships. These tools are very useful to convey design intentions to owners and clients that who not able to visualize 3D space from 2D drawings. These can be very expensive and time consuming to produce (Autodesk, 2012).

BIM greatly increases the user's ability to control and manipulate data and information in an unprecedented way and in an interoperable format. Moving from paper-centric information to parametric, model-based information means that the digital design can be used for cost estimations, simulations, scheduling, energy analysis, structural design, GIS integration, fabrication, erection, and facilities management (Seaman, 2006). All of which are relative to each other, and changes in one category will have impacts on the others that are automatically accounted for. Since all of the above information is dynamically linked, productivity from recalculation of simple and minor changes will be greatly increased because the computer program will be able to handle the changes and calculations internally (Davidson, 2009).

BIM can generate include, but are not limited to, drawings, lists, tables, and 3D renderings related to the project. Thereby contributing more to efficiency, and provide superior accuracy than traditional 2D CAD drawings (OCA, 2006). Building models embedded with detailed information about a construction project are far beyond the capabilities of most design firms at present (which is why historical data is difficult to find and analyze, as it relates to productivity). These models are not just the electronic drafting tools that firms now think of as digital practice, nor are they three-dimensional renderings with separate construction documentation (Seaman, 2006). These are object based digital models which the program itself constructs the appropriate plans, details, and sections from. Any change in one aspect of the drawings, will automatically be accounted for in the other drawings. The BIM process has the potential to remove the guesswork about how the most difficult parts of a building come together, which tend in most cases to be the corners. These models also transcend 3D and can be manifest in 4^{th} dimension (4D) and 5^{th} dimension (5D) (Seaman, 2006).

Projects can digitally be built in the computer environment, showing any possible conflicts with the schedule; this is an incredible tool to relate information to the owners and show models for future production. If delays arise, they can be input into the model, and BIM will be able to determine any the necessary changes in the schedule. Four D (4D) models link components in 3D CAD models with activities from the design, procurement, and construction schedules. Resulting 4D models allow project stakeholders to view the planned construction of a facility over time on a computer screen and to review the planned or actual status of a project in the context of a 3D CAD model for any day, week, or month of the project (Fisher and Kunz 2004).

The 5D represents the money aspect of the program. Projects will have the materials for construction estimated, and work up a cost of material proposal. Changing materials for Bid Alternate purposes will be easy to see both the immediate cost impacts, but also a life cycle costing to the owner (AEdgar, 2006). Moving to an integrated, parametric, and object-based system should lead to dramatic changes in design and construction as well as, possibly, compensation and risk allocation. Life cycle cost analysis can project to the owners, cost savings and operational costs over the lifetime of a building. This information can prove to be very important in determining feasibility of a project. This information is also very important for determining whether a project meets Green Building specifications or LEED accreditation (Fukai, Dennis, 2006).

BIM can be used with distributors for estimating cost of materials and the ability to control the cost of the building is very captivating to the owners. Material suppliers can insert their specific data and cost into the BIM with the appropriate cost factors, and from this information, a hard dollar cost and a solid estimate can be generated, which will be the actual cost of the building. Changes can then easily be made to any of the specified products, creating new estimates and building costs. When changes are made, they can then be assignable to the architect, engineers, or owners. This can then determine responsibilities for payment on change orders (Seaman, 2006).

The most beneficial aspect of using BIM technology with software like Revit® is the way it changes the design process. BIM goal is to recognize the potential benefits that collaborative working through all stages of design and construction can offer. This happens to be the hardest thing to implement in the design process being that there are complications for the interoperability of the design data. In all likelihood, multiple models will be produced in different disciplinary BIM applications and these will have to be combined into one composite model for visualization, clash detection, and other tasks (figure 1). At the same time, the guide emphasizes that it is not necessary to create all the models to derive the benefits of using BIM on a project. Contractors can make many "partial uses" of BIM such as assisting with scoping during bidding and purchasing, reviewing portions of the project scope for analyses such as value engineering, coordinating construction sequencing (even if just for two trades), demonstrating project approaches during marketing presentations, and so on (Khemlani,2006).

Although BIM is able to keep record of how much material is used, it is not able to determine how much labor and effort are required to construct these new and complicated designs, this is a specialty of cost consultants. They will become vital to construction estimators on very complex projects. Additionally, there will be no overnight conversion to collaborative working, but for those practices which have the opportunity and capability to respond positively, the eventual gains could be substantial (The IT Construction Forum 2006).

Building Information Modeling requires both research and development to implement into a construction companies process and a rather large investment. Software that can manipulate BIMs, like Revit®, cost about $6,000 per license. Cost of the software and training make it difficult for design and construction companies to justify purchasing and implementing. Estimates have also suggested that as much as 30% of project costs are wasted through poor management of the design-construction process (Brown and Beaton 1990).

The definition of project success has changed over the years. In the 1960s, project success was measured entirely in technical terms: either the product worked or it did not. In the 1980s, the following definition for project success was offered: project success is stated in terms of meeting three objectives: completed on time, completed within budget, and completed at the desired level of quality. The quality of a project was commonly defined as meeting technical specifications. Note that all three of these measures are internal to a project, and do not necessarily indicate the preferences of the end user or the customer. In the late 1980s, after the introduction of Total Quality Management (TQM), a project was considered to be a success by not only meeting the internal performance measures of time, cost and technical specifications but also making sure that the project is accepted by the customer; and resulted in customers allowing the contractor to use them as a reference (H. Kerzner, 1998).

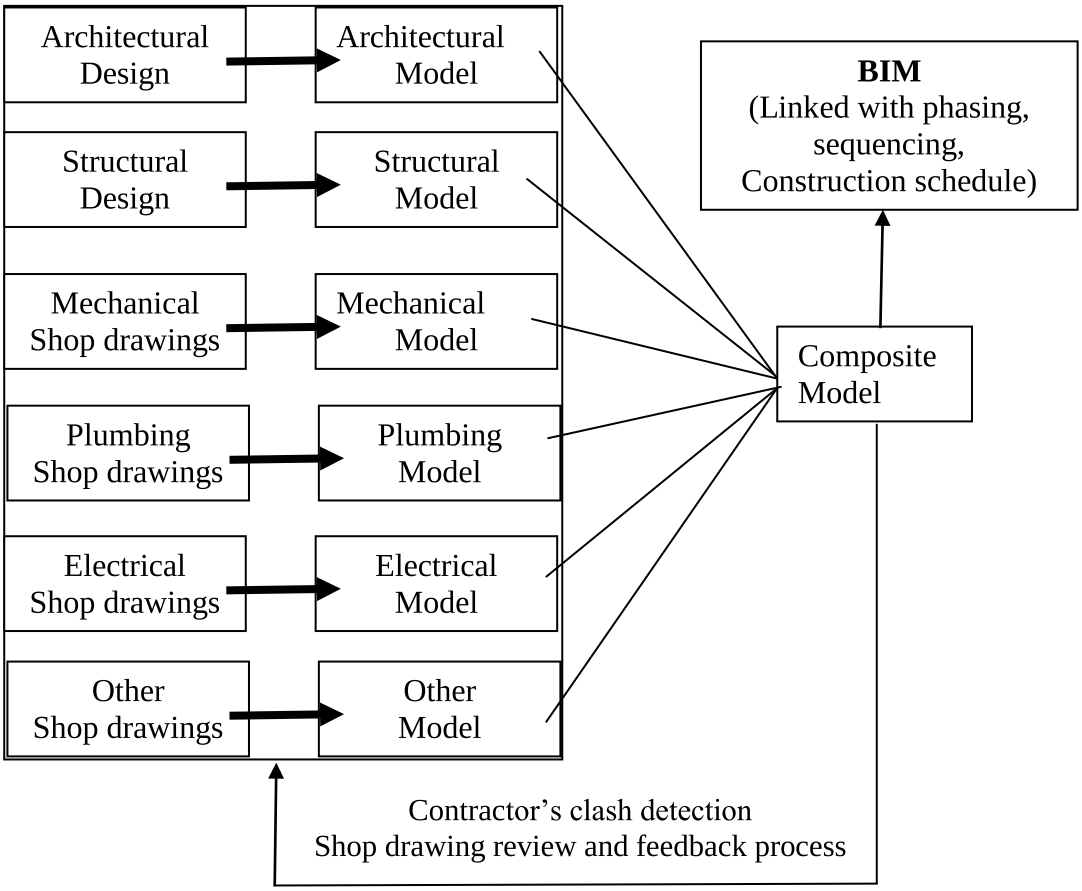

Figure 1: combining multiple models into a composite model adopted from contractors Guide to IM 2006

Atkinson (1999) separates success criteria into delivery and post-delivery stages and provides a "square route" to understanding success criteria: iron triangle, information system, benefit (organizational) and benefit (stakeholder community). The 'iron triangle', has cost, time and quality as its criteria (for the delivery stage). The post-delivery stages comprise: the information system, with such criteria as maintainability, reliability, validity, information quality use; benefit (organizational): improved efficiency, improved effectiveness, increased profits, strategic goals, organizational learning and reduced waste; and benefit (stakeholder community) comprise: satisfied users, social and environmental impact, personal development, professional learning, contractors profits, capital suppliers, content project team and economic impact to surrounding community.

Lim and Mohamed, as reviewed by Chan, modeled project success measurement into 'micro viewpoint: completion time, completion cost, completion quality, completion performance, completion safety; and macro-viewpoints: completion time, completion satisfaction, completion utility, completion operation. A key feature of this model is that it proposes only lagging indicators and gives no room for continuous assessment and monitoring. Patanakul and Milosevic grouped their measurement criteria into three: criteria from organizational perspective: resource productivity, organizational learning, and criteria from project perspective: time-to-market, customer satisfaction and criteria from personal perspective: personal growth, personal satisfaction (P. Patanakul, D. Milosevic, 2009)

2.3 Building Information Modeling budget estimation and completion of construction projects

BIM affords integrators increased accuracy for quantity takeoffs. Metadata attached to objects allows for accurate counting and price modeling, improving the accuracy of bids and project pricing. Automated quantities generation provides a faster, more accurate tool to analyze data and provide better advice. This enables real-time options modeling and facilitates scenario testing to explore ways to improve building design, efficiency, performance and cost (Shaw, 2010). Quantity take-offs from a BIM model enable project teams to quickly generate cost estimates to assist in decision-making and provide cost information about alternatives to owners early in the design phase and throughout the project lifecycle. The BIM model is integrated with cost information from an estimating database, and this approach has proven to be quicker and reduces the possibility for errors and omissions. It can also reduce quantity take-off time and allow estimators to focus on higher value activities, such as identifying construction assemblies, generating pricing, and factoring risks (Autodesk, 2013).

It is no longer news that construction costs are, traditionally, relatively high mainly due to the fragmented nature of the industry (Wong, 2009). The importance of determining the impact of BIM on project cost is underscored by the significant value of losses incurred by the industry on an annual basis. These losses – valued at £100 million (Nisbet and Dinesen 2010) –would otherwise be savings in the coffers of public and private investors alike, hence the need to analyze the value accruable to an investment in BIM over and above traditional means of project executions. When considered with respect to cost, BIM is referred to as '5D BIM' (Vogt 2010 P. 15). In the paper, 'BIM's Return on Investment', Autodesk (2007) argue that firms adopting BIM may easily calculate their returns from investing in BIM using the mathematical formula: Earnings/Cost = ROI.

Azhar et al (2008) reports that a 2007 study by the Stanford University Centre for Integrated

Facilities Engineering (CIFE), based on 32 major projects that employed BIM, found cost benefits including a reduction of unbudgeted change by 40%, accuracy of cost estimation brought to within 3%, time taken to produce a cost estimate reduced by 80%, and clash detections resulting in savings of as much as 10% of the contract value. Perhaps the most compelling evidence for the cost effectiveness of BIM comes from a 2009 US study (Young et al. 2009), with two thirds of over 1,000 BIM users seeing positive return on investment (ROI). Most telling from this study, businesses that actually measured their ROI found substantially greater benefits than those who simply estimated the benefits; 57% of companies who directly measured the benefit found a ROI of 10 percent or greater, compared to 36 percent of companies who simply estimated ROI (Young et al, 2009).

One Island East Office Tower in Hong Kong which was developed by Swire Properties Limited. Together with the project BIM consultant, Gehry Technologies (GT) they began the process of working together to create a single, 3D electronic Building Information Model

(Riese, 2006). The One Island East is a 308 meter high skyscraper with 59 stories of office space and two basement levels. The building has 70 floors in total which comprise of a sky lobby on 37th and 38th floors (Elkem Microsilika, 2009). The outcome of use of BIM in design and construction were: there were more than 2000 clashes and errors were identified prior to bidding and construction stage, which resulted significant cost savings. Without BIM it wouldn't have been detected until the actual construction taken place which might potentially cause additional cost and time to the project, the geometric coordination off the design prior to construction is thought to achieve 10% cost savings whilst construction process modeling is thought to contribute further 20% cost savings on the construction and Gammon Construction has also reported that Construction Process Modeling saved the project at least 20 days. This project was awarded the American Institute of Architects 2008 BIM award for design/delivery process innovation (Shen et al, 2009).

2.4 Building Information Modeling time estimation and completion of construction projects.

The scheduling function of BIM is increasingly being exploited in the construction industry and is an aspect of BIM that has caught the interest of contractors and project owners alike (Young, Jones and Bernstein 2008). Referred to as 4D BIM (Vogt, 2010),the time-savings possibility that BIM offers came as the second top-ranked Key Performance Indicator (KPI) given the most priority by respondents to the survey conducted by Suermann and Issa (2007). It is argued that 4D BIM is the result of combining geometry with Critical Path Method (CPM) schedules (East 2009). The means by which measurement of geometric quantities is executed by software programmes is termed 'auto-quantification' (Olatunji, Sher and Ogunsemi 2010) – a process that has, arguably, reduced the time on the extraction of quantities by nearly half the initial figures (Wilson, 2009).

Again, referring to the results of the survey of 185 construction companies; 70 percent of the respondents claimed they had realised performances in terms of time during construction, the time savings attendant upon a BIM-oriented approach during the construction phase of projects is evident. It must be noted, however, that time savings realised by the respondents in question, however, was mainly through the avoidance of repetitive work during construction (Azhar, 2009)

Buttressing the impact of BIM on project time / schedule further, Autodesk (2010) in the paper, “The Five Fallacies of BIM” used a Georgia based firm (Lott + Barber Architects) as case study to evidence the capacity of BIM to speed up project time. The firm was able to quantify time-gains by simultaneously comparing hours saved using CAD with time saved using BIM on the same project. The result of their findings is illustrated in table 2.1

Table 2. 1: Comparison of time savings between CAD and BIM, Autodesk (2010)

Task	CAD (hours)	BIM (hours)	Hours saved	Time savings
Schematic design	190	90	100s	53%
Design development	436	220	216	50%
Construction documents	1023	815	208	20%
Checking and coordination	175	16	159	91%
Totals:	1,824	1,141	683	

While the result of the comparative exercise in table 1 and clearly highlights the significant impact of a BIM approach, replicating the feat of Lott + Barber Architects across the construction industry and across projects of different sizes may prove challenging (Yan and Damian, 2008).

2.5 Building Information Modeling error elimination and completion of construction projects.

This is the most rated way by which owners save time and money using BIM (McGraw Hill Construction, 2009). In 2D drawings, any changes in one drawing are not updated in other related drawings. This leads to many inconsistency and hence lots of errors and omissions. Lot of these errors is detected only after the work has started at the site, which might lead to many site conflicts, legal disputes and change orders. However, use of BIM eliminates these issues. Conflicts are identified before they are detected at site and hence co-ordination between the designers and the contractors are enhanced. Detection of errors speeds the construction process, reduces costs, minimizes legal disputes and provides a better project process (Eastman, 2008).

The traditional production of project documentation is time consuming, costly, and prone to human error (Williams, 2007). In addition to this 'the project delivery process is fraught by lack of cooperation and poor information sharing' (Howell, and Batcheler, 2005). There is a consistent acknowledgement that 30% of construction costs can be attributed to waste (Montague, 2011) .Most often these inefficiencies are attributed to the ineffective production of construction documentation, wasted materials from inaccurate quantities, additional labour from making changes to completed works and untimely deliveries from unrealistic schedules. Haskell asserts that other industry manufacturers fund research and development which they benefit greatly from, while in the fragmented construction industry, very little research takes place as 'architects and engineers have neither the resources nor incentive to fund research and constructors have little ability to influence innovation in architectural, engineering, or product design' (Haskell, 2004). Haskell recognizes the primary areas of near term productivity gain as coming from information technology and the pre-fabrication of elements (Haskell, 2004).

Parametric Building Information Models allow for the discovery of design errors early and significantly reduce the probability of extensive redesign. Model elements that are dependent upon one another maintain their relationships throughout changes to either element. For example, an electrical outlet in a wall will remain at the correct location in the wall if the wall is moved. The cost of repairing design errors increases as the project design progresses and the earlier discovery of these errors lessens schedule overrun from redesign (Azhar, and Sketo, 2008).

BIM helps reduce errors and omissions (E&O) which should in turn reduce E&O claims and professional liability. A reduction in insurance costs, bonding fees and a positive impact on firm reputation should increase the number, scale and variety of opportunities available to design and integration firms. In the United States, 57% of designers who use BIM say they find the technology directly reduces the number of errors and omissions during the design phase of the project (Mc Graw-Hill SmartMarket report 2014)

The synchronized and collaborative nature of BIM allows for earlier clash detection between the numerous members of the design team. When areas of conflict are identified earlier, conflicts over space allocation are initiated and resolved sooner. Earlier clash detection therefore shortens the time required for building design and reduces costs associated with correcting clashes that were undetected during design reviews (Autodesk 2012)

2.6 Building Information Modeling quality improvement and completion of construction projects.

In construction circles, "the total of features and characteristics of a product or service that bears on its ability to satisfy stated or implied needs" (Tukel and Rom 1997) is generally regarded as quality. While it is argued that BIM contributes to overall project quality (Eastman et al. 2008), it is also widely acknowledged that quality as a concept, especially in the construction industry, is 'elusive' (Pinder and Wilkinson 2000, Ellinkhuizen 2009). This widespread scepticism comes on the heels of numerous criticisms levelled against the industry for the low quality of its products (projects) (Wong 2009). It is no wonder then that the highest priority given by users of BIM is to the issue of quality (Suermann and Issa 2007, Azhar 2009). Nevertheless, BIM adoption is regarded as an efficient contributor to better project quality than was ordinarily possible under the traditional order of things (Wong 2008). The challenge with this assumption, however, is that while BIM may represent a new way of doing work that is significantly different from what is obtainable in traditional settings, project stakeholders have not changed and it is doubtful whether their perceptions have changed either(Eastman et al, 2011).

In order to create checks and balances to quality issues, it is recommended that BIM managers – professionals skilled at handling BIM related projects – be responsible for providing quality control (QC) checks; before and during construction (Fong et al. 2009). On the contrary, CIC (2010) argue that these QC checks are the responsibility of project team members and the BIM manager should, instead, be responsible for confirming model quality subsequent to the revisions by the team members. The CIC (2010) recommend that these quality control checks be done prior to completion of BIM tasks. Arguing about the benefits of BIM, Fong et al. (2009) propose two ways, among several others, of achieving quality control: ensuring that the construction documents fed into a Building Information Model is of high quality in the first place and then maintaining a project environment that promotes clear communication. From the foregoing, it is easy to see that the quality aspect of BIM bears some semblance to Just in Time (JIT) which has as its central philosophy, "do it right the first time" (Ikerd, 2009).

It is argued that one way to deal with the elusive aspect of quality in BIM is by setting and aiming to achieve project goals – like integrating large amounts of prefabrication - during construction (CIC 2010). Nevertheless, (Kalay 2006 cited by Penttilä and Elger 2008) expresses some scepticism regarding quality in BIM; arguing that, while BIM may contribute to efficiency and promote ease of communication, it – inevitably – compromises on project quality. Differing, the CIC (2010) argues that quality will be sustained in addition to the other positive Influence that BIM brings to construction projects so long as the project team members 'buying' to the objective of the project and are willing to work in a collaborative BIM-fostered project environment(CIC,2010).

The BIM quality control mechanism facilitates the analysis of 3D models in order to check integrity, quality as well as physical safety of the designs. While BIM technology offers easy visualization along with virtual walk-through functionality, the quality control services highlight potential flaws or weaknesses in designing. Additionally, it reveals the clashing parts and ensures that the 3D model conforms to the construction codes and the organization's best practices. BIMhub quality control tools are being employed extensively by building owners, construction companies and engineering firms as they help to add great value to the project's lifecycle (Autodesk, 2010)

2.7 Theoretical framework

Several existing theories informed the initial analysis of BIM concepts and their relationships. These theories offered clear insights into how to understand complex knowledge structures and their component parts. However, when attempting to apply these established theories to clarify the knowledge structures underlying the BIM domain and to develop practicable tools based on these constructs, the limitations of each theory became evident.

Table 2.2 identifies five theories initially considered and then discounted as applicable to guide this study.

Table 2.2. Existing theories employed to facilitate BIM understanding

THEORY	HOW THE THEORY INFORMED THIS STUDY
Systems Theory as applied to Organizations and Management	Systems Theory provides a framework by which groups of elements and their properties may be studied jointly to understand outcomes (Ackoff, 1971) (Chun, Sohn, Arling, & Granados, 2008). **Study considerations and theory limitations:** using Systems Theory, BIM can be analyzed as either an *abstract system* or as a *system of systems*; the first deals with concepts without attending to their practical application while the second treats BIM as a collection of interrelated abstract *and* concrete systems. While BIM can be considered in many respects as a System of Systems (Cerovsek, 2012), such an approach does not allow the analysis of BIM concepts and relationships from a non-systems' perspective. Also, Systems Theory is applicable in understanding machine-machine and human-machine interactions, but it is not applicable in understanding human-human interactions
Systems Thinking as applied to Knowledge Management	Systems Thinking focuses on causes, rather than events, but does not isolate the smaller parts of the system being studied. Rather, it considers the numerous interactions of the system in question (Chun et al., 2008). **Study considerations and theory limitations:** through Systems Thinking, BIM can be analyzed as a *knowledge system* leveraged to achieve organizational and industrial goals. Systems Thinking can identify drivers of BIM implementation; however, actual implementation steps cannot be identified. To facilitate BIM implementation, both activities *and* causes/Influence need to be understood. Also, granular parts of the knowledge system – and their interactions - are *as important* to analyze as the knowledge system itself.
Diffusion of Innovation (DoI)	DOI theory attempts to "define the process by which an innovation is communicated through certain channels over time among the members of a social system" (Rogers, 1995, p. 5). That is, DOI theory seeks to explain the dynamics of why/how a new technology spreads.

	Study considerations and theory limitations: Through DOI, the diffusion of BIM -as an *innovative technological solution* proliferating across the construction industry can be analysed (Fox & Hietanen, 2007) (Mutai, 2009). However, DOI does not facilitate the understanding of BIM as an interacting set of technologies, processes and polices; nor does it facilitate the generation of practicable performance improvement tools.
Technology Acceptance Model (TAM)	TAM theorizes that an individual's acceptance of a new technological solution is influenced by its perceived usefulness and ease of use. TAM incorporates several theoretical constructs including subjective norm, voluntariness, image, job relevance, output quality and result demonstrability (Davis, 1989) (Venkatesh & Davis, 2000). **Study considerations and theory limitations:** as a technology-driven solution, BIM adoption by individuals – and by extension project teams - can be analyzed under this model. However, this model cannot be applied to organizational systems, or to identify the relationship between project teams.
Complexity Theory	Complex systems are comprised of a large number of components and causal connections amongst them. Each component is self-contained yet shows a high degree of synergy with other components - where the whole is more than the sum of its parts (Homer-Dixon, 2001) (Froese, 2010). **Study considerations and theory limitations:** understanding BIM as *a complex system* allows the identification of its components and their interconnectedness. However, like many other established theories, Complexity Theory does not facilitate the development of practicable performance improvement tools.

2.8 Conceptual Framework

The study was guided by the following conceptual framework.

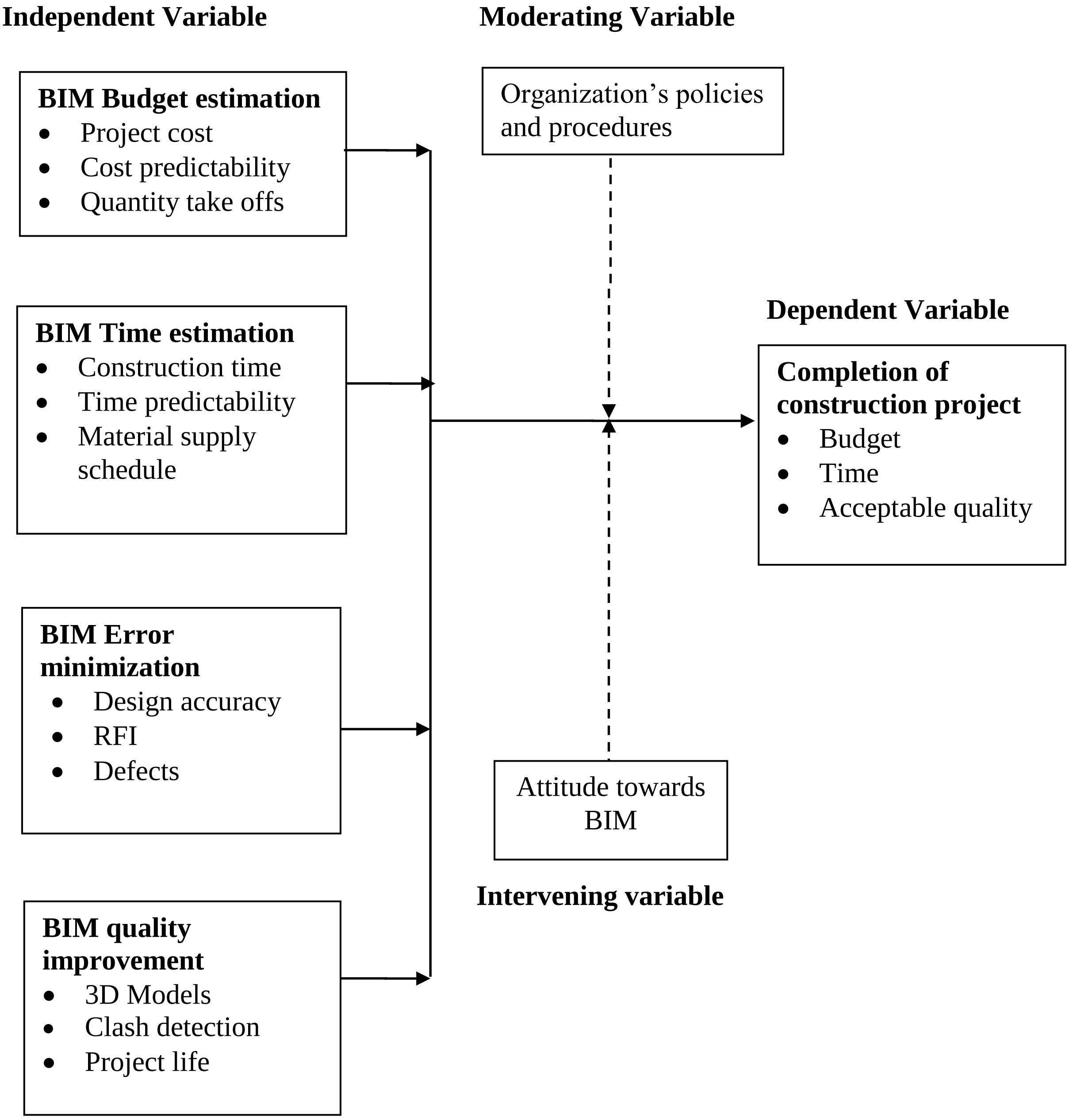

Figure 2: Conceptual Framework

The researcher considered complex theory for analysis on the influence of Building Information modeling adoption on completion of construction projects. The conceptual framework has four independent variables and one dependent variable. The independent variables identified for the study is Building Information Modeling budget estimation, Building Information Modeling time estimation, Building Information Modeling error elimination and Building Information Modeling quality improvement. Completion of construction projects with reference to budget, time, and quality is the dependent variable. The ability of the project to perform is also linked to a large extent on the Organization's policies and procedures (moderating variable). The completion of project tasks with regards to cost, time and quality by use of BIM will also be dependent on the user attitude towards BIM (intervening Variable). This is shown in figure 2.2.

Building information Modeling assimilation to the organization policies and procedure of designing and construction of projects influences the project cost estimation, quantity take offs and cost predictability in case of change in market conditions or unforeseen forces during the implementation stage of the project. However the effectiveness of BIM is affected by the altitude of the users

Adoption of Building information Modeling in the organization policies and procedure of designing and construction of projects influences the project time frame, time predictability under different conditions and their impact on the overall project period and material supply schedule which are derived from the model. However the effectiveness of BIM is affected by the altitude of the users.

Building information Modeling adoption to the organization policies and procedure of designing and construction of projects influences the design accuracy of the consultant's information, the type and number of defects after practical completion of the project and the number of RFIs from the main contractor during construction period. The effectiveness of BIM is however affected by the altitude of the users

Adoption of Building information Modeling in the organization policies and procedure of designing and construction of projects influences the quality of the finished project with reference to clash detection thus less demolitions and recasting, 3D Models produced by BIM enables all stakeholders to have a holistic picture of the entire project and project life of the facility is easily predictable and maintenance measures can be scheduled accordingly. However the effectiveness of BIM is affected by the attitude of the users

2.9 Gaps in literature reviewed

The literature search, no study has been done on the influence of Building Information Modelling adoption on completion of projects a case Nairobi County. Thus, this study will evaluate the influence of BIM budget estimation, BIM time estimation, BIM error minimization and BIM quality improvement on completion of construction projects. The recommendation will communicate to the government, and other stakeholders the influence of BIM adoption on completion construction projects on time, within budget and to acceptable quality standards.

2.10 Summary of literature review

Chapter two discusses the literature relevant to the objectives of the study; BIM budget estimation, BIN time estimation, BIM error minimization and BIM quality improvement. These are discussed in detail and how they influence construction project completion which is the dependent variable. This is also captured in the conceptual framework which is a tabulated relationship between the independent variables and dependent variable. Finally the research gaps are also identified in this chapter

CHAPTER THREE: RESEARCH METHODOLOGY

3.1 Introduction

This chapter gives an outline of how the study was carried out. It describes the research design, the target population, the sample and sampling procedure, research instruments, validity and reliability of instruments, data collection procedures and data analysis techniques that were used. It also entails ethical considerations and operational definition of variables.

3.2 Research Design

A descriptive survey research design was used because descriptive research design does not involve modifying the situation under study nor to determine the cause-effect relationship. It involved acquiring information about a certain segment of the population and getting information on their characteristics, opinions or attitudes (Orodho, 2003). This research design has been chosen for this study because it enabled the researcher to obtain the opinions of Architects, Engineers and project managers involved in construction projects in their natural setting. It was also useful in summarizing the data collected in a way that provided descriptive information. Churchill and Brown (2004) also observe that descriptive research design is appropriate where the study seeks to describe the characteristics of certain groups, estimate the proportion of people who have certain characteristics and make predictions.

3.3 Target population

A target population is the total composition of elements from which the sample is drawn; it is the specific population about which information is desired, (Gerber-Nel, et al, 2011). Burns and Burns (2008), further describe the population as all elements or subjects that meet the criteria for inclusion in a study. The target population is 30 of registered architectural, engineering, project management and construction companies. The study population included project managers, architects, civil and structural engineers, mechanical engineers, electrical engineers and contractors working on the design and construction firms based in Nairobi, Kenya. Five firms were selected from each category.

3.4 Sample size and sampling procedures

Sampling is defined as selecting a given number of subjects from a defined population as a representative of that population (Cooper& Schindler, 2003).

3.4.1 Sample size

Sampling is defined as selecting a given number of subjects from a defined population as representative of that population (Cooper& Schindler, 2003). This defined population is referred to as a sampling frame. Churchill and Brown (2004) further proposes that the correct sample size in a study is dependent on various factors such as the nature of the population to be studied, the purpose of the study, the number of variables in the study, the type of research design, the method of data analysis and the size of the accessible population. Based on the target population consist of 30 and using the Krejice and Morgan table (1970) attached in appendix III, a sample size of 28 will be used for the study.

3.4.2 Sampling procedures

Purposive sampling was used to select the sample from target the population as it allows the researcher study a certain cultural domain with knowledgeable experts within. Selected architectural, engineering and project management firms should have at least have adopted BIM in their operations while contractors should have been registered with the Ministry of Roads & Public Works at least category "C", and currently registered at least as class NCA5 by the National Construction Authority and working with the identified consulting firms. Project management, Architectural, Structural Engineering, Electrical Engineering and Mechanical Engineering firms constituted five respondents while the contractors constituted three respondents. The consulting firms were also duly registered with the relevant registration bodies had a valid practicing license and procured software supporting BIM approach in their projects.

3.5 Research Instruments

The study used both quantitative and qualitative methods of data collection which enabled the researcher to bring together different methodologies for the triangulation of data (Kress, 2011). The researcher prefers the design at it enabled the collection of data from different construction groups and generate numerical and descriptive data that were be used in measuring the correlation between the variables. Data collection was conducted in one phase; this involved a survey to collect both quantitative and qualitative data.

Questionnaires were used to collect information from the selected construction project managers. The questionnaires were self-administered by use of two trained research assistants. Self-administered questionnaire enables one to clarify the questions and probe for more answers. This makes it clear and is likely to yield relevant responses. The questions were phrased in a simple and clear language easily understood by the respondents. The design of the questionnaire was guided by the objectives and the data to be collected.

Secondary data collection is the process of gathering information from sources such as pamphlets, circulars, journals, articles, written reports, related literature that cover topics focused on Building Information Modeling and interoperability and records mainly from Ministry of Public Works and National Construction Authority which were used to provide additional information where appropriate. This contributed towards the formation of background information, needed by the researcher in order to build constructively the project and the reader to comprehend more thoroughly its survey outcome.

3.5.1 Pilot testing

According to Nachmias & Nachmias (2007), pilot testing of research instruments is important because it reveals unclear instruction vague questions and it enables the researcher to improve on the efficiency of the instruments. The research instruments were piloted in one architectural and civil and structural firm which were not part of the main study. This was preferable because the form the main core of Building Information Modeling since most of the other stake holders develop their respective model from architectural and structural models.

3.5.2 Validity of the instruments

Validity relates to the extent to which the research data and the methods for obtaining the data are accurate, honest and on target (Denscombe 2003). Before using a research instrument it is important to ensure that it has some validity. There are three basic approaches to the validity of tests and measures as shown by Mason and Bramble (1989). These are content validity, construct validity, and criterion-related validity. Content validity approach measures the degree to which the test items represent the domain or universe of the trait or property being measured, Construct validity approach concerns the degree to which the test measures the construct it was designed to measure and Criterion-Related Validity approach is concerned with detecting the presence or absence of one or more criteria considered to represent traits or constructs of interest. According to Cooper and Schindler (2006), the researcher may choose to do it alone or may use a panel of experts to judge how well the instrument meets standards. To establish the validity of the research instrument the researcher sought the opinions of experts in the field of study especially the University of Nairobi lecturers in the department of Extra Mural Studies. This assisted to improve the content validity of the data that was collected.

3.5.3 Reliability of the instruments

Reliability is defined as the degree to which research instruments yield consistent results after repeated trials. Reliability is an indication of the stability and consistency with which the instrument measures the concept and is influenced by random error (Mugenda & Mugenda, 1999). This is a measure of how stable, dependable, trustworthy and consistent a tool is in measuring the same thing each time. Piloting of the instruments was done to test the constructive reliability of the instruments. The pilot group should be at least 10% of the sample size (Denscombe, 2003). This is what led the researcher to choose a sample of three participants in the pilot study. In addition, using internal consistency methods, reliability was tested through the Cronbach Alpha test whose formula is: $\alpha = \frac{K}{K-1}\left(1 - \frac{\sum_{i=1}^{K}\sigma_{Y_i}^2}{\sigma_X^2}\right)$ to reveal the reliability of the instrument.

In the pilot study K represented the number of variables being measured in the study. There were twelve questions (variables) asked to the three respondents who were interviewed during the pilot study. The findings were fed into the SPSS software to give a Cronbach Alpha test score of 0.75. In this study, the Cronbach Alpha test score of 0.75 for internal reliability was within the recommendable range indicating an acceptable and good reliability (Manning & Munro, 2006).

3.6 Data collection procedure

The researcher sought permission from the organization of study, (USK) to carry out the study. The questionnaires were administered personally by the researcher and this facilitated any clarifications required in the process of probing for more answers. The researcher also attached a permission letter from the organization and an introductory letter to assure the respondent of confidentiality and encourage free flow of information from the respondent.

3.7 Data Analysis Techniques

Data analysis is the conversion of all the gathered information into something which can easily be understood. The purpose of any research is not simply having data, but to deduce information from the data gathered. Cooper and Schindler (2003), say that data analysis consists of running various statistical procedures and tests on collected data. After data collection, the data was organized and edited to remove any inconsistencies, repetitions or errors that make analysis difficult. Data collected was analysed using both quantitative and qualitative methods. The quantitative data was coded to enable the responses to be grouped into various categories.

Descriptive statistics such as mean, standard deviation and frequency distribution was used to analyse the data. The Statistical Package for Social Sciences (SPSS V. 21.0) was used in the analysis. Frequency tables were used to present the data collected for ease of understanding and analysis. According to Orodho, (2003) the simplest way to present data is in frequency or percentage tables, which summarizes data about a single variable. The purpose of descriptive statistics is to enable the researcher to meaningfully describe a distribution of scores or measurements using a few indices or statistics (Mugenda and Mugenda, 1999). Qualitative data are based on meaning expressed through words. It involves the collection of non-standardized data that require classification and analysation through use of conceptualization.

3.8 Operational Definition of Variables

Table 3.1: Operational Definition of Variables

Research objectives	**Type of variable**	**Indicator**	**Measurement Scale**	**Data Collection Methods**	**Tools of Analysis**	**Data analysis**
To establish the influence of Building Information Modelling budget estimation on completion of construction projects;	Independent	• Project cost • Cost Predictability • Quantity take offs	Ordinal	Questionnaire	Mean Percentage	Descriptive statistics
To determine the influence of Building Information Modelling error minimization on completion of construction projects	Independent	• Design accuracy • RFIs • Defects	Ordinal	Questionnaire	Mean Percentage	Descriptive statistics

Research objectives	Type of variable	Indicator	Measurement Scale	Data Collection Methods	Tools of Analysis	Data analysis
To assess the influence of Building Information Modelling time estimation on completion of construction projects	Independent	• Design period • Construction time • Time predictability • Material supply schedule	Ordinal	Questionnaire	Mean Percentage	Descriptive statistics
To establish the influence of Building Information Modelling quality improvement on completion of construction projects	Independent	• 3D Models • Clash detections • Project life	Ordinal	Questionnaire	Mean Percentage	Descriptive statistics

3.9 Ethical Considerations

The participants were informed of the intentions of the study so that they can participate willingly and from a point of awareness. The researcher also accorded confidentiality while collecting and analyzing the data collected and did not allow any kind of distortion. In addition, the researcher was not subjected to conform to any preconceived opinions but was guided by objectivity. The identity of the respondents is protected and pseudo names are used in case any individual stories are highlighted in the report.

The researcher also obtained the necessary permits from the organization and the University of Nairobi, School of Continuing and Distance Education, Department of Extra-Mural Studies before conducting the study.

CHAPTER FOUR: DATA ANALYSIS PRESENTATION AND INTERPRETATION

4.1 Introduction

In this chapter, the findings of the study are presented and discussed in thematic subsections in line with the study objectives. The thematic areas include: questionnaire return rate, demographic characteristics of the respondents, Building Information Modelling budget estimation and completion of construction project, Building Information Modelling time estimation and completion of construction project, Building Information Modelling error elimination and completion of construction project and Building Information Modelling quality improvement and completion of construction project.

4.2 Questionnaire Return Rate

Out of the sampled 28 respondents, two were not available during the data collection period. Thus the questionnaires were administered to and collected from 26 respondents. This represents 93% return rate and is presented in Table 4.1.

Table 4.1: Questionnaire Return Rate.

		Response Rate	
Firms	**Sample**	**Returned**	**Percentage**
Project Management	4	4	100
Architectural	5	5	100
Civil & Structural Engineer	5	5	100
Mechanical Engineer	5	4	80
Electrical engineer	5	4	80
Contractors	4	4	100
TOTAL	**28**	**26**	**93.0**

The high questionnaire return rate, 26 out of 28 (93.3%) was achieved because the researcher made prior arrangements with the respondents to meet them through email communications.

The researcher introduced the topic and purpose of the study, clarified any issues and provided responses to queries raised, personally administered all the questionnaires and collected the completed questionnaires at the end of the meetings. However, 2 (7%) of the respondents were not available due other work commitments. Mugenda & Mugenda (2003) provides guidelines for the range of rate return acceptable in research. The literature categorizes 50% as adequate, 60% as good and 70% and above as very good for analysis and reporting. Thus, the questionnaire return rate of 98.1% was very good and surpassed the minimum threshold for achieving the objectives of the study.4.3 Demographic characteristics of the respondents

The study sought to find out the demographic characteristics of the respondents in order to have purposeful use of their opinions, thoughts and perceptions to generalize the findings of the study. BIM users within the various firms were taken to give a representative opinion of the influence of BIM on successful completion of projects within Nairobi County. Thus, establishing the demographic characteristics of the respondent was very useful in the study. The demographic characteristics of the respondents were, age, gender, software, and the years of using the software.

4.3 Background Information

4.3.1 Distribution by Gender of the respondents

Table 4.2 shows the data collected on the distribution of the respondents by gender.

Table 4.2: Distribution by Gender of the respondents

Gender	Frequency	Percentage
Male	20	77
Female	6	23
TOTAL	**26**	**100**

From the data collected, the findings revealed that majority, 20 (77%) of the respondents were male, 6 (23%) of them were female, the findings therefore implies that majority of respondents were male as compared to the female, the inclusion of both genders was essential in ensuring diversity of opinion.

4.3.2 Distribution by Age of the respondents

Table 4.3 shows the data collected on the distribution of the respondents by age.

Table 4.3: Distribution by Age of the respondents

Age Bracket.	Frequency	Percentage
(21-30) years	5	19
(31-40) years	12	46
(41-50) years	9	35
TOTAL	**26**	**100**

The data collected, revealed that majority, 12 (46%) of the respondents were aged between (31-40) years, 9 (35%) were aged between (41-50) years, while 5 (19%) were aged between (21-30) years. The findings therefore deduce that majority of the participants into the study were aged between (31-40) years. This represents the age bracket who were more practicing BIM in their daily operations.

4.3.3 Distribution by BIM software used by the respondents

Table 4.4 shows the data collected on the distribution of the respondents by marital status.

Table 4.4: Distribution by BIM software used by the respondents

Software	Frequency	Percentage
Autodesk Revit	14	53
Autodesk NavisWork	3	12
Archicad	9	35
Tekla	0	0
Bentley	0	0
Total	**26**	**100**

From the data collected as shown above, majority 14 (53%) of the respondents used Autodesk Revit, 3 (12%) used Autodesk NavisWork, 9 (35%) used Archicad while 0(0%) used Tekla and Bentley software, the findings therefore implies that majority of the respondents used Autodesk Revit software, implying these were the majority who had incorporated BIM in their operations

4.3.4 Period the respondents have been using BIM software

The study further sought to find out how long the respondents had been using the various BIM software, the data collected were presented in the Table 4.5.

Table 4.5: Period the respondents have been using BIM software

Period	Frequency	Percentage
Less than one year	8	31
Between 1 and 3 Years	10	38
Between 3 and 5 Years	5	19
More than 5 Years	3	12
TOTAL	**26**	**100**

From the data collected as shown in the table above, majority 10 (38%) of the respondents were using BIM software between 1 and 3 years, 8(31%) were using BIM software for less than a year, 5 (19%) were using BIM software between 3 and 5 years while 3(12%) of the respondents were using BIM software for more than 5 years. By implication, majority of the respondents have implemented BIM for 1 to 3 years within their organization.

4.4 Building Information Modelling budget estimation and completion of construction project.

Completion of projects within budget is one of the aspects considered as an indication of success of the project. Building information Modelling has an influence on some of the parameters the affect the project budget and such was the interest of the researcher.

To achieve this objective, the project cost, cost predictability and quantity take offs aspects were considered.

4.4.1 Project cost and completion of construction projects

The project cost may be reduced by use of BIM by compressing time for construction, generating specific costs for changes, and handling changes up front. The respondents were asked the whether the use of BIM reduces the project overall cost at completion of a project. The results were presented in Table 4.6.

Table 4. 6: Influence of project cost on completion of construction projects

Response	Frequency n=26	Percentage	Score on likert scale
Strongly disagree	0	0.0	0
Disagree	2	7.7	4
Neutral	4	15.4	12
Agree	8	30.8	32
Strongly agree	12	46.1	60
Total	**26**	**100.0**	108
Mean Score on likert scale			**4.15 (5)**

Out of the 26 respondents, 2(7.7%) disagreed, 4 (15.4%) of them were impartial, 8 (30.8%) agreed and 12 (46.1%) strongly agreed that the use of BIM reduces the overall cost. This translates to a mean of 4.15 (rounded off to 4) on a 5 point likert scale. It was established that use of BIM in both design and construction phase reduces the overall project cost.

4.4.2 Cost predictability and completion of construction projects

The study sought to establish whether prediction of cost is made easier by implementing BIM, thus ensuring completion of construction on budget, the data collected were presented in the Table 4.7.

Table 4.7: Influence of Cost predictability and completion of construction projects

Response	Frequency n=26	Percentage	Score on likert scale
Strongly disagree	0	0.0	0
Disagree	2	7.7	4
Neutral	4	15.4	12
Agree	12	46.1	48
Strongly agree	8	30.8	40
Total	**26**	**100.0**	104
Mean Score on Likert scale			**4.0 (5)**

Out of the 26 respondents, 2(7.7%) disagreed, 4 (15.04%) of them had no Influence, 12(46.1%) agreed and 8(30.8%) strongly agreed that predicting project cost is made easier while using BIM. This translates to a mean of 4.0 on a 5 point Likert scale. It was established that the AEC industry key players agreed that utilization of BIM has eased project cost prediction enabling completion of construction projects within budget. This finding was agreed with a recent survey, The Challenges Facing a Growing Industry: The 2016 Construction Hiring and Business Outlook done by Kevin Miller in 2016 that concluded that ultimately, 5-D BIM will lead to more reliable cost feedback during the project planning stage. This results in greater cost predictability and minimizes later changes in project scope due to cost overruns.

4.4.3 Quantity take offs and completion of construction projects

The study sought to establish the influence of quantity take offs on the completion of construction projects, the data collected were presented in the Table 4.8.

Table 4.8: Influence of quantity take offs and completion of construction projects

Response	Frequency n=26	Percentage	Score on likert scale
Strongly disagree	0	0.0	0
Disagree	0	0.0	0
Neutral	0	0.0	0
Agree	10	38.5	40
Strongly agree	16	61.5	80
Total	**26**	**100.0**	120
Mean Score on likert scale			**4.6 (5)**

Out of the 26 respondents, 10 (38.5%) agreed and 16 (61.5%) strongly agreed that quantity take offs using BIM were easier and more accurate thus inherently ensuring completion of projects with the allocated budget. This translates to a mean of 4.5 (rounded off to 5) on a 5 point Likert scale. This finding was agreed with the survey done by Deutsch, 2011 that concluded that Metadata attached to objects in the BIM model allows for accurate counting and price modeling, improving the accuracy of bids and project pricing.

4.5 Building Information Modelling Time estimation and completion of construction project.

Objective two of the study sought to establish how BIM time estimation influences completion of project within the specified time frame. Completion of projects within the contract period is one of the aspects considered as an indication of success of the project.

To achieve this objective, the construction time, time predictability and material supply schedule aspects were considered.

4.5.1 Construction period and Completion of construction projects

The study sought to establish the influence construction period on the completion of construction projects, the findings were presented in the Table 4.9.

Table 4. 9: Influence project construction time on completion of projects

Response	Frequency n=26	Percentage	Score on likert scale
Strongly disagree	0	0.0	0
Disagree	2	7.7	4
Neutral	0	0.0	0
Agree	10	38.5	40
Strongly agree	14	53.8	70
Total	**26**	**100.0**	114
Mean Score on Likert scale			**4.38 (5)**

Out of the 26 respondents, 2(7.7%) disagreed, 10 (38.5%) agreed and 14 (53.8%) strongly agreed that use of BIM increases accuracy of time projection for the project thus projects are completed within the stipulated time frame. This translates to a mean of 4.47 (rounded off to 4) on a 5 point likert scale. It was established that the AEC industry key players agreed that utilization of BIM increases accuracy of project time projection for completing projects. The findings are in line with those of Vogt, 2010 which concluded that use BIM models give accurate project time projection for completion of projects because the BIM model being a virtue construction and taking care of any anticipated changes before actual construction begins.

4.5.2 Time predictability and Completion of construction projects

The ability to be able to predict time schedule during project life is one of the ways of ensuring completion of projects on time. The study sought to establish the influence of time predictability of and completion of construction projects, the data collected were presented in the Table 4.10.

Table 4. 10: Influence of time predictability on completion of projects

Response	Frequency n=26	Percentage	Score on likert scale
Strongly disagree	0	0.0	0
Disagree	4	15.4	8
Neutral	0	0.0	0
Agree	14	53.8	56
Strongly agree	8	30.8	40
Total	**26**	**100.0**	104
Mean Score on likert scale			**4.0(5)**

Out of the 26 respondents, 4(15.4%) disagreed, 14 (53.8%) agreed and 8(30.8%) strongly agreed that BIM enhances the project time predictability thus inherently ensuring that projects are completed on schedule. This translates to a mean of 4.0 on a 5 point Likert scale. It was established that the AEC industry key players agreed that utilization of BIM enhance of project time predictability. This finding is line with the research carried out by Davies and Harty, 2013 who found that use of 4D BIM improves the time predictability of construction projects during the planning stage.

4.5.3 Material supply schedule and Completion of construction projects

The study sought to establish the influence material supply schedule on completion of construction projects, the data collected were presented in the Table 4.11.

Table 4. 11: Influence of material supply schedule on completion of projects

Response	Frequency n=26	Percentage	Score on likert scale
Strongly disagree	0	0.0	0
Disagree	0	0.0	0
Neutral	0	0.0	0
Agree	8	30.8	32
Strongly agree	18	69.2	90
Total	**26**	**100.0**	122
Mean Score on likert scale			**4.7 (5)**

Out of the 26 respondents, 8 (30.8%) agreed and 18 (69.2%) strongly agreed that material schedule are easily derived when using BIM. This innately ensure proper planning for the material delivery to avoid delays on the completion of the project. This translates to a mean of 4.7 (rounded off to 5) on a 5 point Likert scale. It was established that the AEC industry key players strongly agreed that utilization of BIM eases material supply schedule preparation. . This finding is line with Autodesk (2007) report that deduced that BIM is a database that contains manufacturer information, pricing, physical information (such as weight, size, and material finish) and electromechanical data for many of the devices in the building. Leveraging this data means that very accurate material schedules can be created from the parametric model elements and they will change automatically with visual component

4.6 Error minimization and Completion of construction project

Objective three of the study sought to establish the influence of BIM error minimization on completion of construction projects. To determine the influence of BIM error elimination on completion of the project, the aspects of design accuracy, defects and RFIs were considered under this theme.

4.6.1 Design accuracy and Completion of construction projects

The study sought to establish the influence of design accuracy on and Completion of construction projects. The data collected was presented in the Table 4.12.

Table 4. 12: Influence of design accuracy on completion of projects

Response	Frequency n=26	Percentage	Score on likert scale
Strongly disagree	0	0.0	0
Disagree	2	7.7	4
Neutral	0	0.0	0
Agree	20	76.9	80
Strongly agree	4	15.4	20
Total	**26**	**100.0**	104
Mean Score on likert scale			**4.0(5)**

Out of the 26 respondents, 2(7.7%) disagreed, 20(76.9%) agreed and 4 (15.4%) of them strongly agreed that BIM accelerates the design process. This translates to a mean of 4.0 on a 5 point likert scale. It was established that the AEC industry key players agreed that utilization of BIM accelerated and increased the accuracy of the design process thus inherently ensuring the project are completed on time, within budget and acceptable quality. This finding is line Azhar (2011) who assert that when BIM is applied the risk of mistakes or discrepancies is reduced, and abortive costs minimized.

4.6.2 Defects and Completion of construction projects

The study sought to establish the influence of defects on completion of construction projects. The data collected was presented in the Table 4.13.

Table 4. 13: Influence of defects on completion of construction projects

Response	Frequency n=26	Percentage	Score on likert scale
Strongly disagree	0	0.0	0
Disagree	0	0.0	0
Neutral	0	0.0	0
Agree	10	38.5	40
Strongly agree	16	61.5	80
Total	**26**	**100.0**	120
Mean Score on likert scale			**4. 62(5)**

Out of the 26 respondents, 2 (7.7%) disagreed, 20 (76.9%) agreed and 4 (15.4%) of them strongly agreed that the use of BIM reduces the number and nature of defects. This implies that project can be completed within budget, time and to acceptable quality standards. This translates to a mean of 4.0 on a 5 point likert scale. It was established that the AEC industry key players agreed that the use of BIM reduces the number and nature of defects. This finding is in line Eastman (2008) which deduced that detection of errors speeds the construction process, reduces costs, reduces defects, minimizes legal disputes and provides a better project process. This is made possible by implementing BIM

4.6.4 RFIs and Completion of construction projects

The study sought to establish the influence of request for information (RFIs) on completion of construction projects. The data collected was presented in the Table 4.14.

Table 4. 14: Influence of RFIs on completion of construction projects

Response	**Frequency n=26**	**Percentage**	**Score on likert scale**
Strongly disagree	0	0.0	0
Disagree	0	0.0	0
Neutral	0	0.0	0
Agree	4	15.4	16
Strongly agree	22	84.6	110
Total	**26**	**100.0**	126
Mean Score on likert scale			**4.85 (5)**

Out of the 26 respondents, 4 (15.4%) agreed and 22(84.6%) of them strongly agreed that the use of BIM reduces the number of RFIs. This translates to a mean of 4.85(rounded off to 5) on a 5 point likert scale. Reduction of RFIs consequently ensure no delays during construction, no cost overruns and reworking of some works. It was established that the AEC industry key players agreed that the use of BIM reduces the number of RFIs. This finding is in line with SmartMarket report (2015) on measuring the impact of BIM on complex buildings which found out that out of the architects, engineers and contractors surveyed three quarters (74%) see at least 5% reduction in RFIs, with almost half (44%) reporting more than 10%

4.7 Building Information Modeling quality improvement and completion of construction project

Objective four of the study sought to establish the influence of BIM quality improvement on completion of construction projects. To determine the influence of BIM quality improvement on completion of construction projects, the aspects of 3D models, clash detections and project life were considered under this theme.

4.7.1 3D models and Completion of construction projects

The study sought to establish the influence 3D models on completion of construction projects, the data collected was presented in the Table 4.15.

Table 4.15: Influence of 3D models on completion of construction projects

Response	**Frequency n=26**	**Percentage**	**Score on likert scale**
Strongly disagree	0	0.0	0
Disagree	0	0.0	0
Neutral	0	0.0	0
Agree	5	19.2	20
Strongly agree	21	80.8	105
Total	**26**	**100.0**	125
Mean Score on likert scale			**4.81(5)**

Out of the 26 respondents, 5 (19.2%) agreed and 21(80.8%) strongly agreed that BIM 3D models increases visualization .This translates to a mean of 4.81 (rounded off to 5) on a 5 point likert scale. . It was established that the AEC industry key players strongly agreed that the use of BIM 3D models increases visualization.

4.7.2 Clash detection and Completion of construction projects

The study sought to establish the influence of clash detection on completion of construction projects the data collected was presented in the Table 4.16.

Table 4.16: Influence of clash detection on completion of construction projects

Response	**Frequency n=26**	**Percentage**	**Score on likert scale**
Strongly disagree	0	0.0	0
Disagree	0	0.0	0
Neutral	0	0.0	0
Agree	11	42.3	44
Strongly agree	15	57.7	75
Total	**26**	**100.0**	119
Mean Score on likert scale			**4.58(5)**

Out of the 26 respondents, 11 (42.3%) agreed and 15(57.7%) strongly agreed that BIM application reduces discrepancies. This translates to a mean of 4.58 (rounded off to 5) on a 5 point likert scale. . It was established that the AEC industry key players strongly agreed that the use of BIM eases clash detection thus ensuring completion of projects within acceptable quality standards. The findings are also in line with those of Kymmell 2008 who assert that BIM application enhances immediate identification of clashes and highlights conflict issues thus enables multi-discipline teams to find solutions before issues reach the site.

4.7.3 Project life and Completion of construction projects

The study sought to establish the influence of project life on completion of construction projects, the data collected was presented in the Table 4.17.

Table 4. 17: Influence of project life on completion of construction projects

Response	Frequency n=26	Percentage	Score on likert scale
Strongly disagree	0	0.0	0
Disagree	6	23.1	12
Neutral	0	0.0	0
Agree	16	61.5	64
Strongly agree	4	15.4	20
Total	**26**	**100.0**	96
Mean Score on likert scale			**3.7(5)**

Out of the 26 respondents, 6 (23.1%) disagreed, 16 (61.5%) agreed and 4(15.4%) strongly agreed that BIM application allows for project life evaluations. This ensures that the project can be kept on within the budget and within the time schedule. This translates to a mean of 3.7 (rounded off to 4) on a 5 point likert scale. . It was established that the AEC industry key players agreed that the use of BIM application allows for evaluation of the project life cycle. The findings are also in line with those of Rokooei (2015) who deduced that a BIM-based IPD approach results in many advantages during the construction project lifecycle. With an integrated collaboration approach, the project team can effectively track, assess and review the project, make decisions when necessary, resolve conflict and discrepancies and execute the project successfully.

CHAPTER FIVE: SUMMARY OF FINDINGS, DISCUSSIONS, CONCLUSION AND RECOMMENDATIONS

5.1 Introduction

This chapter covers summary of the findings, discussion of the findings and conclusion drawn from the study as well as the recommendations based on the study findings and suggestions for further study.

5.2 Summary of the Findings

The first objective was to establish the influence of Building Information Modelling budget estimation on completion of construction projects. To this end, three variables were tested namely project cost, project cost predictability and quantity take offs. On project cost, out of the 26 respondents, 2(7.7%) disagreed, 4 (15.4%) of them were impartial, 8 (30.8%) agreed and 12 (46.1%) strongly agreed that the use of BIM reduces the overall cost. On cost predictability, 2(7.7%) disagreed, 4 (15.04%) of them had no Influence, 12(46.1%) agreed and 8(30.8%) strongly agreed that predicting project cost is made easier while using BIM .On quantity take offs, out of the 26 respondents, 10 (38.5%) agreed and 16 (61.5%) strongly agreed quantity take offs using BIM were easier and more accurate using than conventional ways.. The mean score on a 5 point likert scale on this objective is 4.25 which was rounded off to 4. It was therefore determined that Building information modeling budget estimation positively influences completion of construction projects.

The second objective of the study to assess the influence of Building Information Modelling time estimation on completion of construction projects. To this end, three variables were tested namely construction time, time predictability and material supply schedule. On construction period, out of the 26 respondents, 2(7.7%) disagreed, 10 (38.5%) agreed and 14 (53.8%) strongly agreed that use of BIM increases accuracy of time projection for the project.

This translates to a mean of 4.47 (rounded off to 4) on a 5 point likert scale. On time predictability, 4(15.4%) disagreed, 14 (53.8%) agreed and 8(30.8%) strongly agreed that BIM affects the project time predictability. This translates to a mean of 4.0 on a 5 point Likert scale .On material supply schedule, Out of the 26 respondents, 8 (30.8%) agreed and 18 (69.2%) strongly agreed that material schedule are easily derived when using BIM. This translates to a mean of 4.7 (rounded off to 5) on a 5 point Likert scale.

The third objective of the study was to determine the influence of Building Information Modelling error minimization on completion of construction projects. To this end, four variables were tested namely design accuracy, defects and RFIs. On design accuracy, 2(7.7%) disagreed, 20(76.9%) agreed and 4 (15.4%) of them strongly agreed that BIM accelerates and increases the design process. This translates to a mean of 4.0 on a 5 point likert scale. On defects, out of the 26 respondents, 10(38.5%) agreed and 16(61.5.0%) of the strongly agreed that the use of BIM reduces the number and nature of defects. This translates to a mean of 4.62(rounded off to 5) on a 5 point Likert scale. On RFIs, Out of the 26 respondents, 4 (15.4%) agreed and 22(84.6%) of them strongly agreed that the use of BIM reduces the number of RFIs. This translates to a mean of 4.49(rounded off to 4) on a 5 point likert scale.

The fourth objective of the study to establish the influence of Building Information Modelling quality improvement on completion of construction projects. To this end, three variables were tested namely 3D models, clash detections and project cycle. On 3D models, out of the 26 respondents, 5 (19.2%) agreed and 21(80.8%) strongly agreed that BIM 3D models increases visualization .This translates to a mean of 4.81 (rounded off to 5) on a 5 point likert scale. On clash detections, 11 (42.3%) agreed and 15(57.7%) strongly agreed that BIM application reduces discrepancies. This translates to a mean of 4.58 (rounded off to 5) on a 5 point likert scale. On project life, Out of the 26 respondents, 6 (23.1%) disagreed, 16

(61.5%) agreed and 4(15.4%) strongly agreed that BIM application allows for project life evacuations. This translates to a mean of 3.7 (rounded off to 4) on a 5 point likert scale.

The findings of the study answered the research questions since the influence Building Information Modelling adoption on completion of construction projects within budget, time and to acceptable quality have been quantified by descriptive statistics. The discussion and related literature were presented for each of the four variables of the study.

5.3 Discussion of Findings

The study was conducted to investigate the influence of Building Information Modelling adoption on successful completion of construction projects. The finding derived from the study are discussed in this section.

5.3.1 BIM budget estimation and completion of construction project

On the influence of BIM budget estimation on the completion of construction, the study revealed that that the various dimensions of project budget considered in the study which includes the project cost, project cost predictability and quantity take offs have been greatly influenced the completion of construction projects. The findings also in conforming to literature review reveals that major projects that employed BIM, found cost benefits including a reduction of unbudgeted change, accuracy of cost estimation and projections, and clash detections resulting in savings Azhar et al (2008)

5.3.2 BIM time estimation and completion of construction project

For the influence of BIM time estimation on the completion of construction, the study revealed that that the various dimensions of project time frame considered in the study which includes the project construction time, project time predictability and material supply schedule significantly influenced completion of construction projects. The findings also in conforming to literature review referring to the results of the survey of 185 construction companies; 70 percent of the respondents claimed they had realized performances in terms of time during construction, the time savings attendant upon a BIM-oriented approach during the construction phase of projects is evident. (Azhar, 2009)

5.3.3 BIM error elimination and completion of construction project

On the influence of BIM error elimination on the completion of construction, the study revealed that that the various dimensions of project errors considered in the study which includes the design accuracy, defects and RFIs have been greatly influenced completion of construction projects. The findings also in conforming to literature review reveals that the development of 3D building information modeling (BIM) combined with quantity information management, quantity and cost progress can be monitored and controlled in real-time, with accuracy and with transparency. Discrepancies, cost overflows and problems are seen earlier and steps can be taken to rectify them or at least minimize the consequences (Gren, 2008).

5.3.4 BIM quality improvement and completion of construction project

On the influence of BIM quality improvement on the completion of construction, the study revealed that that the various dimensions of project quality considered in the study which includes the 3D models, clash detection and project life greatly influence completion of construction projects. The findings also in conforming to literature review reveals BIM adoption is an efficient contributor to better project quality than was ordinarily possible under the traditional order of things (Wong 2008).

5.4 Conclusion of study

The study was conducted to investigate the influence of Building Information Modelling adoption on completion of construction projects, from the summary of the finding, the study makes the following conclusions:

On the influence of BIM budget estimation on completion of construction projects, the study concludes that the adoption of BIM reduces the overall cost due to the accuracy of the models, project cost estimation is made easier, accurate and quicker and project cost projections can be easily done since all the necessary information is well stored in the 3D BIM models.

For the influence of BIM time estimation on completion of construction projects, the study concludes that the adoption of BIM increases the accuracy of time projections for the project, reduces the project period because most of the discrepancies are addressed before actual commencement of the project, enhance time predictability of the various components of the project and derives material supply schedules accurately and easily.

On the influence of BIM error elimination on completion of construction projects, the study concludes that the adoption of BIM reduces the design period for the design consortium, reduces the risk of mistakes or discrepancies, and abortive costs are minimized, defines and elaborates the functionality of the end product, reduces the number and nature of defects during and after construction as well as reducing the number of RFIs which in turn ensure productivity and efficiency since so construction works need to reworked and wastage of materials is minimized

For the influence of BIM quality improvement on completion of construction projects, the study concludes that the adoption of BIM increases visualization and understanding of the project, enables clash detections and subsequent solution when identified and ensure that project can be monitored through its entire life including post construction period.

5.5 Recommendations.

Based on the findings and conclusions of the study, the following recommendations were drawn;

1. The study recommends that the government and key players in the construction industry need to adopt BIM 5D for effective budget estimation, monitoring and evaluations.

2. The study recommends that the ACE industry both from private and public institutions embraces BIM 4D to allow them view the planned construction projects over time and review the planned versus actual status time schedules.

3. The study recommends use of BIM clash detection tool in order to minimize errors and discrepancies between the BIM models and the actual construction.

4. Further the study recommends that the stake holders in the construction industry need to invest on 3D printers to enable printing of the 3D models for better visualization.

5.6 Suggestions for Further Studies

The following areas of research could be useful in improving BIM adoption and need to be research further;

1. For future analysis of BIM and productivity in the construction industry, a set of design and interoperability standards has to be adopted, and a shift from CAD to BIM needs to happen.

2. Interoperability with the various programs that are essential to the AEC industry to see how well BIM can be integrated into daily use

3. Legal framework serving the interest of AEC industry players

5.7 Contribution to the body of knowledge

This part highlights the contribution of the study to the body of knowledge based on the findings of the study objectives.

Objective	Contribution
To establish the influence of Building Information Modelling budget estimation on completion of construction projects	The study established that Building Information Modelling budget estimation enhances completion of construction projects with budget .The findings are also in line with those of Azhar et al (2008) who asserts that major projects that employed BIM, found cost benefits including a reduction of unbudgeted change, accuracy of cost estimation and projections, and clash detections resulting in savings.
To assess the influence of Building Information Modelling time estimation on completion of construction projects	The study established that Building Information Modelling time estimation enhances successful completion of construction projects within the specified time frame .The findings are also in line with those of Azhar (2009) who asserts that the results of the survey of 185 construction companies; 70 percent of the respondents claimed they had realized performances in terms of time during construction, the time savings attendant upon a BIM-oriented approach during the construction phase of projects is evident.
To determine the influence of Building	The study established that Building Information Modelling error minimization

Information Modelling error minimization on completion of construction projects.	enhances completion of construction projects within budget, time and acceptable quality standards .The findings are also in line with those of Gren (2008) who asserts that development of 3D building information modeling (BIM) combined with quantity information management, quantity and cost progress can be monitored and controlled in real-time, with accuracy and with transparency. Discrepancies, cost overflows and problems are seen earlier and steps can be taken to rectify them or at least minimize the consequences
To establish the influence of Building Information Modelling quality improvement on completion of construction projects	The study established that Building Information Modelling quality improvement enhances completion of construction projects within acceptable quality. The findings are also in line with those of Wong (2008) who affirms that BIM adoption is an efficient contributor to better project quality than was ordinarily possible under the traditional order of things

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APPENDICES

Appendix I: Letter of Introduction

Date: 18th February, 2015

Manza Daniel Kamanza,

P O Box 26797-00504,

NAIROBI

TO WHOM IT MAY CONCERN

Dear Sir/Madam

RE: REQUEST FOR PARTICIPATION IN A RESEARCH STUDY

I am a Postgraduate student at the University of Nairobi, pursuing a Master's degree in project Planning and Management. As partial fulfillment for the degree I am conducting a research study on "**INFLUENCE OF BUILDING INFORMATION MODELLING ON SUCCESSFUL COMPLETION OF CONSTRUCTION PROJECTS: A CASE OF BUILDING CONSTRUCTION PROJECT IN NAIROBI COUNTY, KENYA**."
Therefore I would appreciate if you could spare a few minutes of your time to answer the following. All the information provided will be purely used for academic purposes and your identity will be treated with utmost confidentiality.

Your assistance will be highly appreciated and thank you in advance.

Yours faithfully,

Manza Daniel Kamanza

L50/62331/2013

Appendix II: Questionnaire

Information provided through the questionnaire will be treated with confidentiality and will be exclusively for academic purpose. All answers will be considered right.

INSTRUCTION:

i. Do not write your name on the questionnaire.
ii. Please read each question carefully.
iii. Kindly answer all the questions by ticking or filling in the spaces provided.

SECTION ONE: BACKGROUND INFORMATION

1. What type of organization do you work within?

☐ BIM Consultant
☐ Client Organisation
☐ Design Consultant
☐ Main Contractor
☐ Quantity Surveying Practise

2. Gender: Male ☐ Female ☐

3. Age: (i) 21- 30years ☐ (ii) 31-40 years ☐ (iii) 41 – 50years ☐

4. What is your profession / background?

☐ Architect
☐ Engineer
☐ Quantity surveyor
☐ Project manager

5. What type of projects do you work generally work on / within?

☐ Publically financed
☐ Privately financed
☐ Both

6. What software is currently in use within your organisation?

- [ ] Autodesk Revit
- [ ] Autodesk NavisWorks
- [ ] Archicad
- [ ] Tekla
- [ ] Bentley

7. How long has the software been in use?

- [ ] Less than one year
- [ ] Between 1 and 3 years
- [ ] Between 3 and 5 years
- [ ] More than 5 years

8. From the following, how would you, to the best of your knowledge, describe BIM?

- [ ] A new way to produce the traditional 2D & 3D information currently produced.
- [ ] A visual model of the building which manages data about it, at the design stage, throughout the construction phase and during its working life.
- [ ] A collaborative way of working, which unlocks more efficient methods of designing, creating and maintaining assets.
- [ ] All of the above
- [ ] Unsure

SECTION TWO: BUILDING INFORMATION MODELLING USE AT THE ORGANISATION AND ITS INFLUENCE ON CONSTRUCTION PROJECTS

A. BIM budget estimation and completion of construction projects

The following statements refer to the influence of BIM budget estimation on project budget. Identify your Level of agreement with the following statements. Likert scale; strongly agree=5, Agree =4, Neutral=3, Disagree=2 and Strongly Disagree=1

Statement	**Strongly Agree**	**Agree**	**Neutral**	**Disagree**	**Strongly Disagree**
The use of BIM reduces overall cost					
Predicting project cost is made easier while using BIM					
The use of BIM reduces increase accuracy of the quantity take offs					

B. BIM time estimation and completion of construction projects

The following statements refer to the influence of BIM time estimation completion of projects. Identify your level of agreement with the following statements. Likert scale; strongly agree=5, Agree =4, Neutral=3, Disagree=2 and Strongly Disagree=1

Statement	**Strongly Agree**	**Agree**	**Neutral**	**Disagree**	**Strongly Disagree**
The use of BIM increases accuracy of time projection for the project					
Use of BIM enhance time predictability					
Material supply schedule are easily derived when using BIM					

C. BIM error minimization and completion of construction projects

The following statements refer to the influence of BIM error minimization on completion of projects. Identify your level of agreement with the following statements. Likert scale; strongly agree=5, Agree =4, Neutral=3, Disagree=2 and Strongly Disagree=1

Statement	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
There is speeding up and increase accuracy of design process					
The use of BIM reduces the number of RFIs					
The use of BIM reduces the number and nature of defects.					

D. BIM quality improvement and completion of construction projects

The following statements refer to the influence of BIM quality improvement on project completion. Identify your level of agreement with the following statements. Likert scale; strongly agree=5, Agree =4, Neutral=3, Disagree=2 and Strongly Disagree=1

Statement	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
BIM 3D Models increases visualization					
The use of BIM eases clash detection					
Project life cycle evaluations can be carried out					

Appendix III: Krejice and Morgan Table.

N	S	N	S	N	S
10	10	220	140	1,200	291
15	14	230	144	1,300	297
20	19	240	148	1,400	302
25	24	250	152	1,500	306
30	28	260	155	1,600	310
35	32	270	159	1,700	313
40	36	280	162	1,800	317
45	40	290	165	1,900	320
50	44	300	169	2,000	322
55	48	320	175	2,200	327
60	52	340	181	2,400	331
65	56	360	186	2,600	335
70	59	380	191	2,800	338
75	63	400	196	3,000	341
80	66	420	201	3,500	346
85	70	440	205	4,000	351
90	73	460	210	4,500	354
95	76	480	214	5,000	357
100	80	500	217	6,000	361
110	86	550	226	7,000	364
120	92	600	234	8,000	367
130	97	650	242	9,000	368
140	103	700	248	10,000	370
150	108	750	254	15,000	375
160	113	800	260	20,000	377
170	118	850	265	30,000	379
180	123	900	269	40,000	380
190	127	950	274	50,000	381
200	132	1,000	278	75,000	382
210	136	1,100	285	1,000,000	384

Note.—N is population size and S is sample size
Source: Krejcie, R.V., & Morgan, D.W., (1970)