EXPLORING THE EVIDENCE OF BIM COLLABORATION IN ZAMBIA

BY

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DECLARATION

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ABSTRACT

Collaboration is critical to the successful implementation of construction projects; the sharing of knowledge and information on a construction project is one of the key factors of a successful contractual relationship. Currently, the visualization, coordination and management of project life-cycle data in the construction industry has been enhanced due to the availability of a wide range of Building Information Modelling (BIM) software, which enable construction industry practitioners to create intelligent BIM models. The aim of the research was to explore the evidence of BIM collaboration in the Zambian construction industry by conducting a comparative study of the private and public sectors of the industry. The objectives of the study were to determine the degree to which BIM is perceived to have been adopted in the Zambian construction industry. The study further identified the challenges and opportunities in the implementation of BIM in the management of construction projects in Zambia. The research also investigated how effectively project team members perceived to have collaborated on a project. The data collection techniques included literature review, structured interviews, questionnaire surveys and case studies. A total of 60 questionnaires were issued and 54 questionnaires were returned indicating a response rate of 90%, the questionnaire survey results were complemented by interviews carried out with ten participants. Further two case studies were reviewed: The Proposed E.I.Z Headquarters at the Agricultural & Show Society Grounds in Lusaka and The Proposed Expansion of National Science Center in Lusaka from the private and public sectors of the construction industry respectively. The study established that individual discipline based BIM software are already being used in Zambia with project team members working at BIM level 1. However, the main barriers hindering full BIM adoption are the prohibitive cost of setting up BIM and lack of Government will and support in terms of policy in BIM implementation. It was further established that mostly it was the Architects who were fully aware of the benefits of BIM collaboration. Being among the first such investigations to be conducted at this level in Zambia, it is expected that information brought out in this study would assist the Zambian construction industry sectors to comprehend and increase their utilisation of BIM in project management processes. Further, the identified challenges and strategies in this study would help project teams in Zambia to plan for the effective utilization of BIM in their future projects.

Keywords: Building Information Modelling, Collaboration, Zambia Construction Industry

DEDICATION

To my wife and my daughter Kukeña, thank you for your support and encouragement. I love you all.

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A number of individuals have contributed in countless ways to enable the completion of this study. It is understandable that some of them preferred to remain anonymous. This notwithstanding, I am especially indebted to Dr Balimu Mwiya who supervised my work thoroughly and efficiently. This dissertation would not have been possible without the vital advice, information, corrections, assistance and mentorship from my supervisor.

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LIST OF ABBREVIATIONS

2D-	Two dimensional
3D-	Three dimensional
AEC -	Architecture, Engineering and Construction Industry
BIM -	Building Information Modelling
CAD-	Computer-aided design
EIZ -	Engineering Institute of Zambia
Eng-RB-	Engineers Registration Board
ICT -	Information and Communication Technology
NCC-	National Council for Construction
QSRB-	Quantity Surveyors Registration Board
SIZ-	Surveyors Institute of Zambia
SPSS -	Statistical Package for the Social Sciences
ZEPIU-	Zambia Education Projects Implementation Unit
ZIA-	Zambia Institute of Architects

CHAPTER 1: INTRODUCTION

1.1 Background

Information and Communication Technology (ICT) is very cardinal in the efficient management of construction projects and it is essential for Project Managers to ensure that ICT systems being used by project team members are compatible, in order to facilitate efficient and effective electronic exchange of project data (CIOB, 2011).

Computer-aided design (CAD) is the use of computer hardware and software in the design of products used by the general populace (Encarnacao & Schlechtendahl, 2012). The use of computer-aided design (CAD) in design and construction traces its roots in 1951 with the establishment of the MIT Lincoln Laboratories, who in 1956 developed the TX-2 a research computer that was used in 1961 for the development of the sketchpad project, one of the first 2D CAD programs which in 1964 was expanded for 3D use (Peddie, 2013).

The 1970s saw the beginning of the transformation from two dimensional (2D) to three dimensional (3D) with organizations like the French Aerospace Company, Avions Marcel Dassault developing a software program called CATIA after purchasing a source code from Lockhead Martin (Gonzalez, 2010). It was in the 1980s that the world saw the emergence of software programs such as Autodesk on 2D and personal computer (PC) platforms. However, the leading 3D software packages of the time where CATIA, Pro/Engineer, Unigraphics and I-DEA which were mainly used for industrial production (Gonzalez, 2010).

The evolution of CAD oriented software continued with the introduction of object-oriented CAD in the early 1990s, three-dimensional geometric modelling of buildings was now possible, many tasks which where laborious such as producing building sections and schedules could now be done with ease. The increased use of the internet for sharing data in the 1990s enabled design firms to share CAD files through emails and websites (Autodesk, 2002). It was the work of Leonid Raiz and Gábor Bojár two Computer Programmers from the Soviet Union that defined BIM as it is known today. These two are the respective co-founder and founder of Revit and Archicad (Quirk, 2012).

The National Institute of Building Sciences building SMART alliance® (2015) defines Building Information Modelling (BIM) as a term which represents three separate but linked functions:

- *Building Information Modeling: Is a* ***Business process*** *for generating and leveraging building data to design, construct and operate the building during its lifecycle. BIM allows all stakeholders to have access to the same information at the same time through interoperability between technology platforms.*
- *Building Information Model: Is the* ***Digital representation*** *of physical and functional characteristics of a facility. As such it serves as a shared knowledge resource for information about a facility, forming a reliable basis for decisions during its life cycle from inception onwards.*
- *Building Information Management: Is the organization and control of the business process by utilizing the information in the digital prototype to effect the sharing of information over the entire lifecycle of an asset. The benefits include centralized and visual communication, early exploration of options, sustainability, efficient design, integration of disciplines, site control, as built documentation, in essence it is effectively developing an asset lifecycle process and model from conception to final retirement.*

Eastman, et al., (2011) highlights the following to be the benefits of using BIM on construction projects: increased building performance and quality, improved collaboration using integrated project delivery, earlier and more accurate visualizations of a design, automatic low-level corrections when changes are made to design, generation of accurate and consistent 2D drawings at any stage of the design, earlier collaboration of multiple design disciplines, easy verification of consistency to the design intent, extraction of cost estimates during the design stage, improvement of energy efficiency and sustainability, use of design model as basis for fabricated components, quick reaction to design changes, discovery of design errors and omissions before construction, synchronization of design and construction planning, better implementation of lean construction techniques, synchronization of procurement with design and construction, improved commissioning and handover of facility information, better management and operation of facilities, and integration with facility operation and management systems.

Building Information Modelling (BIM) is all about collaboration in a three-dimensional environment between Architects, Engineers, Owners, and Contractors. It allows design and construction teams to communicate about design and coordinate information across different levels (National BIM report, 2015).

This research therefore sought to study the use of Building Information Modelling as a collaborative technique in the management of construction projects in Zambia.

1.2 Statement of Problem

Collaboration is essential to the success of construction projects; the project participants are realizing that sharing of knowledge and information is one of the key elements of a successful contractual relationship (Rahman et al; 2014). BIM is a process for creating and managing information on a construction project across the project lifecycle, with one key output of this process being the Building Information Model, which is a digital potrayal of every aspect of the construction project created from information assembled and updated collaboratively at key stages of the project (National Building Specification, 2017). Presently, the visualization, coordination and management of project life-cycle information in the construction industry has been improved due to the availability of a wide range of BIM applications, which enable construction industry practitioners to create intelligent building information models (Amor, 2013). BIM is a process for creating and managing information on a construction project across the project lifecycle, with one key output of this process being the Building Information Model, which is a digital potrayal of every aspect of the construction project created from information assembled and updated collaboratively at key stages of the project (National Building Specification, 2017). BIM has been adopted as a collaborative technique in most developed countries with the United Kingdom leading the way by making it mandatory for all practitioners to be certified BIM level 2. Although BIM software such as ArchiCAD and Revit are becoming more widely used in the Zambian construction industry, the technology is not always used correctly (Sujesh *et al*; 2016). There is therefore a need for BIM to be fully adopted as a collaboration technic on projects in the Zambian Construction Industry.

1.3 Aim of the Research

The aim of the research was to explore the evidence of Building Information Modelling (BIM) collaboration in the Zambian construction industry by conducting a comparative study of the private and public sectors of the industry.

1.4 Research Objectives

1. To establish the extent to which BIM is being used as a collaboration technique on construction projects in Zambia.

2. To compare BIM collaboration on construction projects in the private sector vs public sector.

3. To identify the challenges and opportunities in the implementation of building information modelling (BIM) in the management of construction projects in Zambia

4. To determine the degree to which BIM is perceived to have been adopted in the Zambian construction industry as this will give an overview on how BIM is regarded and understood by industry practitioners.

1.5 Research Questions

The following are the research questions formulated for this study;

1. To what extent has BIM been adopted in Zambia
2. Is there evidence of BIM collaboration in the Private and Public sectors the Zambian construction industry?
3. What are the challenges and opportunities in the implementation of BIM in the management of construction projects in Zambia?

1.6 Scope of the Research

The Zambian Construction Industry is categorized in two sectors which are the private and public sectors. The study compares evidence of BIM collaboration on building projects such as schools, hospitals, office blocks being executed in these two sectors, however due to the vastness of the number of projects being executed and time limitations, the study focused on Project managers, Architects, Engineers, Quantity Surveyors, Site Engineers and Contract Managers directly working in both sectors of the Zambian Construction Industry. Further two case studies were reviewed: one (1) from the public sector and one (1) from the private sector of the Zambia Construction Industry.

1.7 Research Methodology

Approach

Since the aim of the research was to explore the evidence of Building Information Modelling (BIM) collaboration in the Private and Public sectors of the Zambian construction industry as well as to investigate individual experiences in depth, a mixed methods approach is adopted for this study.

Literature review

A comprehensive review of the literature pertaining to Building Information modelling (BIM) was undertaken in order to provide solid background information as well as develop an understanding of previous work conducted.

Data collection

Interviews, surveys and questionnaires to Architects, Engineers, Quantity Surveyors, Planners, and Project Managers working on private and public-sector projects in the Zambian Construction Industry are the methods used to collect data. Further, a comprehensive review of project record documents was undertaken so as to get an independent insight on how the projects where managed in relation to BIM.

Data Analysis

Microsoft office Excel software was used to tabulate, analyze and present the data in various formats for ease of interpretation. Percentages were used in data presentation in that they simplified and translated data to a standard basis for easy comparison.

1.8 Significance of the Study

Research on the evidence of BIM collaboration in Zambia in the management of construction projects in Zambia is significant for the following reasons; It highlights the status of BIM implementation in Zambia, it also determines the level of BIM collaboration on construction projects in the Zambian Construction industry, Challenges, opportunities and strategies in the implementation of BIM collaboration on Zambian construction projects are identified. Further, being among the first studies to be carried out on the topic at this level in Zambia, the study forms the foundation for further research in the field.

1.9 Chapter Synthesis

The study is divided into the following chapters:

Chapter one: in this chapter, the research topic is introduced, justification of the research is done the background, purpose, scope, aims, objectives and significance of the thesis are described. It further states the research questions.

Chapter two: reviews the literature on BIM, its applications in the whole project life cycle from predesign through to construction and completion. Furthermore, technical aspects of BIM and how its use can be classified in maturity levels, are presented.

Chapter three: the research methodology and justification for the research design to be followed in carrying out the research are outlined in this chapter and an overview of the type of analysis used is presented.

Chapter four: presents the data collected in an analysed format using the Microsoft Office Excel to tabulate, analyze and present the data in various formats for ease of interpretation. Percentages were used in data presentation in that they simplified and translated data to a standard basis for easy comparison.

Chapter five: focuses on two case studies, comparing their selection and results.

Chapter Six: in this chapter key aspects of the results are discussed.

Chapter Seven: concludes and provides recommendations drawn from the study.

CHAPTER 2:LITERATURE REVIEW

2.1 Introduction

The key purpose of this chapter is to explore several discussions regarding the main areas of the literature review on collaboration in the construction industry and building information modelling (BIM).

2.2 Definitions of Building Information Modelling

Various definitions of Building Information Modelling (BIM) where examined in order to have a clear understanding of the real agenda of BIM.

In the first definition, the National Institute of Building Sciences building SMART alliance (2015) defines BIM as a term which represents three separate but linked functions:

- "Building Information Modelling: Is a business process for generating and leveraging building data to design, construct and operate the building during its lifecycle. BIM allows all stakeholders to have access to the same information at the same time through interoperability between technology platforms.
- Building Information Model: Is the digital representation of physical and functional characteristics of a facility. As such it serves as a shared knowledge resource for information about a facility, forming a reliable basis for decisions during its life cycle from inception onwards.
- Building Information Management: Is the organization and control of the business process by utilizing the information in the digital prototype to affect the sharing of information over the entire lifecycle of an asset. The benefits include centralized and visual communication, early exploration of options, sustainability, efficient design, integration of disciplines, site control, as built documentation, in essence it is effectively developing an asset lifecycle process and model from conception to final retirement"

The Second definition highlights the impact the use of BIM has on the natural environment, the owners and the users of a building throughout its lifecycle as outlined by Arayici & Aouad (2010) "BIM is defined as the use of ICT technologies to streamline the building lifecycle processes to provide a safer and more productive environment for its occupants, to assert the least possible environmental impact from its existence, and to be more operationally efficient for its owners throughout the building lifecycle”

In the third definition, BIM is defined as a process for creating and managing information on a construction project across the project lifecycle, with one key output of this process being the Building Information Model, which is a digital potrayal of every aspect of the construction project created from information assembled and updated collaboratively at key stages of the project (National Building Specification, 2017). The National Building Specification (2017), goes on to state that the creation of the digital Building Information Model enables those who interact with the building to optimize their actions, resulting in a greater whole life value for the building.

From the above three definitions, it can be deduced that the real BIM agenda is to efficiently manage all aspects of a building project throughout a projects lifecycle using ICT technologies.The study adopted the third definition as the working definition of Building Information Modelling as it summarises the other two definitions and emphasises the need for all project stakeholders to work collaboratively as they create and manage information throughout the project lifecycle.

2.3 Benefits of Building Information Modelling (BIM) Implementation

Eastman et al. (2011), categorised the benefits of using BIM on construction projects in four broad categories which are; the benefits to the project owner, the benefits to the designers, building maintenance and service benefits and the benefits to the Contractors and fabricators on the project. Table 2.1 highlights particular benefits obtained by each stakeholder in the four broad categories, it can be seen that the benefits of BIM are different for each category, this gives each stakeholder to have a clear understanding of the benefits that they are obtaining from BIM.

Table 2.1 Benefits of BIM (Eastman *et al*., 2011)

OWNER/CLIENT	**MAINTENANCE AND SERVICE**
a. Quick grasp of the concept, feasibility and overall design	a. Improved commissioning and handover of facility information
OWNER/CLIENT	**MAINTENANCE AND SERVICE**
b. Increased building performance and quality	b. Better management and operation of facilities
c. Improved collaboration using integrated project delivery	c. Integration with facility operation and management systems
DESIGNERS	**CONTRACTORS AND FABRICATORS**
a. Early and more accurate visualisations of a design	a. Use of design model for fabrication
b. Automatic low-level corrections when changes are made to the design	b. Quick reaction to design changes
c. Geometrically accurate and consistent 2D drawings at any stage of the design	c. Errors and omissions are identified before construction
d. Earlier collaboration of multiple design disciplines	d. Synchronization of design and construction planning
e. Easy verification of consistency to the design intent	e. Synchronization of procurement with design and construction
f. Extraction of cost estimates during the design stage	
g. Improvement of energy efficiency and sustainability	

2.4 Challenges of Building Information Modelling (BIM) Implementation

With successful implementation, BIM is not spared from the challenges associated with its application. Sujesh *et al*. (2016), characterised the challenges of BIM implementation on construction projects in three broad classes which are; technical, organizational and environmental challenges as shown in Table 2.2. The challenges highlighted in Table 2.2 need to be dealt with individually as per project characteristics to ensure that all stakeholders are getting the full potential of BIM.

Table 2.2: Challenges of BIM (Sujesh *et al*., 2016)

TECHNICAL	ORGANISATIONAL
a. Lack of hardware/networking capability to run BIM applications	a. Lack of understanding about BIM
b. Lack of interoperality	b. BIM education and training costs
c. Lack of universality and poor adoptability of data and software standards	c. Changing the way companies do business
d. Unavailability of vendor neutral data models for effective exchange	d. Adapting existing workflows to lean oriented workflows
e. Scalabity and capacity constraints	e. Getting individuals to understand the value of BIM over traditional approaches
f. Accesabity and security of data	f. Lack of understanding of the responsibilities of different stakeholders
g. Regular model updates with respect to site conditions	g. Lack of control over supervision and authority over usage in such intergrated environments
h. Cost of software	h. Lack of interest shown by management
i. Lack of software support in good physical proximity	i. The required BIM maturity level varies between projects in the same market
ENVIRONMENTAL	
a. Lack of awareness or promotion of BIM software	b. Lack of standardised BIM processes with defined guidelines
c. Lack of insight into the discipline/profession specific challenges	d. Lack of comprehensive covereage of BIM related issues in procurement documents

2.5 Collaboration

Rahman *et al* (2014) highlighted that collaboration is essential to the success of construction projects. Collins English Dictionary (2015) defines collaboration as “the act of working with another or others on a joint project, or something created by working jointly with another or others”

The definition above provides a basic understanding of collaboration. However, several definitions of partnering which is a form of collaborating place greater importance on integration, common

objectives, enhanced efficiency and effectiveness as well as collective performance management. (Masons, 2016). This is well exemplified in Thomas and Thomas (2005) definition of partnering:
"An integrated team-working approach to achieve better value for all partners by reducing duplication and waste of resources, based on mutual objectives, a robust approach to issue resolution and a proactive approach to measurable continuous improvement."
In the above definition key aspects of collaboration are highlighted such as working together, effective communication, trust, openness, mutual objectives, agreed problem resolution methods, and a proactive focus on continuous measurable improvements.

2.5.1 Characteristics of Collaboration

Table 2.3 categorises the key characteristics exhibited by most successful collaborative construction projects and teams into; behavioural, integration, organisational, leadership and commercial. All these aspects are needed for effective and efficient collaboration on a construction project.

Table 2.3:Characteristics of Collaboration (Masons, 2016)

BEHAVIOURAL	**INTEGRATION**
a. Building the right culture (organisations b. and individual behaviours) c. Using psychometric profiling as a means of ensuring that team members exhibit complementary traits and characteristics d. Adopting team coaching as a means of e. promoting high performance f. Recognising the importance of relationships: g. Positive/negative contributors h. Emphasis on value-added activities i. People, behaviours and trust	a. Common goals and objectives b. Early engagement with supply chain c. Effective communications d. Collective performance management **LEADERSHIP** a. Committed leadership b. Core groups and project boards c. Driving change and performance
ORGANISATIONAL	**COMMERCIAL**
a. Adopting the principles of British Standards (BS) 11000 (BS 11000 standards are a Collaborative Business Relationship Systems that help organisations to develop effective joint ventures, particularly with supply chain partners)	a. Risk and reward systems b. Integrated project insurance c. Transparency and open book accounting

2.5.2 Forms of Collaboration

Collaborative working arrangements in the construction sector takes many forms which include; informal relationships, joint ventures, partnerships, frameworks and alliances (Masons, 2016).

a) Informal Relationships

In this form of collaboration, binding or non-binding team contracts are used. The client usually defines how the project team members collaborate. Sometimes the client appoints an independent advisor to promote effective team work and cooperation.

b) Joint Ventures

Joint Ventures are defined as a joint arrangement in which the parties that have joint control of the arrangement have rights to the net assets of the arrangement (Chaudhry et al., 2016). On large projects, joint ventures can be integrated into a company. A joint venture agreement is established which sets out clearly the provision of capital, constitution of the board, voting rights, dispute resolution, and the contribution of key staff, profit share and dissolution upon the completion of the project (Masons, 2016).

c) Partnerships

A legal partnership is a contractual relationship involving close cooperation between two or more parties having specified and joint rights and responsibilities. Each party has an equal share of the risk as well as the reward (NCHV, 2016).

d) Frameworks

The UK's Office of Government Commerce (2008), defines a framework agreement as an agreement or other arrangement between one or more contracting authorities and one or more economic operators which establishes the terms such as price and quality under which the economic operator will enter into one or more contracts with a contracting authority in the period during which the framework agreement applies. A framework agreement is not in itself a contract but rather a general term for agreements with suppliers that set out terms and conditions under which specific acquisitions (often termed a call-offs contract) can be made throughout the period of the agreement. (UK Office of Government Commerce, 2008).

e) Alliances

Alliances are voluntary arrangements between organisations that involve the exchange sharing or co-development of products, technologies or services (Akiner & Yitmen, 2011). Alliances in the construction industry are established when two or more firms employ their resources and capabillities in a cooperative manner to effectively accomplish a task (Akiner & Yitmen, 2011).

2.5.3 Ways of collaboration

Verganti and Pisano (2008), highlighted that companies in their quest to establish collaborative working relationships are tempted to do so without proper consideration of their purpose, structure and key objectives. When deciding on ways to collaborate on a given project,two basic issues should be considered: namely participation and governance, participants should consider collaborating in an open or closed manner. In addition, a decision on whether the network's governance structure for choosing problems and solutions be hierarchical or flat should be made (Verganti & Pisano, 2008). The model in figure 2.1 summarises the key factors that project teams should consider when deciding on how to collaborate on a project.

Innovation mall A place where a company can post a problem, anyone can propose solutions, and the company chooses the solutions it likes best	**Innovation community** A network where anybody can propose problems, offer solutions, and decide which solutions to use	**Participation**	**Open**
Elite circle A select group of participants chosen by a company that also defines the problem and picks the solutions	**Consortium** A private group of participants that jointly select problems, decide how to conduct work, and choose solutions		**Closed**
Governance			
Hierarchical	**Flat**		

Figure 2.1:The Four Ways to Collaborate (Verganti & Pisano, 2008; Masons, 2016)

Figure 2.1 illustrates four ways of collaboration: an open and hierarchical network which is an innovation mall kind of collaboration, an open and flat network which is an innovation community, a closed and flat network which is a consortium and a closed and hierarchical network which is an elite circle.It should however be noted that all these ways of collaboration relationships can be summarised into a governance and participation manner of collaboration.

Innovation mall	**Innovation community**	**Participation**	**Open**	**Advantage:**A large number of solutions from sources that are beyond ones area of experience and knowledge and one usually gets a broad range of ideas **Challenge:**Attracting several ideas from a variety of sources and screening them **Enablers:**The capability to test and screen solutions at low cost;information platforms that enable all parties to contribute easily; minor problems that can be solved with simple design tools, or major problems that can be broken into discrete parts that contributers can work on autonomously
Elite circle	**Consortium**		**Closed**	**Advantage:**Solutions are received from the best experts in a particular knowledge area **Challenge:**Identifying the right parties and the right knowledge area **Enablers:**The ability to find untapped talent in the relevant network;the ability to develop privalaged relationships with the best parties
Governance				
Hierarchical	**Flat**			
Advantage: The ability to control the course of innovation and who benefits from it. **Challenge:**Choosing the right course. **Enablers:** The ability to comprehend the needs of the users;the ability to design systems so tha work can be divided among outsiders and then integrated	**Advantage**: The burden of innovation is shared. **Challenge:** Getting contributors to agree on a profitable solution. **Enablers:** Procesess and rules that drive parties to work in unison to achieve common goals			

Figure 2.2: Advantages and Challenges of The Four Ways to Collaborate (Verganti & Pisano, 2008)

BIM is all about collaboration in a three-dimensional environment between engineers, owners, architects and contractors. It allows design and construction teams to communicate about design and coordinate information across various levels (National BIM report, 2015). Project team members when choosing an approach to collaboration as highlighted in figure 2.1 need to carry out distinct strategic trade-offs of each approach following the advantages and disadvantages highlighted in figure 2.2.

2.6 BIM as a collaboration technique

BIM as a collaborative technique is being used at various levels depending on the extent of BIM collaboration and adoption on the project. Figure 2.3 shows the BIM wedge or Bew-Richards Model. It highlights the different levels at which practices can identify where they are on their BIM journey (The Landscape Institute, 2016).

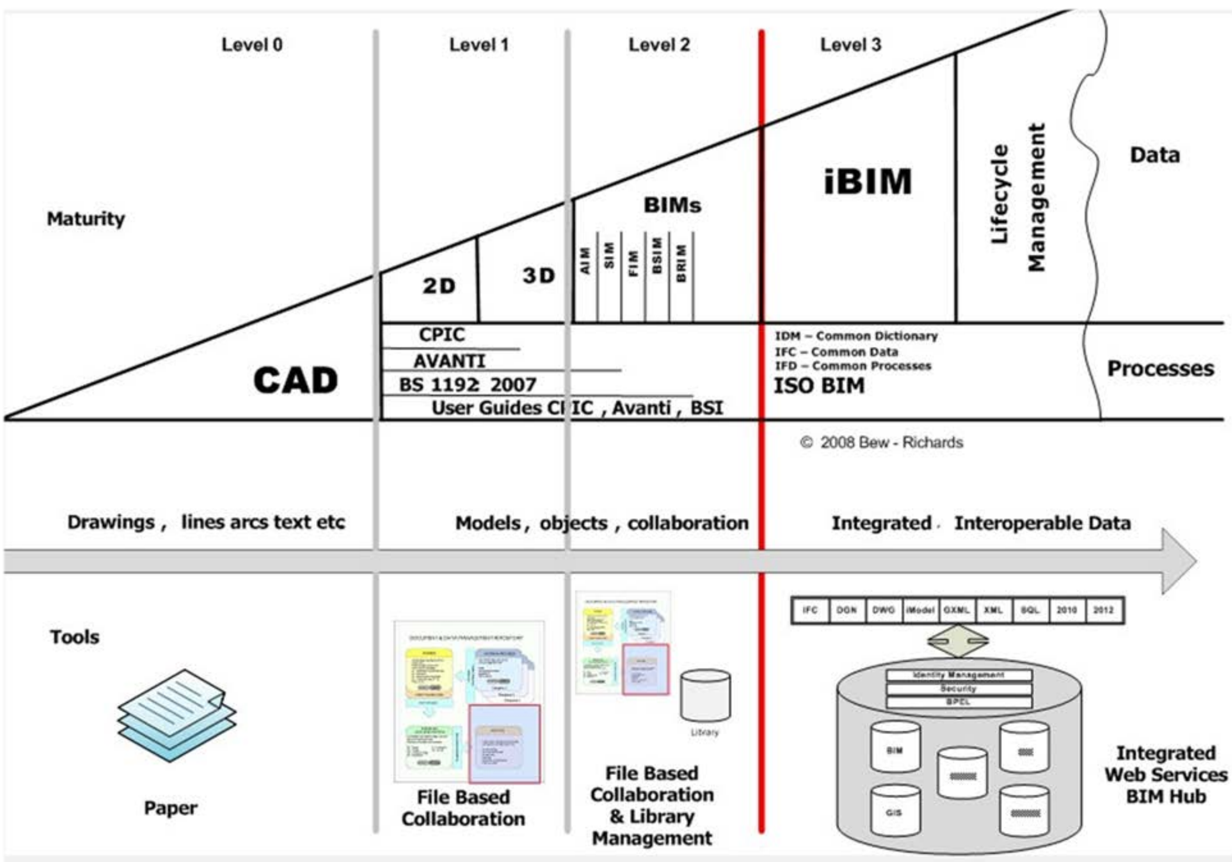

Figure 2.3: The Bew-Richards BIM Maturity Model (Bew and Richards, 2008)

The four levels indicated in figure 2.3 are defined as:

Level 0: Unmanaged Computer Aided Design (CAD) in 2D, at this level information is usually exchanged in uneditable documents, either in printed form or digital files such as PDF.

Level 1: This level involves managed CAD in 2D or 3D format with a collaborative tool providing a common data environment with a standardised approach to data structure and format. Commercial data will be managed by standalone finance and cost management packages with no integration.

Level 2: Involves a managed 3D environment held in separate discipline 'BIM' tools with data attached. Commercial data will be managed by enterprise resource planning software and integrated by proprietary interfaces or bespoke middleware. This level of BIM may utilise 4D construction sequencing and/or 5D cost information.

Level 3: A fully integrated and collaborative process enabled by 'web services' and compliant with emerging Industry Foundation Class (IFC) standards. This level of BIM will utilise 4D construction sequencing, 5D cost information and 6D project lifecycle management information

2.7 BIM Software

BIM is not a process solved by one software, but several processes involving numerous software solutions, each with distinct capabilities to accomplish specific work-related tasks (Thomassen, 2011). A wide range of BIM software applications that perform 3D modelling are available, however from a technical perspective,3D modelling software can be categorised into two broad categories, surface modelling and solid modelling tools. The surface modellers are 3D capable software without parametric value generated in the models while the solid modellers are software which incorporate rich parametric data and capabilities into 3D models enabling the model to depict a real-world project (Rodgers *et al.*, 2015).

There is no BIM software accredited or comparison list and this tends to keep BIM users particularly inexperienced users struggling with the dilemma of choosing which software is the best, thus wasting time and financial resources on unnecessary features or inappropriate software packages (Elgohari, 2016). The BIM-Forum has categorised BIM software into; preliminary design and feasibility software, BIM authoring software, BIM analysis software, shop drawing and fabrication software, construction management software, quantity takeoff and estimating software, scheduling tools and file sharing and collaboration software (Elgohari, 2016).This helps a BIM user to select an appropriate software package.

Table 2.4 highlights software which can be used for preliminary sketch designs such as defining levels, grids, project location and creating a site plan.

Table 2.4: selected preliminary design and feasibility software (Bim-Forum, 2011)

Preliminary Design and Feasibility Software			
Product Name	**Manufacturer**	**BIM use**	**Primary Function**
Revit Architecture	Autodesk	Creating and reviewing 3D models	Architectural modelling and parametric design.
DProfiler	Beck Technology	Conceptual Design and Cost Estimation	3D conceptual modelling with real-time cost estimating
Bentley Architecture	Bentley Systems	Creating and reviewing 3D models	Architectural modelling
SketchUp Pro	Google	Conceptual 3D Modelling	Conceptual Design modelling
ArchiCAD	Graphisoft	Conceptual 3D Architectural Model	Architectural model Creation
Vector works Designer	Nemetschek	Conceptual 3D Modelling	Architectural model Creation
Tekla Structures	Tekla	Conceptual 3D Modelling	A structural 3D model Application
Affinity	Trelligence	Conceptual 3D Modelling	A 3D Model Application for early concept design
Vico Office	Vico Software	Conceptual 5D Modelling	5D conceptual model which can be used to generate cost and schedule data

BIM authoring tools and their primary functions are listed in Tables 2.5 - 2.7 the list includes mechanical, electrical, and plumbing (MEP), structural, architectural, and site work 3D modeling software. Some of these software are also capable of scheduling and cost estimation.

Table 2.5: Selected BIM authoring software (Bim-Forum, 2011)

BIM Authoring Software			
Product Name	**Manufacturer**	**BIM use**	**Primary Function**
Revit Architecture, AutoCAD Architecture	Autodesk	Architecture and site design	Architectural modelling and parametric design.
Revit Structure	Autodesk	Structural	Structural modelling and parametric design
Revit MEP, AutoCAD MEP	Autodesk	MEP	MEP modelling
Bentley BIM Suite - Includes Micro Station, Bentley Architecture, Bentley Structural, Bentley Building Mechanical Systems, Bentley Building Electrical Systems, Bentley Building Electrical Systems for AutoCAD, Generative Design and Generative Components	Bentley Systems	Multi-discipline	Architectural, Structural, Mechanical, Electrical and Generative Components - all within the 3D modelling environment
Digital Project	Gehry Technologies	Multi-discipline	Digital Project Designer is a high-performance 3D modelling tool for architectural design, engineering, and construction. It provides an extensive set of tools for creating and managing building information throughout the building lifecycle.

Table 2.6: Selected BIM authoring software (Bim-Forum, 2011) continued from previous page

BIM Authoring Software			
Product Name	**Product Name**	**Product Name**	**Product Name**
Digital Project MEP Systems Routing	Gehry Technologies	MEP	MEP Design
SketchUp Pro	Google	Multi-discipline	3D Architectural and Structural modelling
ArchiCAD	Graphisoft	Architecture, MEP and site design	3D Architectural modelling
Vector works	Nemetschek	Architecture	3D Architectural modelling
Fastrak	CSC (UK)	Structural	3D Structural modelling
SDS/2	Design Data	Structural	3D Structural modelling and Detailing
RISA	RISA Technologies	Structural	Full Suite of Structural Design Applications for steel, wood, concrete, and masonry
Tekla Structures	Tekla	Structural	3D Structural modelling, Detailing, Fabrication and Construction Management
Cadpipe HVAC	AEC Design Group	MEP	3D HVAC modelling
MEP Modeler	Graphisoft	MEP	3D MEP modelling
Fabrication for ACAD MEP	East Coast CAD/CAM	MEP	MEP detailed modelling, for Fabrication
CAD-Duct	Micro Application Packages Ltd.	MEP	3D MEP detailed modelling, for Fabrication
Duct Designer 3D, Pipe Designer 3D	QuickPen International	MEP	3D MEP detailed modelling
Trimble® Design Link	Trimble	MEP	3D MEP detailed modelling

Table 2.7: Selected BIM authoring software (Bim-Forum, 2011) continued from previous page

BIM Authoring Software			
Product Name	**Product Name**	**Product Name**	**Product Name**
Site Design Site Planning	Eagle Point	Civil & Infrastructure and Site Logistics	Site development
Synchro Professional	Synchro Ltd.	Site Logistics	Scheduling (4D), sequencing
HydraCAD	Hydratec	Fire Protection	3D Fire Sprinkler Design and modelling
AutoSPRINK VR	M.E.P. CAD	Fire Protection	3D Fire Sprinkler Design and modelling
FireCad	Mc4 Software	Fire Protection	Fire piping network design and modelling
AutoCAD Civil 3D	Autodesk	Civil & Infrastructure and Site Logistics	Site development
PowerCivil	Bentley Systems	Civil & Infrastructure and Site Logistics	Site development

The BIM analysis software in Tables 2.8 – 2.10 are used to predict the model behaviour. They are used by the designers and consultants to validate the model's compliance with standards/codes.

Table 2.8: Selected BIM analysis software (Bim-Forum, 2011)

BIM Analysis Software			
Product Name	**Manufacturer**	**BIM use**	**Primary Function**
Robot	Autodesk	Structural Analysis	Bi-directional link with Autodesk Revit Structure
Green Building Studio	Autodesk	Energy Analysis	Measure energy use and carbon footprint

Table 2.9: Selected BIM analysis software (Bim-Forum, 2011) continued from previous page

BIM Analysis Software			
Product Name	**Manufacturer**	**BIM use**	**Primary Function**
Ecotect	Autodesk	Energy Analysis	Weather, energy, water, carbon emission analysis
Structural Analysis/Detailing- (STAAD.Pro, RAM, ProStructures), Building Performance- (Bentley Hevacomp, Bentley Tas)	Bentley Systems	Structural Analysis/Detailing, Quantity Take-off, Building Performance	Measure, assess and report building performance.
Solibri Model Checker	Solibri	Model Checking & Validation	Rules-based checking for compliance and validation of all objects in the model
VE-Pro	Integrated Environmental Solutions (IES)	Energy & Environmental Analysis	All aspects of energy analysis and simulation in many areas
GTSTRUDL	Georgia Institute of Technology	Structural Analysis	Structural Analysis
Energy Plus	U.S. Department of Energy & LBNL	Energy Analysis	Energy Simulation
DOE2	Lawrence Berkeley National Lab (LBNL)	Energy Analysis	Energy Simulation
FloVent	Mentor Graphics	Air Flow/CFD	Environmental simulation and analysis

Table 2:10: Selected BIM analysis software (Bim-Forum, 2011) continued from previous page

BIM Analysis Software			
Product Name	**Manufacturer**	**BIM use**	**Primary Function**
Fluent	Ansys	Air Flow/CFD	Environmental simulation and analysis
Acoustical Room Modelling Software	ODEON	Acoustical Analysis	Acoustic Simulation and Analysis
Apache HVAC	IES	MEP Analysis	HVAC Plant Simulation
Carrier E20-II	Carrier	MEP Analysis	HVAC system analysis
Digital Project	Gehry Technologies	Structural Analysis	Comprehensive suite of BIM tools based upon the CATIA CAD engine.
RISA	RISA Technologies	Structural Analysis	Full suite of analysis tools for steel, wood, concrete and masonry

Table 2.11 shows selected software that the project team can use to transfer information from BIM authoring software into fabrication software where further detailing can be done in readiness for fabrication (Mordue *et al*., 2016).

Table 2.10:Selected BIM shop drawing and analysis software (Bim-Forum, 2011)

Shop Drawing and Fabrication Software			
Product Name	**Manufacturer**	**BIM use**	**Primary Function**
CADPIPE Commercial Pipe	AEC Design	Shop Drawing & Fabrication	Fabrication
Revit MEP	Autodesk	Shop Drawing	Detail Design for Shop Drawings
SDS/2	Design Data	Shop Drawing	Detail Design for Shop Drawings
Fabrication for AutoCAD MEP	East Coast CAD/CAM	Fabrication	Interact with AutoCAD MEP for custom libraries and fabrication
CAD-Duct	Micro Application Packages Ltd.	Fabrication	Use AutoCAD geometry, for fabrication
Pipe Designer 3D & Duct Designer 3D	QuickPen International	Fabrication	Use AutoCAD geometry, for fabrication
Tekla Structures	Tekla	Shop Drawing	Structure-centric fabrication
Trimble® Design Link	Trimble	MEP	Uses AutoCAD MEP geometry and sheet metal manufacturer design libraries

The software highlighted in Table 2.12, allow project team members to take a holistic review of the model by integrating the 3D model produced by the BIM authoring software with project schedule software this produces a 4D model showing construction sequencing, simulations and scheduling capabilities (Mordue *et al.*, 2016). For instance, using the Autodesk Revit platform in combination with Autodesk Navisworks Manage produces a workflow that allows project teams to successfully plan construction procedures, identify potential glitches, and explore and evaluate alternatives (Autodesk University, 2016).

Table 2.112: Selected BIM construction management software (Bim-Forum, 2011)

Construction management Software			
Product Name	**Manufacturer**	**BIM use**	**Primary Function**
Navisworks Manage	Autodesk	Clash Detection	Model-based Clash Detection between trades
ProjectWise Navigator	Bentley	Clash Detection	Coordination between models and disciplines
Digital Project Designer	Gehry Technologies	Model Coordination	Full featured suite, based upon CATIA application
Solibri Model Checker	Solibri	Spatial Coordination	QA/QC of models based upon rulesets and spatial requirements
Synchro Professional	Synchro Ltd.	Planning & Scheduling	Schedule-driven site coordination
Tekla Structures	Tekla	Construction Management	Structures is a very broad BIM offering from a structure-centric perspective

A number of BIM authoring software are able to perform automated quantification of items, areas, surfaces and volumes of a project and export this information to a spreadsheet format, they however do not produce cost estimates (Mordue, *et al.*, 2016). Table 2.9, lists quantity take-off and estimating software which are usually linked to BIM authoring software via a plug-ins or embedded BIM information from a BIM authoring software into quantity take off and estimating software, these then automatically extract information and necessary quantities from 3D geometrical data which is used by these software to form project cost estimation (Mordue, *et al.*, 2016).

Table 2.12: Selected BIM quantity take-off and estimating software (Bim-Forum, 2011)

Quantity Take-off and Estimating Software			
Product Name	**Manufacturer**	**BIM use**	**Primary Function**
QTO	Autodesk	Quantity Take-offs	Generating take-offs from multiple environments both 2D & 3D
DProfiler	Beck Technology	Conceptual Estimates	Conceptual 3D modelling with cost estimating and life cycle operational costs Forecasting
Visual Applications	Innovaya	Estimating	Extracting quantities and building estimates from ADT & Revit files
Vico Take-off Manager	Vico Software	Quantity Take-offs	Quantity Take-offs, feeding into estimating and scheduling

2.8 BIM in Zambia

Building Information Modelling is a relatively new concept to the Zambian Construction industry, with about 45 percent of practitioners having used 3D modelling software, coupled with only 8 percent having previously worked with BIM in Zambia (Sujesh *et al*., 2016). The low usage of BIM in the Zambian architecture, engineering and construction (AEC) industry can be attributed to three main factors; the first factor being the lack of BIM training to the practitioners in the industry mainly comprising of architects, quantity surveyors, engineers and contractors, this is coupled with the lack of locally available BIM training providers, secondly BIM is perceived to be too costly by most practitioners, the third factor is that practitioners in the industry feel the existing 2D CAD systems fulfills their requirements to design and draft (Chipulu *et al*., 2015).

Sujesh *et al*., (2016), concluded that the level of digital technology usage in the Zambian AEC industry is very low. Further the study suggested the need for more research in the area as the gap in literature and knowledge with respect to the global market is considerable and must be rectified before the ever-growing gap gets harder to fill. Chipulu *et al.*, (2015) also concluded that there was a need and a necessity to fully adopt BIM information modelling in the Zambian AEC industry. This was because the current 2D CAD approach to design, drafting, construction and documentation had a lot of limitations such as difficulty to visualise and the immense coordination required when using it. The most commonly used BIM software identified in the Zambian AEC industry are Autodesk Revit Architecture, Autodesk Architecture desktop and Archicad by Graphisoft (Chipulu *et al.*, 2015).

2.9 Collaboration in Zambian Construction Industry

Mukuka et al (2014) noted that collaborative working arrangements can be used in the Zambian Construction Industry to mitigate project delays thus improving overall construction project(s) delivery in the industry. However, collaboration among project team members in the Zambian Construction Industry is still a challenge (Chiponde *et al.*,2017). Chiponde *et al.* (2017) attributes this to the following factors;

a) The huge reliance on the traditional procurement approach, whose key participants are the client/financier, contractors, and designers consisting of architects, engineers (structural, civil and service engineers) and quantity surveyor(s), this leads to poor quality of works, delays and cost overruns.
b) The low usage of BIM software particularly among quantity surveyors working in the Zambian Construction Industry and the exchanging of information through hard copies resulting in inefficiencies during the construction process since the documents cannot be shared faster or any changes made easily.

2.10 Summary

This chapter examined a range of available literature on BIM and collaboration. It was established that there was some BIM usage in Zambia with Autodesk Revit Architecture, Autodesk Architecture desktop and ArchiCAD being among some of the major software used particularly by Architects. Further the chapter analysed the concepts of building information modelling and collaboration and the benefits project teams and projects acquire from using and/or adopting them. Literature content analysis is captured in Tables 2.13 – 2.16. The next chapter examines the research methods employed to achieve the objectives of the study.

Table 2.13:Content analysis of reviewed literature

Author	Year	Title	Objectives	Methodology	Conclusions/Comments
A. Abanda F. H. et al.,	2014	Building Information Modelling in Cameroon: Overcoming Existing Challenges	To explore BIM implementation in Cameroon	Descriptive	Provides an insight into BIM implementation in developing countries
B. BIM Task Group	2011	A report for the Government Construction Client Group, Building Information Modelling (BIM) Working Party Strategy Paper	To come up with a strategy on BIM adoption in the UK.	Working Group	Gives an understanding on how Governments can lead the BIM agenda
C. National Institute of Building Sciences building SMART alliance	2015	National BIM Standard - United States® Version 3	To highlight BIM standards in the United states	Descriptive	The BIM agenda is outlined
D. Arayici, Y. & Aouad, G	2010	Building information modelling (BIM) for construction lifecycle management in Construction and Building: Design, Materials, and Techniques	To show how BIM adoption for an architectural company helps to mitigate the management and communication problems in remote construction project.	Case study	Outlines the impact of BIM usage on the natural environment, the owners and users
E. National Building Specification	2017	National BIM Report 2017	The report is packed with a range of insight and expertise, it gives a snapshot of the changes the industry has been going through.	Explanatory	Gives a comprehensive review into the latest trends in BIM

Table 2.14:Content analysis of reviewed literature continued from previous page

Author	Year	Title	Objectives	Methodology	Conclusions/Comments
F. Eastman, et al	2011	BIM handbook: a guide to building information modeling for owners, managers, designers. 2nd edition	A BIM guide handbook	Descriptive and Explanatory	Provides a guide to BIM for owners, managers, and designers
G. Rahman, et al	2014	The Importance of Collaboration in Construction Industry from Contractors' Perspectives.	To identify the views of contractors on the importance of collaboration in construction supply chain	Mixed methods approach	Highlights the importance of collaboration to successful project implementation.
H. Collins Dictionaries	2015	Collins English Dictionary. 7 edition	Outlines definitions to words	Explanatory	Gave exact definitions
I. Pinsent Masons	2016	Collaborative Construction: More myth than reality? A critical review of the theory and practice of collaborative working in construction	To provide a critical review on collaboration	Literature Review	Provides an insight into collaborative working arrangements in the construction industry
J. The Landscape Institute	2016	BIM for Landscape. 1st edition	To identify BIM usage in landscaping	Descriptive	Provides comprehensive definition of BIM
K. Sujesh, et al	2016	Barriers to implementation of forms of systemic innovation in the construction industry departing from the possible adoption of Building Information Modelling in Zambia	To critically assess the barriers and drivers to the systemic change of using BIM in Zambia.	Questionnaire Surveys	Gives an understanding to the extent of BIM adoption in Zambia.
L. Thomas, G. & Thomas, M	2005	Construction Partnering and Integrated Teamworking,. 1st edition	Outline issues pertaining to partnering and teamwork	Descriptive	Definitions on partnering
M. NCHV	2016	National Coalition For Homeless Veterans	To end homelessness through collaborations, partnership and frameworks	Explanatory	Provides an understanding on how partnerships work

Table 2.15:Content analysis of reviewed literature continued from previous page

	Author	Year	Title	Objectives	Methodology	Conclusions/Comments
N.	UK Office of Government Commerce	2008	Framework Agreements: OGC Guidance on Framework Agreements in the Procurement Regulations	To support the procurement and acquisition process of public sector organisations in the UK through policy and process guidance and the negotiation of overarching service and provision frameworks.	Descriptive	Gives a critical insight into framework agreements
O.	Chaudhry, A. et al	2016	Interpretation and application of International Financial Reporting Standards. 1st edition	To achieve global convergence of accounting standards, which will lead to uniformity in financial reporting around the world	Descriptive	Joint venture definitions
P.	Verganti, R. & Pisano, G. P		Harvard Business Review	Gives a critical understanding on collaborations	Literature review	Collaborations
Q.	Bim-Forum	2011	Bim-Forum	Categorises BIM software	Descriptive	An understanding of BIM Software
R.	Chipulu, et al	2015	Adoption of Building Information Modelling in the Zambian Architectural, Engineering and Construction Industry	To ascertain whether there is need to fully adopt Building information modelling (BIM) as an approach to the construction projects life cycle in Zambia and to suggest the best or most efficient way to implement the adoption of BIM in Zambia.	Questionnaire surveys	Gives an insight on BIM in Zambia
S.	Rodgers, J. et al.	2015	BIM Development and trends in developing Countries	Case studies outlining BIM in developing countries	Case Studies	Gives a concise outline of BIM in developing countries

Table 2.16:Content analysis of reviewed literature continued from previous page

	Author	Year	Title	Objectives	Methodology	Conclusions/Comments
T.	Mordue, S., Swaddle, P. & Philp, D	2016	Building Information Modelling for Dummies. 1 edition	Explains BIM in simple language	Descriptive	Simplifies BIM

CHAPTER 3: RESEARCH METHODOLOGY

3.1 Introduction

This chapter discusses the research methodology used for the study. It outlines the procedures and methods used for the research in evidence of BIM collaboration in Zambia. It also specifies how the research was conducted and how the data collected was analysed. The chapter has four main sub sections dealing with research approach, methods of data collection, sampling methods and triangulation.

3.2 Research Approach

Research approaches are plans and procedures for the research that explore all the various steps involved in carrying out a study from broad assumptions to detailed methods of data collection, analysis and interpretation (Creswell, 2014). According to Creswell, (2014) research approaches can be categorised into qualitative, quantitative, and mixed methods:

3.2.1 Qualitative research

This approach to research involves the examination and comprehension of the connotations individuals and/or groups attribute to a social or human problem (Creswell, 2014). Qualitative research aims at describing, exploring, and explaining a phenomenon under study. Qualitative research questions often take the form of what is this? or what is happening here? and are more concerned with the process rather than the outcome (Ploeg , 2016). There are many different types of qualitative research, such as narrative research, ethnography, phenomenology, grounded theory, and ethnomethodology (Creswell, 2014):

a) Narrative Research

This is mainly used in the fields of humanities in which the researcher studies the lives of individuals and asks one or more individuals to provide stories about their lives, the researcher then compiles this information into a narrative chronical often combining the views from the researcher's life with those from the participant's life in a collaborative narrative (Creswell, 2014). This research method was not considered applicable for this study due to the nature of the problem, which aims to explore the evidence of Building Information Modelling (BIM) collaboration in the Zambian construction industry.

b) Ethnography

Ethnography traces its roots back to the early 1900s, when researchers such as Bronislaw Malinowski and Alfred Radcliffe-Brown participated in anthropological studies of small, rural (and often remote) societies over long periods and documented their social arrangements and belief systems (Reeves *et al.*, 2008).It involves the researcher studying the collective patterns of behaviors, language, and actions of a complete cultural group in a natural setting over a prolonged period and data collection is often through observations and interviews (Creswell, 2014). Ethnography aims to provide rich, holistic insights into people's views and activities, as well as the nature of the environment they inhabit, through the gathering of detailed observations and interviews (Reeves et al., 2008). This research does not intend to study the behavioral patterns or physiologies of participants, as in the case of ethnographical studies, so this method was not considered appropriate.

c) Phenomenology

Phenomenology as a methodology of inquiry stems from the academic disciplines of philosophy and psychology in which the researcher describes the lived experiences of individuals about a phenomenon as described by participants (Creswell, 2014). Phenomenology studies emphasise on experiences, events and occurrences with little or no consideration for the external and physical reality (Dudovskiy, 2016). The nature of the problem does not place emphasis only on experiences, events and occurancies therefore, this method was considered inappropriate for this study.

d) Grounded theory

Sociologists, Barney Glaser and Anselm Strauss developed grounded theory in 1967 as a method that would allow them to move from data to theory, so that new theories could emerge which would be specific to the context in which they had been developed (Willig, 2013). It involves the researcher deriving a general, abstract theory of a process, action, or interaction grounded in the views of participants (Creswell, 2014). This research method was not selected due to the nature of the problem as the theory has already been established through the literature.

e) Ethnomethodology

Ethnomethodology was first developed during the 1960's by a sociologist named Harold Garfinkel, it is a theoretical approach in sociology based on the belief that the researcher can discover the normal social order of a society by disrupting it (Crossman, 2017). This research method was not selected due to the nature of the problem which aims to explore the evidence of Building Information Modelling (BIM) collaboration in the Zambian construction industry and this cannot be achieved if the researcher was involved in the study.

The advantages and disadvantages of using qualitative methods to conduct a research are (Anderson, 2017):

Advantages

1. Issues can be examined in detail and in depth,
2. Interviews are not restricted to specific questions and can be guided/redirected by the researcher in real time,
3. The research framework and direction can be quickly revised as additional information emerges,
4. The data based on human experience that is obtained is powerful and sometimes more compelling than quantitative data,
5. Subtleties and complexities about the research subjects and/or topic are discovered that are often missed by more positivistic enquiries, and
6. Data usually are collected from a few cases or individuals, so findings cannot be generalized to a larger population, but can however be transferable to another setting.

Disadvantages

1. Research quality is heavily dependent on the individual skills of the researcher and more easily influenced by the researcher's personal biases and idiosyncrasies,
2. Rigor is more difficult to maintain, assess, and demonstrate,
3. The volume of data makes analysis and interpretation time consuming,
4. It is sometimes not as well understood and accepted as quantitative research within the scientific community,
5. The researcher's presence during data gathering, which is often unavoidable in qualitative research, can affect the subjects' responses,
6. Issues of anonymity and confidentiality can present problems when presenting findings, and
7. Findings can be more difficult and time consuming to characterize in a visual way.

3.2.2 Quantitative research

Quantitative research focuses on collecting numerical data and generalising it across groups of individuals or to explain a phenomenon. Quantitative research methods place emphasis on objective measurements and the statistical, mathematical, or numerical analysis of data collected through polls, questionnaires, and surveys, or by manipulating existing statistical data using computational techniques such as Statistical Package for the Social Sciences (SPSS) (Babbie, 2014).

Regoniel (2015), highlighted seven key characteristics that differentiate qualitative methods of research from qualitative ones:

a) Data gathering tools should contain items that implore measurable characteristics of the population (such as age, weight, educational status, economic status).
b) Data gathering tools should be standardised and pre-tested to ensure the information collected is accurate, reliable and valid.
c) For more reliable data analysis, a normal population distribution curve is preferred over a non-normal distribution. This requires a large population, the numbers of which depend on how the characteristics of the population vary. This requires adherence to the principle of random sampling to avoid researcher's bias in interpreting the results that defeat the purpose of research.
d) The data obtained using quantitative methods should be organised using tables, graphs, or figures that merge large numbers of data to show trends, relationships, or differences among variables. This fosters understanding to the readers or clients of the research investigation.
e) Researchers can repeat the quantitative method to verify or confirm the findings in another setting. This reinforces the validity of ground-breaking discoveries or findings thus eliminating the possibility of bogus or erroneous conclusions.
f) Quantitative models or formula derived from data analysis should predict outcomes.
g) Advanced digital or electronic instruments are used to measure or gather data from the field.

The advantages and disadvantages of using quantitative methods to conduct a research as outlined by Manheim, et al.(2008) and Babbie (2014) are:

Advantages

Quantitative methods allow for a wider study consisting of a larger number of subjects which enhances the generalisation of the results. Greater objectivity and accuracy of results is also obtained with the use of these methods as they tend to summarise data that support generalisations about the phenomenon under study. By using reputable standards the research can be replicated, and then analysed and compared with similar studies. Further, individual bias is avoided as the researcher keeps a distance from the subjects taking part in the study.

Disadvantages

Although quantitative data is more efficient and able to test hypotheses effectively, contextual details can be omitted. The results obtained provide little detail on behaviour, attitudes, and motivation of the participating subjects and the use of standard questions by the researcher can result in structural bias as the data can reflect the opinions of the researcher instead of the participating subjects. Further, chances of obtaining a much narrower and insincere dataset are increased and the outcomes tend to be scanty as they show numerical descriptions as opposed to detailed narratives which provide a more elaborate account of the human perception. Quantitative research is usually undertaken in an unnatural, artificial environment so that a level of control is applied to the exercise, however, this level of control might not normally be in place in the real world thus yielding "laboratory results" as opposed to "real world results". Also predetermined responses will not essentially reflect how people really feel about a subject and, in some cases, might just be the closest match to the preconceived hypothesis.

3.2.3 Mixed Methods

Mixed methods is a methodology for executing research that encompasses collecting, analysing and combining both quantitative methods such as experiments, surveys and qualitative methods such as focus groups, interviews research (FoodRisC, 2016). Qualitative data usually lean towards open-ended independent (un-predetermined) responses while quantitative data tends to include close-ended responses such as those found on questionnaires or psychological tools (Creswell, 2014).Several mixed method designs exist in the mixed methods field, FoodRisC (2016), highlights four types of mixed method designs: sequential explanatory design, sequential exploratory design, concurrent triangulation and concurrent nested.

When determining the type of mixed methods design to use, it is imperative to take into account the purpose of the research, the specific research questions, and the strengths and weaknesses of each design (Bryman, 2015; Creswell, 2014; Saunders *et al.*, 2011).

In Table 3.1 and 3.2 the four mixed methods designs are compared in terms of their purposes, strengths and weaknesses.

Table 3.1: Mixed method types comparison (Bryman, 2015; Creswell, 2014; Saunders *et al*., 2011).

S/n	**Mixed method types**	**Purpose**	**Strengths**	**Weakness**
1	Sequential explanatory design	This design involves the collection and analysis of quantitative data followed by the collection and analysis of qualitative data.	▪ Easy to implement. ▪ The design is easy to describe and the results easy to report.	▪ Requires a substantial length of time to complete all data collection.
2	Sequential exploratory design	In this design, qualitative data collection and analysis is followed by quantitative data collection and analysis.	▪ Easy to implement. ▪ The design is easy to describe and the results easy to report.	▪ Requires a substantial length of time to complete all data collection.
3	Concurrent triangulation	In this design only one data collection phase is used, during which quantitative and qualitative data collection and analysis are conducted separately yet concurrently. The findings are integrated during the interpretation phase of the study. Usually, equal priority is given to both types of research.	• Provides well validated and substantiated findings. • Compared to sequential designs, data collection takes less time.	Requires great effort and expertise to adequately use two separate methods at the same time. • It can be difficult to compare the results. Given that data collection is conducted concurrently, results of one method cannot be integrated in another other method

Table 3.2: Mixed method types comparison (Bryman, 2015; Creswell, 2014; Saunders *et al.*, 2011) continued from previous page.

S/n	Mixed method types	Purpose	Strengths	Weakness
4	Concurrent nested	In this design only one data collection phase is used, during which a predominant method (quantitative or qualitative) nests or embeds the other less priority method (qualitative or quantitative, respectively).	• Two types of data are collected simultaneously, reducing time and resources . • Provides a study with the advantages of both quantitative and qualitative data.	• The data needs to be transformed in some way so that both types of data can be integrated during the analysis, which can be difficult. • Inequality between different methods may result in unequal evidence.

This study adopted a mixed methods approach by combining both quantitative and qualitative methods in Concurrent triangulation. Creswell (1994) and Musonda, (2011) stated that there were five objectives for combining such methods in a single study:

a) development, wherein the first method is used sequentially to help inform the second method. Partial results from one method might suggest that other assessments should be incorporated;

b) triangulation tests consistency in the classic sense of seeking convergence of results;

c) complementarity, in that overlapping and different facets of a phenomenon may emerge. It clarifies and illustrates results from one method with the use of another;

d) initiation, wherein contradictions and fresh perspectives emerge. This stimulates new research questions or challenges; and

e) expansion, wherein the mixed methods add scope and breadth to a study providing more details on the specific issues.

3.3 Methods of Data Collection

Research involves the collection of data; different research types have different data collection methods. Data gathering techniques can generally be classified into primary and secondary methods (Kaliba, 2015):

3.3.1 Primary method

In this method, the researcher gathers firsthand information which no one has ever collected before, it includes methods like observations, interviews and administration of questionnaires and focus group discussions (Kaliba, 2015).

a) Observation

This method involves the researcher joining a group of people or an organisation, taking an active part in their day to day lives as a member of that group or organisation and making in-depth recordings of the researcher's observations (Kaliba, 2015). The observation may be done openly, in which case the respondents know that the researcher is conducting a research, or secretly (undercover) where the respondents are deceived into thinking the researcher is 'one of them' and do not know the researcher is conducting research (Kaliba, 2015).

b) Case study

This is an in-depth and thorough investigation of a few real-life circumstances, providing a way of organising data and looking at the objects to be studied (Kaliba, 2015). The case study approach is mostly beneficial to use when there is a need to gain an in-depth appreciation of an issue, event or phenomenon of interest, in its natural real-life setting (Crowe, *et al*., 2011).

c) Survey research

This method involves the administration of questions to a sample selected from a population through interviews and questionnaires (Kaliba, 2015).

(i) Interviewing

This is a data gathering process involving the researcher asking oral questions to either individuals or groups of individuals (Kaliba, 2015). This method has, however, its own advantages and disadvantages as outlined by (Bryman, 2004; Kaliba, 2015):

Advantages:

- It includes illiterate respondents;

- It allows clarification of issues; and
- It gives a higher response rate in comparison to written questionnaires.

Disadvantages:

- the presence of the interviewer may influence responses;
- reports of events may not be as comprehensive as in the case of observation;
- it is costly and time consuming and;
- a risk of serious discrepancies is likely to occur if more than one interviewer is used and this reduces comparability of responses.

(ii) Questionnaires

Questionnaires comprise the use of written questions that are administered to the respondent who responds to them in a written form. Questionnaire surveys are mainly in two forms (Achola and Bless, 1988; Bryman, 2004; Kaliba, 2015):

- self-administered questionnaires are posted to respondents and returned completed; and
- administered questionnaires are delivered by the interviewer.

The following are the advantages and disadvantages of using questionnaires as outlined by (Debois, 2016):

Advantages

- Questionnaires are cost-efficient
- They are practical way to collect data
- They enable the researcher to gather information from a large audience.
- They provide fast results
- Allow for anonymity that could result in more honesty responses
- Cover all aspects of a topic

Disadvantages

- Respondents may not be 100 percent truthful with their answers resulting in dishonesty
- Lack of conscientious responses
- Feelings and meanings are unable to be conveyed
- Respondents may have a hidden agenda
- Lack of personalization
- Skipped questions
- No matter what form of delivery is used, lack of accessibility is a threat.

Questionnaires generally consist of two types of questions (Achola and Bless, 1988; Bryman, 2004; Kaliba, 2015):

- open-ended; and
- closed-ended or structured questions.

Open-ended questions are ones that require more than one-word answers. The answers could come in the form of a list, a few sentences or something longer such as a speech, paragraph or essay. This is important when the researcher wants to get information on opinions, attitudes and reactions to sensitive questions (Achola and Bless, 1988; Bryman, 2004; Kaliba, 2015).

Advantages of open-ended questions are:

- matters that may not have been asked may be discovered, thereby enabling the researcher to gain more information;
- information is given impulsively, and it is more likely to be accurate than answers which are limited to a choice; and
- the information in the respondent's own way may be very useful as examples or illustrations that add interest to the final report.

Disadvantages include:

- Analysis of data built on open-ended questions can be time consuming, requiring responses which are not numeric and may mean going through all the questions and summarising the relevant information.

Closed-ended or structured questions offer a list of choices from which respondents must make a choice of what is most suitable. The options must be comprehensive and firm (Achola and Bless, 1988; Bryman, 2004; Kaliba, 2015):

Advantages of closed-ended questions include:

- answers could be recorded quickly; and

- analysis of answers is very easy

Disadvantages include:

- they are not suitable for face-to-face interviews;
- respondents may choose options that they might otherwise not have thought of especially if the options are not exhaustive;
- information may be missed out through lapses; and
- the respondents may lose interest and suffer from boredom and fatigue.

3.3.2 Secondary method

This method consists the use of existing data that was collected by somebody else. The researcher in this scenario is the secondary user of the data. An example of such a technique is literature review. This technique has some advantages and disadvantages as well (Bryman, 2004; Kaliba, 2015):
Advantages include:

- it is cheaper in that the data is already in existence and one just gets it and uses it; and
- it allows the analysis of trends such as traffic or population growth trends.

Disadvantages include:

- ethical issues of secrecy for instance in the scenario of on-going government projects, information may not be availed to the researcher; and
- Depending on the methods employed information may be incomplete and imprecise.

The study employed both primary and secondary research methods:

i. Primary data was collected through a semi-structured questionnaire, which was administered directly to Architects, Engineers, Quantity Surveyors, Planners, and Project Managers working in the private and public-sectors of the Zambian Construction Industry.
ii. Secondary data was drawn from written reports and publications, published books from different authors on BIM worldwide. Several other articles were sourced and downloaded from selected websites on the internet. Other sources include conference papers and University of Zambia dissertations.

Because this study is not experimental and cannot be conducted in a laboratory under a controlled environment so as to achieve the objectives of the research a case study approach was adopted. Two (2) projects, one (1) from the private sector and the other from the public sector were identified as case studies for this research. Through the case studies:

- BIM implementation on projects in the Zambian Construction Industry were determined,
- Challenges and benefits of BIM implementation were identified, and
- Modes of collaboration on projects were identified.

3.4 Sampling

In social research, sampling is the method of choosing a group of research participants for the study from the larger population under study (Lombardini, 2016). There are a wide variety of sampling approaches available for use, these are classified in two main groups, probability and non-probability sampling (Lombardini, 2016).

Probability samples: These are sometimes referred to as random samples. In this sampling method, every unit in the population has a chance of being selected. It is not necessary for each element to have an equal chance of selection, but it must at least have some chance, and this chance needs to be known (Lombardini, 2016). The following are the most common kinds of probability sampling as outlined by Lombardini, (2016):

- simple random sampling — selection at random;
- stratified sampling — sampling within groups of the population, and
- multi-stage sampling— sampling in two or more successive stages.

Non-probability samples: In this sampling method, the sample is chosen in such a way that the probability of each unit being selected is not known. The selection of the participants may be based on the individual researcher's experience, judgement, and access to potential participants (Trochim, et al., 2015). Lombardini, (2016) outlines three common non-probability sampling techniques:

- convenience sample — selecting a sample based on its accessibility or other factors of convenience,
- snowball sampling — building up a sample through informants, and
- purposive sampling — hand picking supposedly typical or interesting cases.

Some pros of non-probability sampling are the ability to capture a wide range of facets and selection is deliberate allowing the researcher to select with prior design and purpose. This type of sampling is convenient and economic and is beneficial to pilot studies. The cons include higher subjectivity and bias as compared to probability sampling which may lead to distorted findings.

The study targeted players in two sectors of the construction industry namely, consultancy and construction, drawn from the public and private sectors of the industry. The study adopted purposeful (or 'judgement') sampling because it was the most cost-effective method for quality control. The cost of studying all items in the construction industry is exorbitant and time consuming. Therefore, judgmental sampling was used where the researcher depended on experience or previous research findings to obtain participants representative of the relevant population. The sample included Project managers, Architects, Engineers, Quantity Surveyors and Contractors working in both the private and public sectors of the construction industry in Zambia.

3.5 Triangulation

Triangulation derives its name from a method employed by surveyors in their work. It comprises looking at the research question from several different viewpoints as in mapping in land surveying when instruments are positioned on two or three known control points to get overlapping data sets regarding the area or plain bound by the three control points to authenticate the accuracy of the points or data (Musonda, 2011).

The research employed multiple research methods with different advantages and disadvantages and, given this fact, it was imperative that a strong methodological approach that considered the viewpoints of all the research paradigms was adopted. Therefore, data triangulation combining aspects both of qualitative and quantitative data was employed. Guion et al. (2014) outlined five types of triangulation:

a) Data triangulation: involves using various sources of information to increase the validity of a research.
b) Investigator triangulation: involves using several different investigators in the analysis process.
c) Theory triangulation: involves the use of various viewpoints to interpret a single set of data, it typically entails using professionals outside of a particular field of study.

d) Methodological triangulation: involves the use of various qualitative and/or quantitative methods to study a phenomena. For instance, findings from surveys, focus groups, and interviews could be compared to see if similar results are being found. If the conclusions from each of the methods are the same, then validity is established.

e) Environmental triangulation: involves the use of different locations, settings, and other key factors related to the environment in which the study took place, such as the time, day, or season.

The advantages and disandvantages of triangulation are as follows (Guion, et al., 2014):

Advantages include:

- increasing confidence in research data;
- creating innovative ways of understanding a phenomenon;
- revealing unique findings;
- challenging or integrating theories; and
- providing a clearer understanding of the problem.

Disadvantages include:

- it can be time-consuming;
- collecting more data requires greater planning and organization-resources that are not always available to lead researchers;
- possible disharmony based on investigator biases;
- conflicts because of theoretical frameworks; and
- lack of understanding about why triangulation strategies were used.

Data triangulation was attained using questionnaire surveys, structured interviews and case studies to explore the evidence of BIM collaboration in the Zambian construction industry. In addition, the use of data triangulation effectively reduced data discrepancies and helped to overcome problems of bias.

3.6 Descriptive and inferential statistics

This study employed both descriptive and inferential statistics. Descriptive statistics gave information that described the data in some way such as percentages, mean, and averages, the data was usually described by compiling it into a graph, table or other visual representation. Inferential statistics on the other hand make inferences about populations using data drawn from the population. Instead of using the entire population to gather the data, the statistician collects a sample or samples from millions of residents and make inferences about the entire population using the sample (Bundly, 2016). Descriptive statistics were used to describe the basic features of the data in the study. A database was developed based on frequency tables used to perform a tally against each question to discover the frequency of each response. Additionally, pie charts and bar charts were used as a way of displaying relative comparisons of nominal data. Percentages were used in data presentation in that they simplify and translate data to a standard basis for easy comparison.

3.7 Data Analysis

In every research, the methods of collecting and analysis of data determine its quality. The data processing phase undergoes through various steps before data can be organised into meaningful information, reported and presented as final results to other users and the public. Upon receiving filled-in questionnaires, they were checked. Thereafter, all responses to open-ended questions were extracted and assigned equivalent codes to ease data entry. Microsoft office Excel software was used to tabulate, analyze and present the data in various formats for ease of interpretation. Percentages were used in data presentation in that they simplified and translated data to a standard basis for easy comparison. Questions in part three and four of the questionnaire asked the respondents to rate the challenges and benefits of BIM implementation and perception of the collaborative environment respectively. The Likert scales provided ranged from 1 to 6 as shown in table 3.3. The quantitative measures of the frequency were obtained using the same scale that was assigned to them.

Table 3.3 frequency weighting

Frequency	Weight
Strongly agree	6
Agree	5
Neutral	4
Disagree	3
Strongly Disagree	2
Don't Know	1

3.8 Summary

This chapter highlighted common research methodologies and the available methods used in the collection of data. The advantages and disadvantages of the various methods were considered before choosing a suitable research approach or simply an action plan for achieving the aims and objectives of the study. The appropriate methods identified for the study were the case study and survey methods using questionnaires to collect primary data. Secondary data was drawn from written reports, publications and published books as from different authors on BIM worldwide downloaded from selected websites. Paper based sources of secondary data included Journals and dissertations from the university library. Judgmental sampling was used to target research participants the Zambian construction industry. Data triangulation was used to reduce data error and assist to overcome problems of bias. The next chapter presents, and analyses data collected.

CHAPTER 4: DATA PRESENTATION AND ANALYSIS

4.1 Introduction

This chapter presents the research results and how they were analysed. The objectives of the survey were to determine the degree to which BIM is perceived to have been adopted in the Zambian construction industry. The survey further identified the challenges and opportunities in the implementation of BIM in the management of construction projects in Zambia. The survey also investigated how effectively project team members perceived to have collaborated on the projects. It was hoped that the questionnaire survey might act as an information tool that would highlight the potential of BIM as a collaborative technique in the management of projects in the Zambian construction industry.

4.1 Surveys

The study employed two types of surveys, questionnaires and structured interviews. The intention was to try and relate or compare the results from the two methods. To prevent bias from the respondents, a self-administered questionnaire was adopted as the most suitable method of data collection. The respondents were assured of secrecy and were encouraged to be as open as is possible. This boosted the confidence that was derived from the results of the research. Structured interviews were used to obtain further insight into the evidence of BIM collaboration in the Zambian construction industry.

4.1.1 Layout

a) Questionnaires

The questionnaire was established with the objectives of the study in mind. The layout of the questionnaire comprised four parts. Part one covered general questions on the respondent and their organisations. Part two sought to showcase perceptions of BIM in the Zambian construction industry. The third part probed the challenges and benefits of BIM implementation through experiences of the respondents. The fourth and last part of the questionnaire comprised of questions that delved into the respondent's perception of the collaborative environment. Closed-ended questions with a few provisions for open-ended questions to elicit any other additional relevant information from the respondents were adopted for the questionnaire.

b) Structured Interviews

Structured interviews were used to obtain further insight into the evidence of BIM collaboration in the Zambian construction industry. They were designed to reinforce and verify questionnaire results as part of data triangulation. The layout of the interview guide comprised three parts. Part one covered general questions on the respondent and their organisations. The second part comprised of questions that delved into the respondent's perception of the collaborative environment in the industry. The third and final part sought to showcase perceptions of BIM in the Zambian construction industry.

4.1.2 Pre-Testing

The preparation of the survey instruments involved literature review, suggestions, consultations and several reviews. Drafts of the survey instruments where pilot-tested with three industry practitioners to ensure that questions were clear and unambiguous. The individuals that were involved in the pre-testing are shown in Appendix A.1. As a result of the pilot testing, changes were made to the order and the wording of certain questions to reflect the feedback received, but the substantive document remained unchanged. The questionnaire is reproduced in its entirety in Appendix A.4 while structured interview questions are reproduced in Appendix B. 1.

4.1.3 Response rate

For this study, a cover letter was drafted to accompany the questionnaire, outlining the purpose of the survey, explaining certain terms such as BIM, requesting co-operation in completing the document and re-assuring the participants that their responses will be confidential and strictly used for academic purposes. A sample of the cover letter is shown in Appendix A.3 The respondents for this study included Project managers, Architects, Engineers, Quantity Surveyors, Site Engineers and Contract Managers directly working in both the private and public sectors of the Zambian Construction Industry. A total of 60 questionnaires were issued and 54 questionnaires were returned indicating a response rate of 90%, this was deemed sufficient for the study. The questionnaire survey results were complemented by interviews carried out with ten participants.

4.2 Questionnaire Survey

The questionnaire survey was carried out over a period of six weeks from July to August, 2017. The questionnaires were sent to Project managers, Architects, Engineers, Quantity Surveyors and Contractors working in the construction industry in Zambia.

4.2.1 Respondent's demographics

The respondents provided the information under the assurance that their names would remain anonymous. This part of the questionnaire covered general questions on the respondents and their organisations. To establish whether the respondents were active in the construction sector, they were requested to state the name of the organisation they worked for. All the organisations stated were active in the Zambian construction industry as verified by the 2017 registers of regulatory and professional bodies such as QSRB, ZIA, SIZ, Eng-RB and NCC.

Figure 4.1 displays the percentage breakdown of respondents by Sector. The majority of respondents at 58 percent belonged to the private sector while 42% came from the public sector.

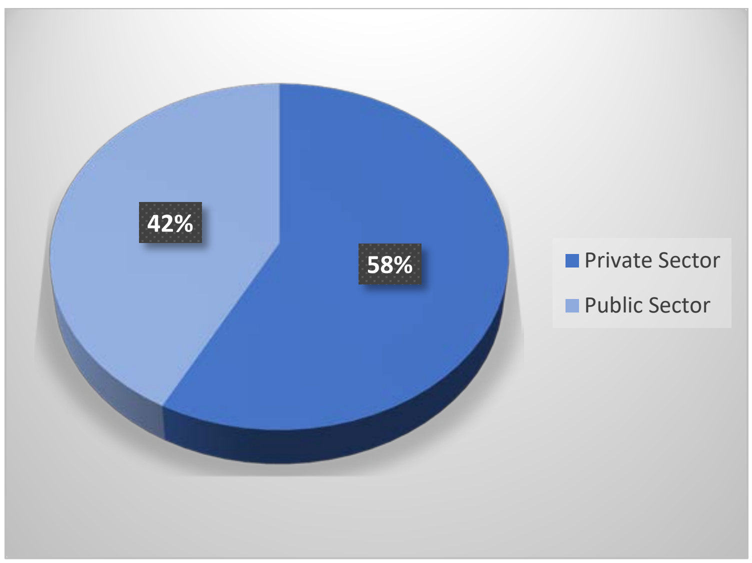

Figure 4.1: Percentage breakdown of respondents by sector

Figure 4.2 shows a breakdown of the total respondents by their professional involvement on the projects. The purpose of establishing the professions of the respondents was to assess whether they would be able to respond to the subsequent questions in the questionnaire with a high degree of certainty. The analysis concluded that most respondents had the necessary background and experience. All the respondents taking part in the study where males clearly demonstrating the gender inequality in the industry this however didn't affect the credibility of the respondents.

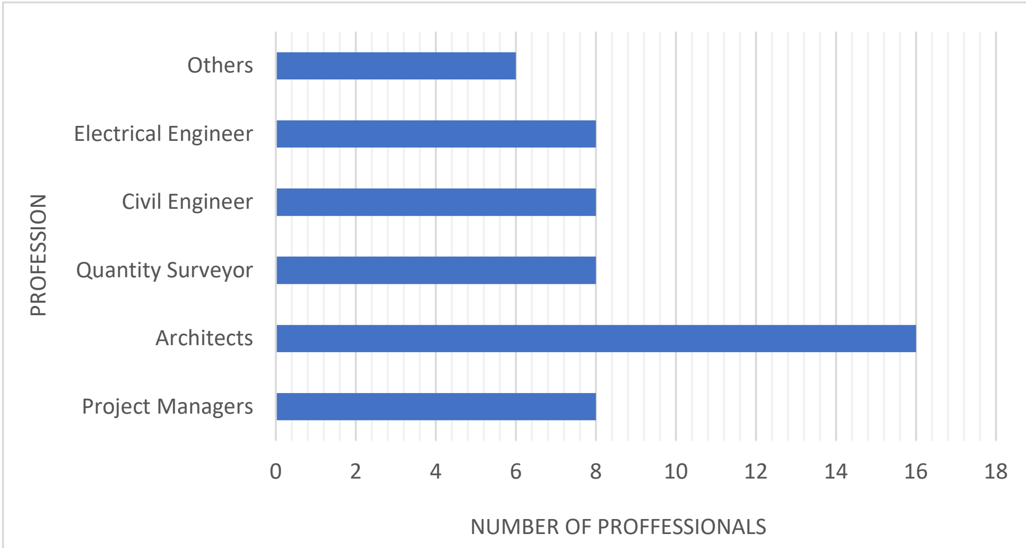

Figure 4.2: Professional involvement on the projects

Figure 4.3 shows the academic qualifications of the respondents. Although the qualifications varied, of the 20 respondents,12 had a minimum of a bachelor's degree, four had master's degrees and one had a diploma this was adequate for the study.

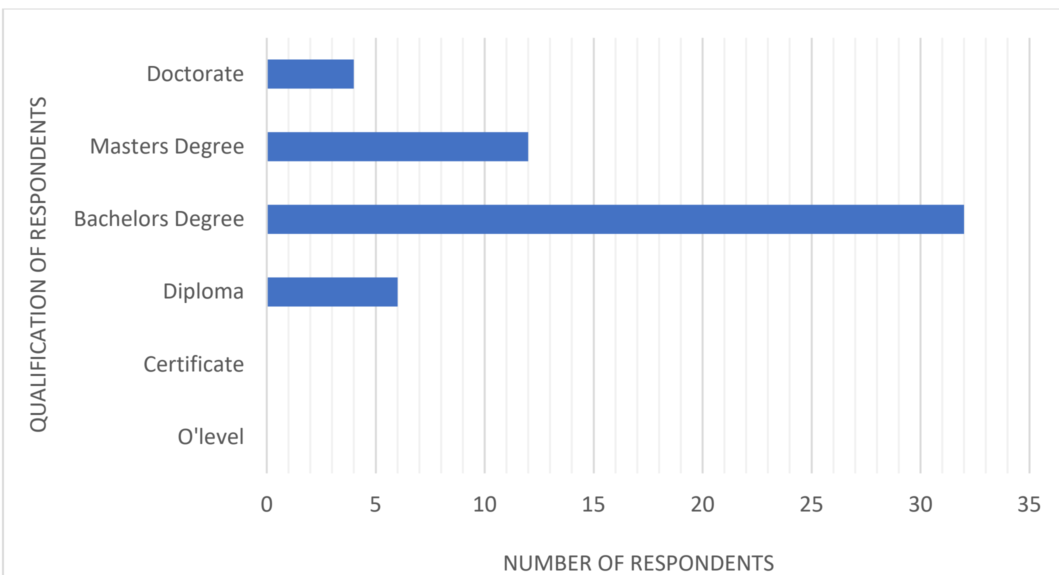

Figure 4.3: Respondent qualifications

Apart from academic qualifications of respondents, another important factor the research considered was their experience in the construction industry. All the respondents, had experience in the construction industry with 59 percent having had more than 10 years' experience and 41 percent with between 5-10 years' experience as indicated in Figure 4.4. This was satisfactory for the research as the information submitted in the questionnaires would be reliable and based on actual experience.

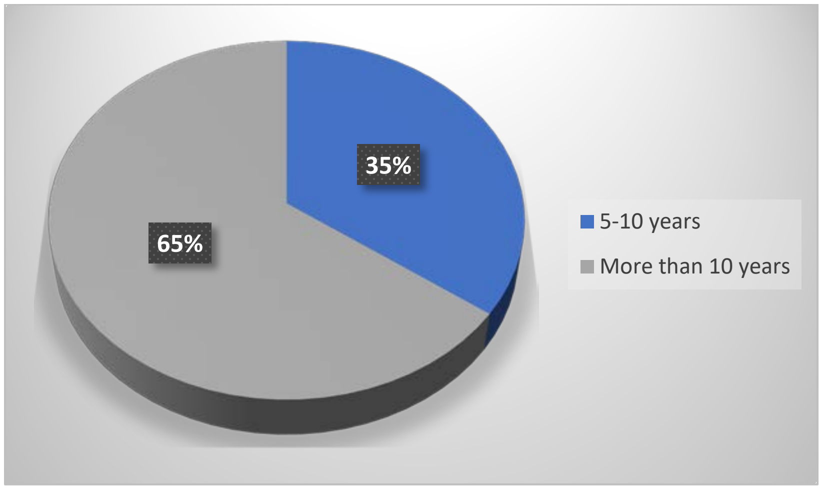

Figure 4.4: Percentage breakdown by length of respondents' experience in the construction industry

4.2.2 Perception of BIM

From figure 4.5, it can be deduced that 60 percent of the respondents perceive BIM to be a 3D design and modelling software while 40 percent think it's a digital platform for information exchange. This result gives an understanding on how the practitioners in the Zambian Construction Industry perceive what BIM is. The lack of knowledge on what BIM is indicates that a lot of work needs to be done to educate and inform the construction industry practitioners on the full capabilities of BIM for it to be effectively implemented in the execution of construction projects.

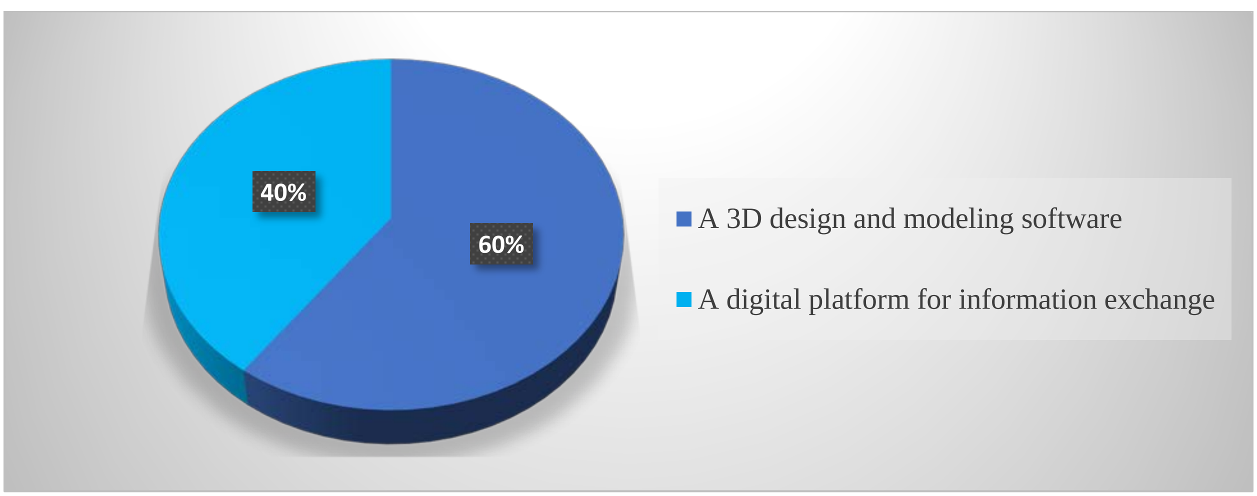

Figure 4.5: Percentage breakdown by respondent's definition of BIM

Figure 4.6 shows that 30 percent of the respondents where not sure if the software there are using was a BIM software or not, 20 percent didn't use any form of BIM software at all while 50 percent used some BIM software. The result shows that the Zambian Construction Industry practitioners are already knowledgeable with software designed for BIM and the implications are that most practitioners are slowly gravitating towards complete BIM adoption. Further, the results show that the use of BIM software packages in the design to construction workflow have become the focus of most participants in the construction industry.

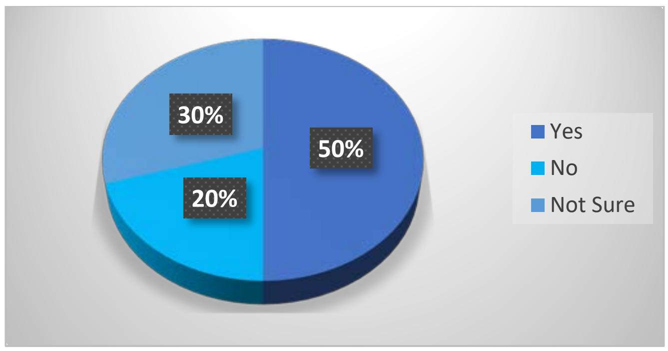

Figure 4.6: Percentage breakdown of respondents usage of BIM software

From figure 4.7 it can be established that there is some segmented BIM software usage in the industry with each discipline using its own industry related software with most respondents using Revit. These results suggest a need for cohesion in the usage of software among the different disciplines in the Zambian Construction industry.

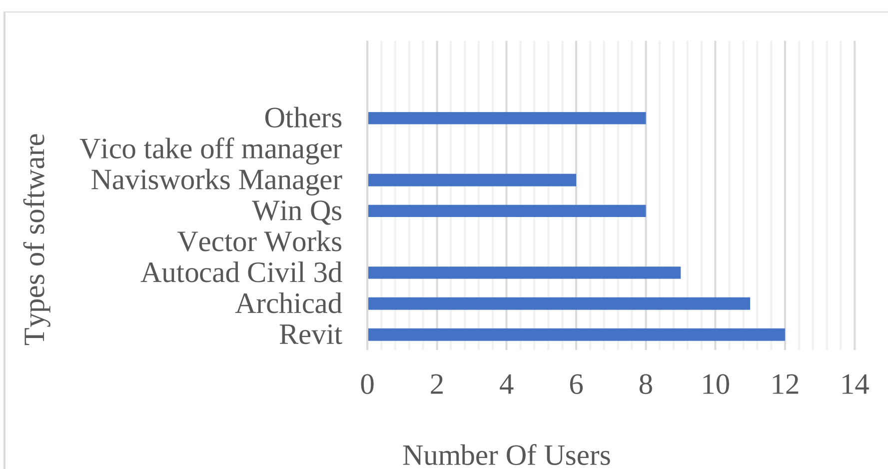

Figure 4.7: Types of BIM software used

Figure 4.8 shows how BIM software was used on the projects, BIM software was mainly used in the production of; renderings and perspectives, construction documents and scheme designs. From literature review the Bew-Richards BIM Maturity Model indicates that BIM usage starts at level 0 with unmanaged Computer Aided Design (CAD) in 2D and progresses to level 3 with a fully integrated and collaborative process enabled by 'web services' and compliant with emerging Industry Foundation Class (IFC) standards. These results therefore, indicate that BIM software is being used in the Zambian Construction Industry, however there is also a need for increased awareness on BIM as 10 respondents out of the 54 sampled were not sure how they used BIM on the projects.

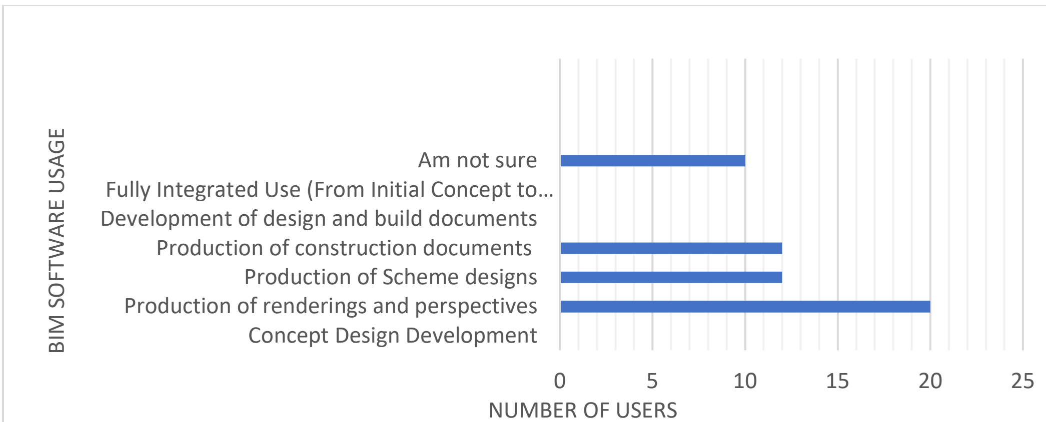

Figure 4.8: BIM Software usage on the projects

Figure 4.9 indicates that 83 percent of the respondents were aware of the different levels of BIM collaboration, this suggests that the respondents have sufficient knowledge to the BIM collaboration technique and this makes the surveyed data a reliable basis for discussion and analysis of BIM collaboration on construction projects in the Zambian Construction Industry.

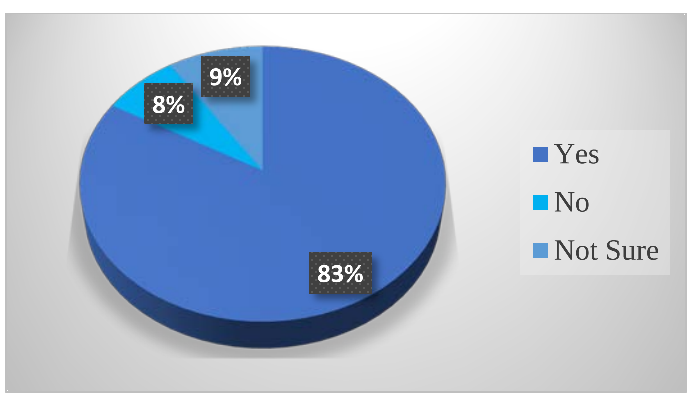

Figure 4.9: Percentage breakdown of respondents’ awareness of BIM collaboration levels

Figure 4.10 shows respondent results on the Bew-Richards BIM Maturity Model which depict the BIM usage maturity levels from 0-3, it can been seen that 62 percent of the respondents are collaborating at level 1 while 38 percent collaborating at level 0. This indicates that there is some evidence of BIM collaboration in the Zambian construction however it should be noted that this collaboration is still in its infancy.

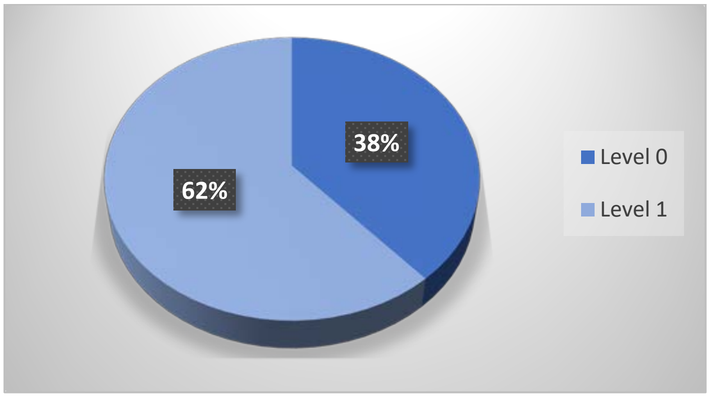

Figure 4.10: Levels of BIM collaboration

The results in Figure 4.11 indicate that most respondents acknowledge that the use of BIM technology improves collaboration among project team members.

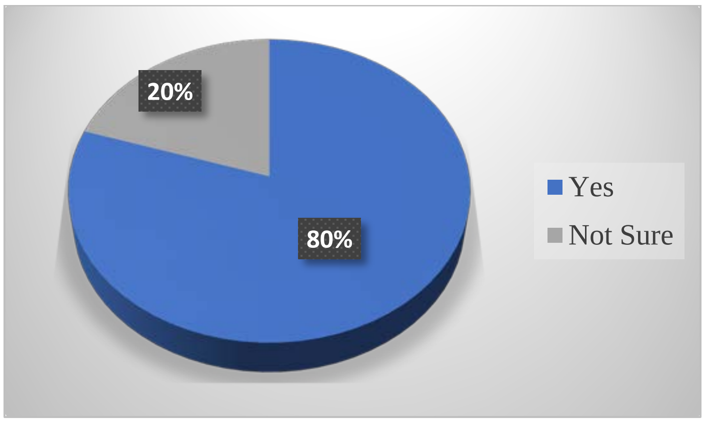

Figure 4.11: Percentage breakdown of respondent's responses if BIM improves collaboration among project team members

Figure 4.12 indicates that there is a general belief among respondents that the use of BIM technology in Zambia will increase in the next 5 years. The respondents also highlighted that the increased BIM usage will make collaboration among project team members more efficient thus making the management of projects more efficient.

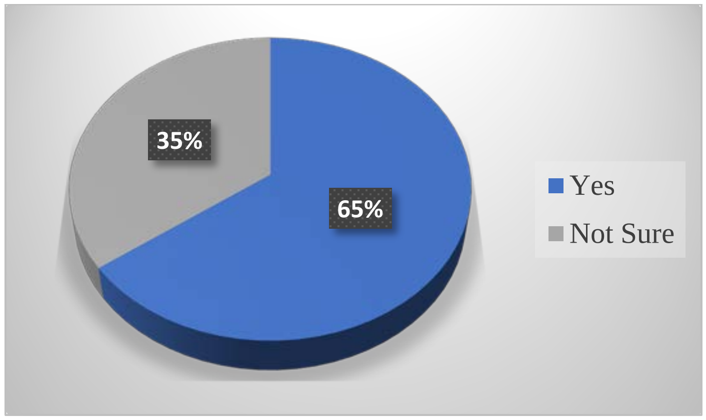

Figure 4.12: BIM utilisation in the next 5 years

4.2.3 Challenges and benefits of BIM implementation

This section of the research probed the challenges and benefits of BIM implementation as reviewed from literature through experiences of the respondents working in the Zambian Construction Industry. Figure 4.13 indicates that the main barriers hindering full BIM adoption are the prohibitive cost of setting up BIM, the lack of local institutions offering adquate BIM training and a lack of Government will and support in the adoption of BIM in Zambia and practitioners feel the current ICT systems sufficiently carter for the management of construction projects in Zambia.

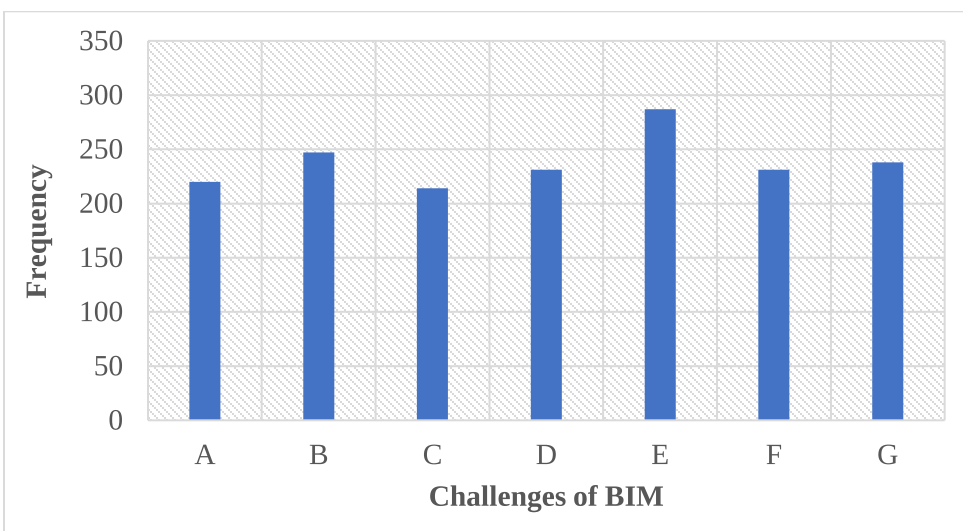

Figure 4.13: Challenges of BIM implementation

A. There is a lack of a technical pool of skilled of BIM personel in Zambia

B. There is a lack of Government will and support in the adoption of BIM in Zambia

C. BIM technology is not necessary or applicable for the nature of projects undertaken in Zambia

D. Zambia doesn't have institutions offering adquate BIM training

E. The cost of setting up BIM is too high

F. There is no demand for BIM in Zambia

G. The current ICT systems sufficiently carter for the management of construction projects in Zambia

Figure 4.14 shows that the main benefits obtained from the usage of BIM are that; it allows multiple design disciplines to collaborate at an early stage in the design, it enables the client to quickly grasp the concept, feasibility and overall design, With a shared BIM model, there's less need for rework and duplication of drawings for the different requirements of building disciplines and allows designers to automatically make low-level corrections when changes are made to the design.

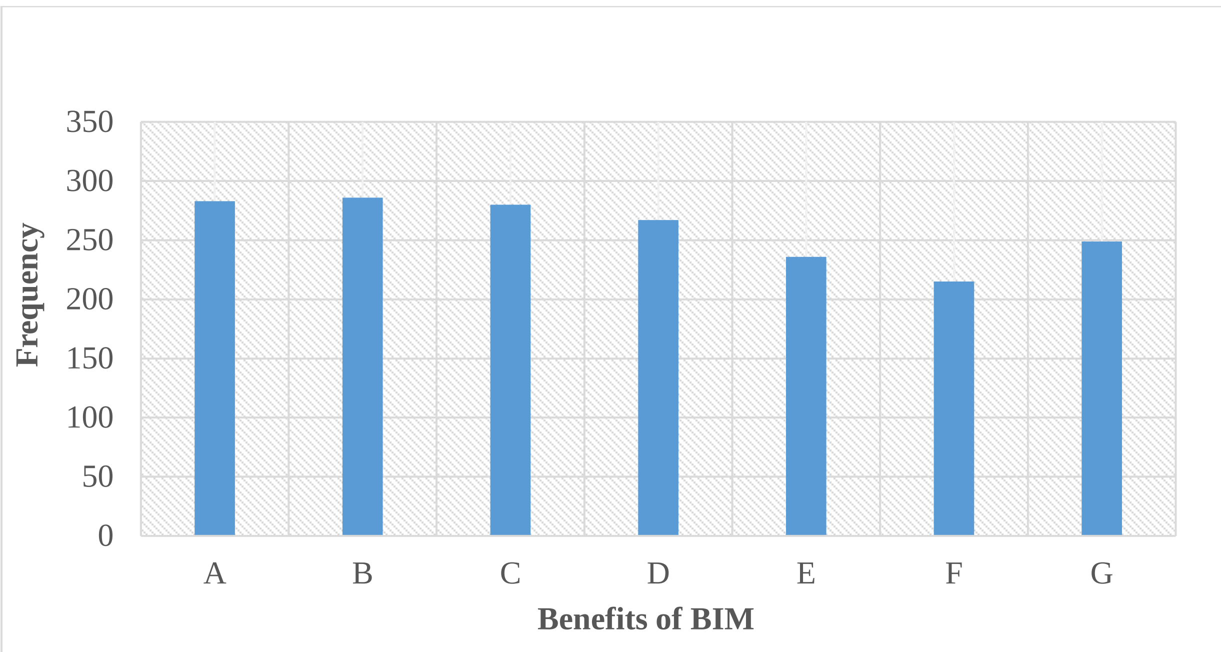

Figure 4.14: Benefits of BIM implementation.

A- BIM enables the client to quickly grasp the concept, feasibility and overall design

B- The use of BIM allows multiple design disciplines to collaborate at an early stage in the design

C- BIM allows designers to automatically make low-level corrections when changes are made to the design

D- With a shared BIM model, there's less need for rework and duplication of drawings for the different requirements of building disciplines.

E- BIM allows for the extraction of cost estimates during the design stage

F- When the design is completed, the BIM model is the ultimate communication tool to convey the project scope, steps, and outcomes.

G- BIM enables the production of geometrically accurate and consistent 2D drawings at any stage of the design

4.2.4 Perception of the collaborative environment

The last section of the questionnaire delved into the respondent's perception of the collaborative environment. The questions asked aimed to gain an understanding on how project team members collaborated on the projects. The results in Figure 4.15 show how project team members collaborated on the projects. It can be seen from the results that the projects had a clear and defined team leader who arranged tasks in ways that helped each team member to attain their goals. The respondents also had trust in the lead designer's ability to safeguard the interest of all disciplines involved in the design.

The results similarly indicate that problems, challenges and obstacles were encountered on the projects, however they were solved collaboratively. Further it can be seen that priorities where agreed upon, there was relevant feedback among team members and that there was no problem with information sharing on the projects. From these results it can be deduced that there was harmonious and effective collaboration on the projects.

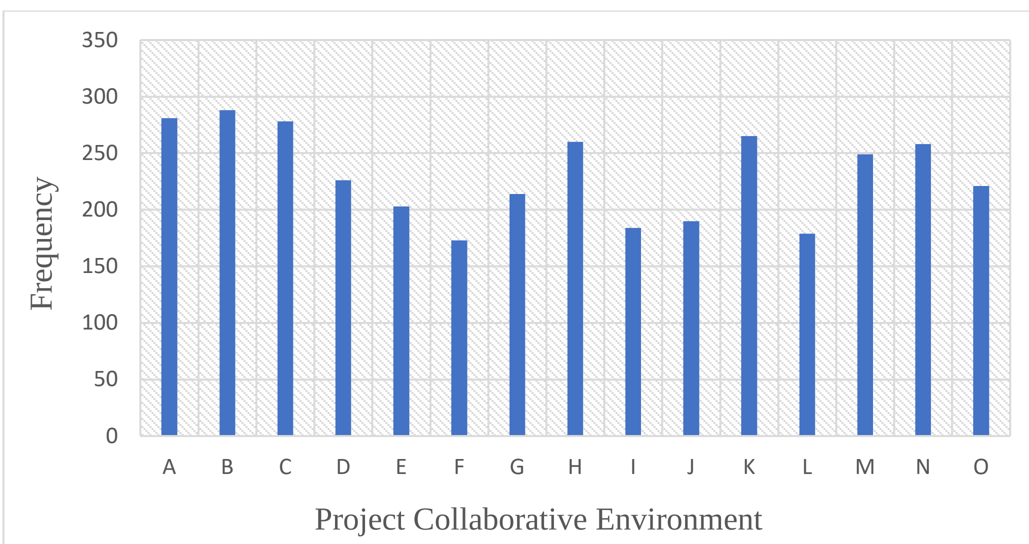

Figure 4.15: The collaborative environment.

A- I feel that the project has a clear and defined lead designer

B- It is important that the lead designer arranges work in ways that helps each disciplinary group reach their goals

C- I trust that the lead designer will safeguard the interest of all disciplines involved in design

D- We rarely solve defined problems in collaboration with all disciplines

E- There are rarely problems with collaboration in doing inter-disciplinary work

F- In most inter-disciplinary work, we rarely agree about priorities

G- Professionals from different disciplines are often frustrated with each other

H- I get relevant feedback from other disciplines about my team's contributions

I- Exchange of information between disciplines is always a problem

J- I find that professionals from other disciplines are not willing to listen to me if I have problems

K- I find that my teams view is appreciated by other disciplinary groups

L- I rarely find that other disciplinary teams understand what my organisation's team is trying to express or report

M- I feel that I am not able to make significant decisions without consulting the lead designer

N- I can be open about an error that affects other design firm's work as soon as it is recognised

O- I feel team members collaborate well when they are all from the same organisation

4.3 Structured Interviews

Structured interviews were used to obtain further insight into the evidence of BIM collaboration in the Zambian construction industry. They were designed to reinforce and verify questionnaire results as part of data triangulation. The layout of the interview guide comprised three parts. Part one covered general questions on the respondent and their organisations. The second part comprised of questions that delved into the respondent's perception of the collaborative environment in the industry. The third and final part sought to showcase perceptions of BIM in the Zambian construction industry.

The structured interview questions are reproduced in Appendix B. 1. The guide targeted ten (10) individuals from the private and public sectors of the industry, though the sample size was small it encompassed all the key players in the Zambian construction industry and provided an indicative feedback on the prevailing situation in the industry. Interviewees were initially contacted via telephone to introduce and explain the layout of the interview. The designed structured interview questions were then sent by email for the interviewees to acquaint themselves with the subject matter. The list of the interviewed individuals is in Appendix B.2.

4.3.1 Respondent's demographics

The interviewees were asked to state the name of the organisation they worked for, which sector of the construction industry they belonged, position in the organisation, professional background and experience. Figure 4.16 indicates the distribution of interviewees according to construction industry sector.

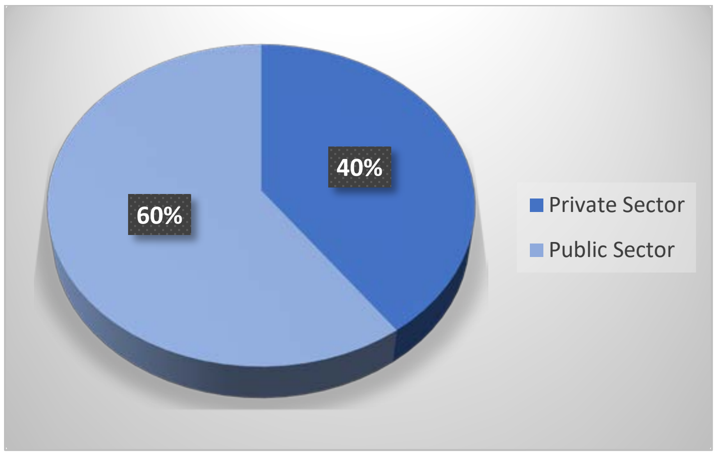

Figure 4.16: Percentage breakdown of respondents by sector

Of the interviewees, three (3) were in middle management positions while seven (7) were in senior management positions. All of them had construction background with experience ranging from 10 to 35 years. The experience of the respondents showed adequate exposure to construction processes to make the data collected a reliable basis for discussion and analysis of perceptions into construction industry practices in Zambia.

4.3.2 Collaboration in the Zambian Construction industry

All the interviewees agreed that the use of ICT enhances collaborative working arrangements on construction projects by improving communication and quickening information sharing among project team members. It was also established that for effective communication to exist on a project communication channels must be put in place at project initiation and all project related templates such as report templates and change order templates must be given to all relevant project team members.

The interviewees indicated that it doesn’t matter whether project team members are from the same organisation or from different organisations effective collaboration was dependent on how effectively the project team leader motivated his team members. It was also observed that the interviewees encountered some problems during project implementation, common among them where; poor communication, a lack of following laid down procedures and lack of professionalism. There was also a consensus among the interviewees that a lot needed to be done to achieve effective collaboration in the Zambian Construction Industry.

4.3.3 Building Information Modelling

The interviewees indicated that they are using BIM software on their projects with Revit, ArchiCAD and Win-Qs being the top software used. These software packages where mostly used for preparation of presentation drawings, preparation of 3D illustrations, preparation of BOQs and preparation of as built drawings.

The benefits and challenges of using BIM on projects were also highlighted by the interviewees with the common benefits being: enhanced project monitoring and evaluation, quick resolution of design team conflicts, easier and faster update of project data to all team members, and the designer easily expresses themselves. The common challenges included the cost of BIM, the lack of technical education in BIM software, and a lack of political/government will to spearhead BIM implementation.

Interviewees highlighted that some of these challenges can be overcome by doing the following: lobbying software companies to lower the prices for the third world market, conducting workshops to provide training and sensitization on BIM, a deliberate Government policy to encourage the use of BIM in construction and lower taxes on BIM products to help bring the cost down. All the interviewees agreed that most of the challenges they encountered on their projects could have been avoided with full BIM implementation.

It was also established that the adoption of BIM in the management of construction projects in Zambia is still in its infancy as seven (7) out of the ten (10) interviewees agreed that the availability of BIM software has significantly improved the visualisation, coordination and management project life cycle. All the interviewees agreed that there utilisation of BIM would increase in the next 5 years and with it improved collaboration among project team members.

4.4 Summary

This chapter presented and analysed the data obtained from interviews and questionnaire survey. The survey established that individual discipline based BIM software are already being used in Zambia with project team members collaborating at BIM level 1. However, the main barriers hindering full BIM adoption are the prohibitive cost of setting up BIM and a belief among project team members that BIM technology is not necessary or applicable for the nature of projects undertaken in Zambia. Further it was established that there was harmonious and effective collaboration on the projects. The next chapter presents a review of case studies to provide a comprehensive examination of issues because they draw from actual experiences and practices.

CHAPTER 5: CASE STUDIES

5.1 Introduction

From the research methodology, case studies were highlighted as a research tool that would be used in this study. Case studies provide a comprehensive examination of issues because they draw from actual experiences and practices. In this chapter, two case studies were reviewed:

The Proposed E.I.Z Headquarters at the Agricultural & Commercial Show Society Grounds in Lusaka and The Proposed Expansion of National Science Center in Lusaka from the private and public sectors of the construction industry respectively.

5.2 Case Studies

Construction is generally considered a private affair between the clients and their consultants and project information is normally concealed. Consequently, the willingness of consultants to subject their projects to scrutiny determined which case studies were selected. Since the lead consultants on most construction projects in Zambia are Architects a list of Architectural firms operating in the country was obtained from the Zambia Institute of Architects. Emails where sent to the Architectural firms seeking authority to use one of their projects as a case study most declined sighting privacy as the main reason. However, the Principle partner for A+ Urban Technics agreed and recommended The Proposed E.I.Z Headquarters at the Agricultural and Show Society Grounds in Lusaka to be used as a case study for the private sector of the industry.

For the public sector project authority was sought from the Ministry of General Education to use one of their projects as a case study as they are one of the largest Ministries implementing public sector building projects in the country. And authority was granted to use the Proposed Expansion of National Science Center in Lusaka as the second case study.

5.2.1 Proposed E.I.Z Headquarters at the Agricultural & Commercial Show Society Grounds in Lusaka

The Engineering Institution of Zambia's vision for its new Office Park is to achieve a harmonious cohabitation of the secretariats in one Headquarter facility in which the Engineering profession in Zambia will be celebrated and honored in the design of this building. The Institute commissioned a team comprising; Architects and Project managers – A+ Urban Technics, Electrical Engineers – Utilink, Mechanical Engineers – ESB, Quantity Surveyors – MLN, Civil Engineers – Zulu Barrow, and

Structural Engineers – Civil-struts Consulting Engineers as the project consultants with the lead contractor being Hua Chang Infrastructure.

The site is located at the Agricultural and Commercial Show Society of Zambia in Lusaka, right behind the Arcades shopping complex, along Thabo Mbeki Road as shown in Figure 5.1.

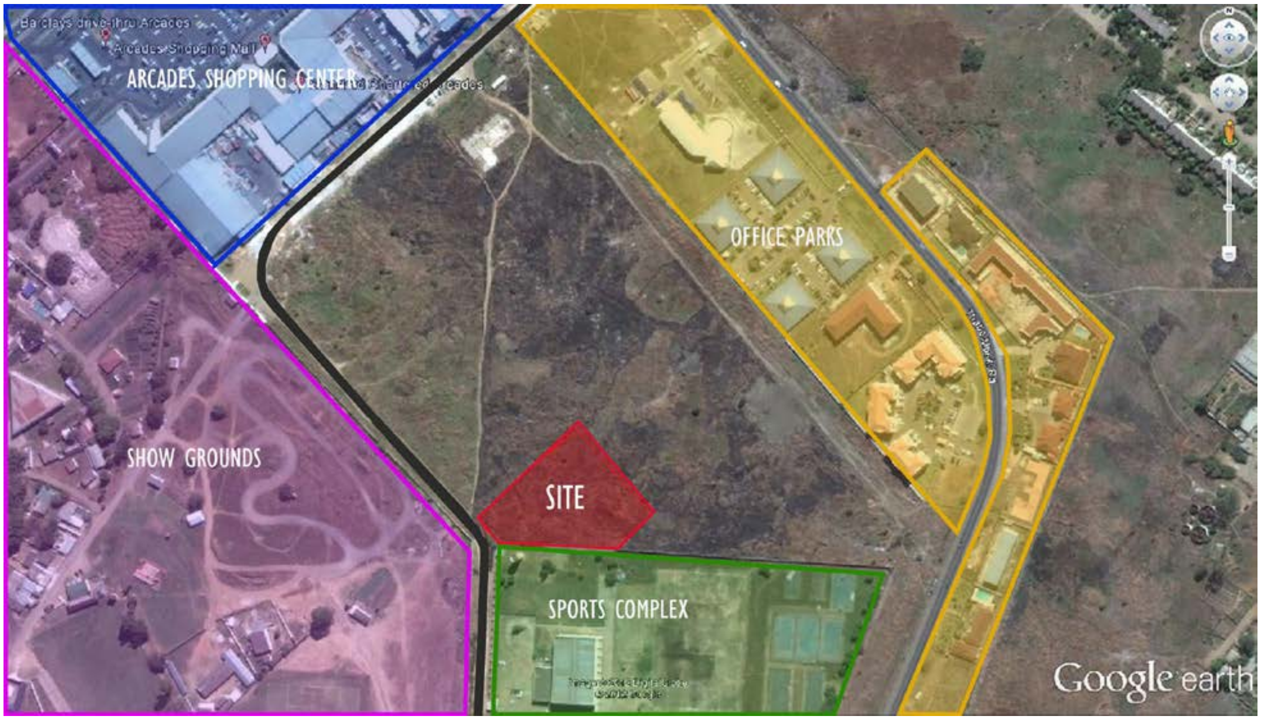

Figure 5.1: The Site For the E.I.Z office block (source: A+ Urban Technics)

5.2.2 Project Description

The Complex consists of two interconnected office blocks with an elevated car-park with the following general accommodation and other ancillary support spaces; offices for the EIZ (National Secretariat), offices for the EIZ (Southern Region), an auditorium (500 capacity), exhibition galleries, a crèche, a gym and coffee shop/ deli.

5.2.3 The Design

The designers aimed to prepare creative and inspiring architectural and engineering designs that will guide the construction and utilization of the EIZ Headquarters and incorporate principles of sustainable management of the environment. The building consists of four floors. Figure 5.2 shows the Ground

Floor Plan which comprises of 144 parking spaces, a terrace, an exhibition gallery, a café, a hall, two lobby spaces, two stairwells, gents and ladies' toilets. It has a total floor area of 632 square meters.

Figure 5.2: Ground Floor Plan (source: A+ Urban Technics)

Figure 5.3 shows the First Floor Plan consisting of 12 office spaces, a Kitchen, three store rooms, equipment room, a registry, two lobby spaces, two stairwells, gents and ladies' toilets, two board rooms, a resource center and 59 parking spaces. It has a total floor area of 632 square meters.

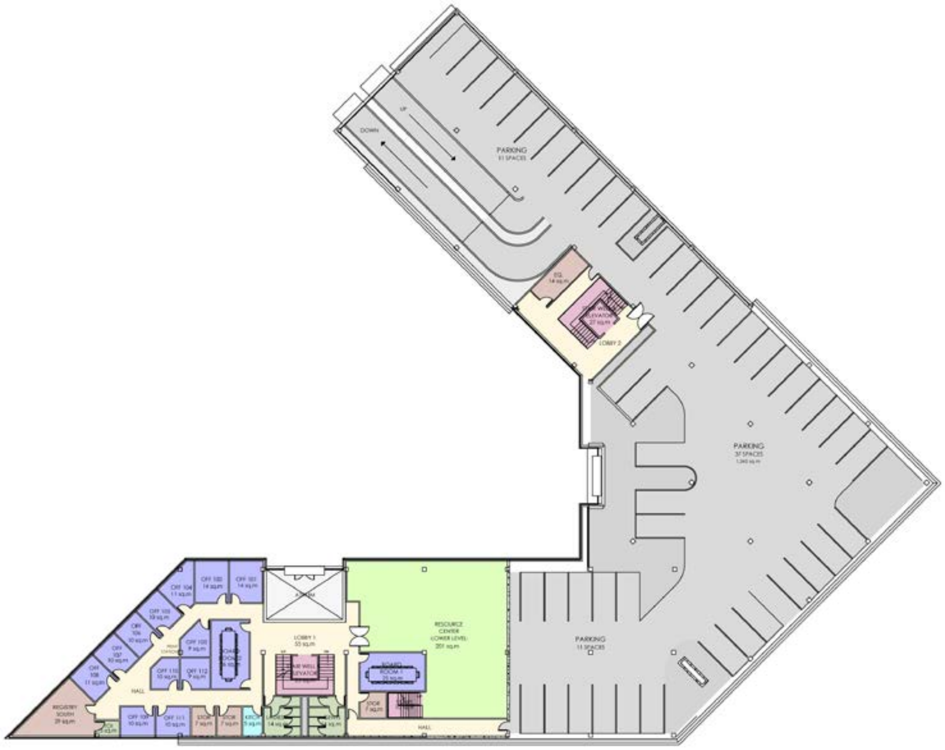

Figure 5.3: First Floor Plan (source: A+ Urban Technics)

The Second Floor Plan with a total floor area of 2486 square meters is shown in Figure 5.4, it consists of offices, an auditorium, gents and ladies' toilets, waiting hall, a kitchen, a gymnasium, a creche, two boardrooms, two stairwells and a resource center. The third and final floor has a total area of 1597 square meters consisting of office spaces, an executive lounge, a terrace, gents and ladies' toilets, store rooms and a kitchen.

Figure 5.4: Second Floor Plan (source: A+ Urban Technics)

5.2.4 BIM on the project

Individual discipline based BIM software where used on this project with the Architects employing the use of Revit to produce 3D illustrations as depicted in Figure 5.5 and 5.6. It was established that after the Architects did the designs in Revit they then had to convert them to PDF and DWG formats which they had to share with the other consultants using E-mails and Google Docs. Win Qs and Microsoft Excel was used by the Quantity Surveyors to produce Bills of Quantities and Cost estimates these where then printed or shared in pdf formats with the client and other project team members. The Electrical and Mechanical Engineers did their drawings in AutoCAD 2d while the Structural and Civil Engineers used Prokon and AutoCAD Civil 3D respectively. On this Project BIM usage was lowest during the construction phase, as the contractor was mostly availed with printed hard copy drawings and the only form of soft copy drawings where in pdf format. It should be noted that this project did not have a comprehensive BIM model where all the consultants could simultaneously work on.

5.2.5 Benefits of BIM software usage on the project

The Literature review in Chapter 2 highlighted the benefits obtained from BIM. Despite the project not having a common BIM software platform it was discovered that they were some benefits obtained from the use of BIM software. Figure 5.5 and 5.6 show Architectural three dimensional illustrations of the project. These illustrations made it easier for the Architects to explain the design to the client and with these illustrations it enabled the client to easily lobby for construction funding. Further the usage of BIM software on this project enabled the quick implementation of the design process as it was faster for project team members to understand the feasibility and overall concept of the design.

Figure 5.5: 3D Illustration of the office block (source: A+ Urban Technics)

BIM software usage on the project also made it easier for individual project team members to make corrections and changes to the design. Accuracy was similarly enhanced both during the design process and the construction phase as it was easier to produce geometrically accurate design details at any stage of the project life cycle.

Figure 5.6:3D Illustration of the office block (source: A+ Urban Technics)

5.2.6 Challenges of BIM software usage on the project

A review of the project document records showed that the main challenge in the implementation of BIM was the lack of the usage of a common BIM software platform it was discovered that each discipline was using individual discipline based software for instance Architects where using Revit and ArchiCAD, Quantity Surveyors where using Win Qs, and Engineers used mostly AutoCAD 2d this resulted in repetition of tasks and time delays. This lack of cohesion in terms of software among project consultants working on this project made it impossible to come up with a comprehensive BIM model. The absence of a networked BIM model resulted in repetition of tasks as some team members particularly Engineers had to convert the drawings given to them by the Architects to the appropriate software format. Further the lack of a BIM model made it difficult for effective data exchange among project team members particularly when changes to the design are made. Another challenge was the cost of software licenses which proved to be high with some consultants depending on cracked BIM software to execute their works this exposed there computers to potential malware attack.

5.2.7 Collaboration on the Project

The collaborative working relationship among project team members on this project has taken the form of an alliance in which the different firms have voluntarily come together to execute the project. It was established that the project has a Contract which explicitly outlines the roles of all team members on the project. The project has a clearly defined team leader who is also the project manager. The team leader coordinates everyone on the project. A project implementation strategy has been developed, each team members roles are clearly defined, project communication channels have been clearly outlined and dispute resolution modalities have been established. Regular site meetings are held on site chaired by the project manager at which the progress on the project is established, all the various consultants present their reports and the necessary instructions given to the contractor.

The project team members collaborated in way that is private in which the team members decide how to conduct work, and choose solutions to the problems on the project. From the literature review, this manner of collaboration is described as a consortium.

5.3 Proposed Expansion of National Science Center in Lusaka

National Science Center (NSC) is a unit in the Ministry of General Education mandated with upgrading the teaching of Science, Mathematics and Technology (SMT) subjects. The unit has embarked on the expansion of infrastructure at the NSC offices in Kabulonga Lusaka. The Project Consultants are The Zambia Education Projects Implementation Unit (ZEPIU) a unit under the Ministry of General Education. The project is being constructed in phases with the first being the construction of the administration building which was awarded to October First Enterprise Limited on 6th November 2017 and the second phase consisted the construction two double storey lecture rooms and laboratories.

5.3.1 Project Description

The Project comprises an Administration Building, Double Storey Lecture and laboratory block, An Exhibition hall, A Multi-Purpose Hall and Three storey Hostels.

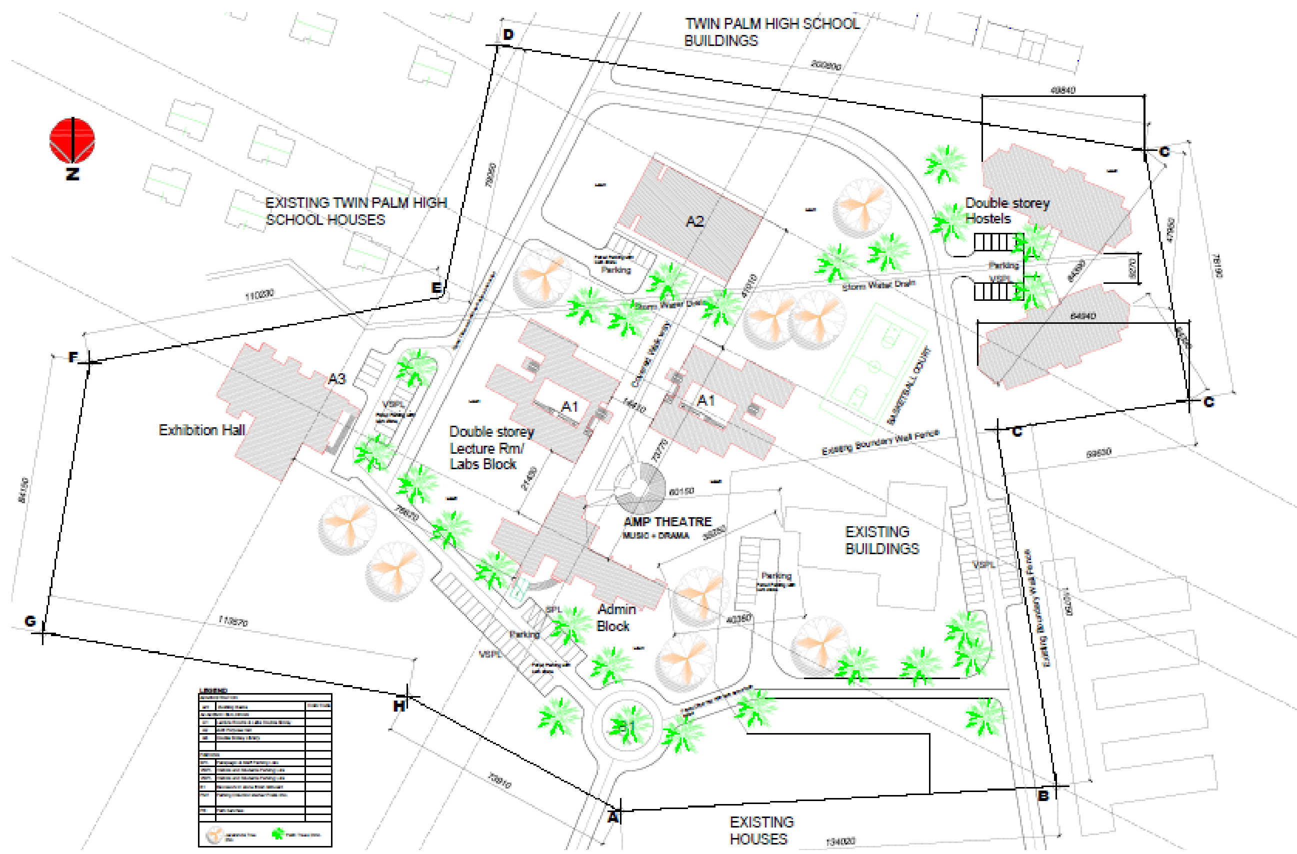

Figure 5.7: Site layout of the Proposed Development (Source: ZEPIU)

5.3.2 BIM on the project

The project was designed using Revit and ArchiCAD as the primary BIM software packages, these two software packages where mostly used for production of 3D illustrations and presentational drawings.

Detailed Architectural drawings where done in AutoCad 2d this entailed changing the format from the Revit and ArchiCAD model into the dwg format supported by AutoCAD. Win Qs was used to produce Bills of Quantities and Cost estimates these where then printed or shared in pdf formats with the client and other project team members. The Electrical and Mechanical Engineers did their drawings in AutoCad 2d while the Structural and Civil Engineers used Prokon.

From the interviews with project team members it was deduced that individual discipline based BIM software where used on this project however this project lacked the cohesion among team members to work on one model, resulting in repetitions as some team members had to completely redraw the works.

5.3.3 Benefits of BIM software usage on the project

ArchiCAD and Revit where the primary BIM software used on this project mainly for the production of 3d illustrations, these 3D design views gave the Architects an opportunity to quickly try out different designs, while the high-quality documents produced enabled them to detect and correct problems early in the design process and this resulted in savings on time and money. The illustrations in Figure 5.8 and 5.9 respectively made it easier for the client and the project donors to clearly grasp the design concepts. Further, the usage of BIM software by the consultants on this project ensured that the design process was quickly implemented as it was easier for project team members to understand the feasibility and overall concept of the design.

Figure 5.8: 3D Illustration of the Hostel Block (Source: ZEPIU)

It was also observed that the usage of BIM software on this project provided flexibility and efficiency in the design process. It also Increased the productivity and efficiency of project team members. Accuracy was equally enhanced both during the design process as it was easier to produce geometrically precise design details at every stage of the project life cycle.

Figure 5.9: 3D Illustration of the Laboratory Block (Source: ZEPIU)

5.3.4 Challenges of BIM software usage on the project

Despite all the Consultants working for the same organisation it was deduced that each individual professional consultant used their own preferred BIM software. This lack of cohesion among team members to work on one model, resulted in repetitions as some team members had to completely redraw the works. Another challenge observed was that with the exception of the Quantity Surveyors who regularly renewed the Win Qs license all the other professionals are using cracked BIM software owing to the cost of the license.

5.3.5 Collaboration on the Project

The project has a written contract (based on the FIDIC contract) between the client and the contractor which outlines the obligations of all parties to the contract. It was established that the collaborative working relationship among project team members on this project has taken the form of an alliance in which the different professionals have come together to execute the project. All aspects of the project are coordinated by the Director of Projects ZEPIU who then assigns tasks to a team of Architects, Quantity Surveyors and Engineers under him. Collaboration among project team members on this project involved the team members identifying Problems and solutions on the project and from literature review this way of collaboration can be described as an elite circle.

From examination of project documents, it was observed that the project has been marred with delays and changes to scope. The delays can be attributed to delays in honoring of interim payment certificates by the client as the major contributing factor. The project team members visit the project once every month to inspect the progress of the works, provide corrective measures to poorly executed works and issue necessary instructions to the contractor. The team then prepares a project monitoring report which details the status of the project. The report is presented to the client, and it is a basis on which the contractor is paid.

5.4 Summary

In the two case studies presented, it can be seen that BIM usage on both projects was segmented with each discipline using their own professional related software, this resulted in both projects not having a comprehensive networked BIM model where all the professions on the projects could work on in real-time. The cases studies also revealed opportunities and challenges of BIM implementation in the Zambian construction industry as reported in literature and established in structured interviews and questionnaire survey. Further collaborative working arrangements for both projects were also highlighted. In the next chapter the key aspects of the results are discussed.

CHAPTER 6: DISCUSSION OF RESULTS

6.1 Introduction

The preceding chapter reviewed and analysed two case studies. In this chapter the key aspects of the results are discussed and linked to theory.

6.2 Research findings

The research aimed to: establish the extent to which BIM is being used as a collaboration technique on construction projects in Zambia, compare BIM collaboration on construction projects in the private sector vs public sector, identify the challenges and opportunities in the implementation of building information modelling (BIM) in the management of construction projects in Zambia and to determine the degree to which BIM is perceived to have been adopted in the Zambian construction industry.

6.2.1 BIM as a collaboration technique on construction projects in Zambia

From literature BIM is defined as a process for creating and managing information on a construction project across the project lifecycle, with one key output of this process being the Building Information Model, which is a digital potrayal of every aspect of the construction project created from information assembled and updated collaboratively at key stages of the project (National Building Specification, 2017). Going by this defination it can be deduced that BIM has not been fully adopted as a collaboration technique on construction projects in Zambia as the results showed no evidence of a comprehensive BIM model where all the consultants could simultaneously work on. However, according to the Bew-Richards BIM usage maturity model, it can be construed that BIM as a collaboration technique on construction projects in Zambia involves project team members collaborating at BIM level 1, as the results showed evidence of managed CAD designs in both 2D and 3D standard formats being shared via a collaborative tool such as E-mails and Google Docs.

Further, it can be seen that the projects had a clear and defined team leader, who arranged tasks in ways that helped each team member to attain their goals and the project team members had confidence in the lead designer's ability to safeguard the interests of all disciplines involved in the design. The team leader's importance was also emphasised by the interviewees who indicated that it doesn't matter whether project team members are from the same organisation or from different organisations, effective collaboration was dependent on how effectively the project team leader motivated his team members. These results are validated by Masons (2016), in which the key characteristics of collaboration are highlighted as; leadership, integration, behavioral, organizational and commercial demonstrating effective and efficient collaboration on the projects.

Verganti and Pisano (2008), also established that when deciding on ways to collaborate on a given project, two basic issues should be considered: namely participation and governance, participants should consider collaborating in an open or closed manner. From the results it can be seen that participants on projects in both the private and public sectors of the Zambian Construction Industry are collaborating in a way in which only project team members could propose solutions, and the project through the team leader chooses the solution that is best suited for the project this form of collaboration is a closed form of collaboration.

6.2.2 Comparison of BIM collaboration in the public and private sector of the Zambian construction industry

The study sought to investigate the evidence of BIM collaboration in the management of projects in the Zambian Construction Industry by comparing BIM usage in the public and private sectors of the industry. Two projects namely; the Proposed E.I.Z Headquarters at the Agricultural and Commercial Show Society Grounds in Lusaka and the Proposed Expansion of National Science Center in Lusaka from the private and public sectors of the industry respectively, where sampled for this study. Self-administered questionnaires were issued to the Project Managers, Architects, Engineers and Quantity Surveyors who were identified as the key stakeholders involved in the day to day management of the projects, this was done to get an insight into the respondent's views about the perceptions of BIM in the Zambian construction industry, challenges and benefits of BIM implementation through experiences of the respondents and perception of the collaborative environment. The results where further enhanced by structured interviews which sought the views of experts in the Zambian Construction Industry on BIM as a collaboration technique.

From the two case studies presented, it can be seen that BIM usage in both the private and public sector of the Zambian construction industry is segmented with each discipline using their own professional related software, this resulted in both projects not having a comprehensive networked BIM model where all the professions on the projects could work on in real-time.

Questionnaire surveys results and structured interviews also showed BIM usage in both the private and public sectors of the Zambian Construction Industry with the leading software packages being Revit, ArchiCAD, AutoCAD Civil 3D,WIN QS and NAVISWORKS MANAGER. These software were mainly used in the production of; renderings and perspectives, construction documents, scheme designs and concept design development. The results further showed that some project team members in both sectors are lagging behind as they still rely on AutoCAD 2D a non-BIM software to execute their works resulting in repetitions as they mostly had to redraw the same drawings which mostly leads to delays in the project and some problems on the project could be avoided with the execution of an intelligent BIM model as it would highlight the challenges which could be encountered during project execution.

The results further indicate that problems, challenges and obstacles were encountered on the projects, for instance the project document records reviewed that the Proposed Expansion of National Science Center in Lusaka a public-sector project was marred with a lot of delays and changes in scope. Nevertheless, these challenges were solved collaboratively. Further it can be seen that priorities where agreed upon and there was relevant feedback among team members and that there was no problem with information sharing on the projects. It was also established that for effective communication to exist on a project communication channels must be put in place at project initiation and all project related templates such as report templates and change order templates must be given to all relevant project team members.

However, it must be noted that BIM as a collaboration technique in both sectors of the Zambian Construction Industry is yet to be fully adopted. Most project information is still being shared via emails and flush drives or memory sticks. Collaborative working relationships in the Zambian Construction Industry are just beginning to work in BIM level 1 which involves managed CAD in 2D or 3D format with a collaborative tool providing a common data environment with a standardised approach to data structure and format. Commercial data will be managed by standalone finance and cost management packages with no integration (The Landscape Institute, 2016).

The case studies highlighted that project team members on the private sector collaborated in a consortium manner while those in the public sector collaborated in an elite circle manner. Verganti and Pisano (2008) , Masons (2016), categorised the participation in both the consortium and elite circle ways of collaboration as closed while the governance is flat in the consortium and hierarchical in the elite circle.

A lot needs to be done for the Zambian Construction Industry to start collaborating at BIM level 3 which involves a fully integrated and collaborative process enabled by 'web services' and compliant with emerging Industry Foundation Class (IFC) standards. This level of BIM will utilise 4D construction sequencing, 5D cost information and 6D project lifecycle management information (The Landscape Institute, 2016). This can only be achieved by overcoming the challenges alluded to by the respondents.

6.2.3 Opportunities in the implementation of BIM in the management of construction projects in Zambia

The results of the study indicated that the following are the main benefits obtained from the usage of BIM in both the public and private sectors of the Zambian Construction Industry:

1. It allows multiple design disciplines to collaborate at an early stage in the design,
2. It enables the client to quickly grasp the concept, feasibility and overall design,
3. With a shared BIM model, there’s less need for rework and duplication of drawings for the different requirements of building disciplines, and
4. It allows designers to automatically make low-level corrections when changes are made to the design.

These results correspond with what was highlighted by Eastman, et al. (2011), in literature review where the oppurtunities obtained from BIM implementation were categorised in four broad categories which are; the benefits to the project owner, the benefits to the designers, building maintenance and service benefits and the benefits to the Contractors and fabricators on the project. Further Eastman, et al. (2011), categorised the particular benefits obtained in each category.

It can be seen that the benefits which allowed multiple design disciplines to collaborate at an early stage in the design and designers to automatically make low-level corrections when changes are made to the design were mostly beneficial to Architects and Engineers. The benefit that enabled the client to quickly grasp the concept, feasibility and overall design was more beneficial to the Client.

6.2.4 Challenges in the implementation of BIM in the management of construction projects in Zambia

As the results showed, the greatest challenge regarding implementing more utilization of BIM are the prohibitive cost of setting up BIM and a lack of Government will and support in the adoption of BIM in Zambia. According to Thomassen, (2011) BIM is not a process solved by one software, but several processes involving numerous software solutions, each with distinct capabilities to accomplish specific work-related tasks. Therefore, if the initial costs associated with education and acquiring the hardware and software necessary to set up BIM for every professional working in the Zambian Construction Industry are lowered BIM implementation on construction projects in Zambia will be enhanced.

The finding that the lack of Government will and support is a hinderance to the adoption of BIM in Zambia corresponds to what was described in theory. The BIM Task Group (2011), highlights the UK government's 2011 Construction Strategy which embraced the use of BIM and mandated its use to maturity Level 2 on all centrally procured Government projects by April 2016.

6.2.5 Perception of BIM adoption in Zambia

From Literature review, BIM aims to efficiently manage all aspects of a building project throughout a projects lifecycle using ICT technologies. The results indicate that the respondents defined BIM simply as a 3D modelling software and a digital platform for information exchange, looking at the working definition of BIM adopted from Literature, BIM is defined as a process for creating and managing information on a construction project across the project lifecycle, with one key output of this process being the Building Information Model, which is a digital potrayal of every aspect of the construction project created from information assembled and updated collaboratively at key stages of the project (National Building Specification, 2017). This clearly shows that the respondents lacked the understanding of BIM's full capabillities resulting in under utilisation of BIM software.

According to Elgohari (2016), the BIM-Forum categorised BIM software into; preliminary design and feasibility software, BIM authoring software, BIM analysis software, shop drawing and fabrication software, construction management software, quantity takeoff and estimating software, scheduling tools and file sharing and collaboration software. From the results it can be seen that the respondents were not sure whether the software they were using where BIM capable software or not. It was however noted that there was some segmented BIM software usage with each individual discipline using their own industry related software with mostly Revit and ArchiCad being the main software in use, BIM-Forum (2011), categorised these software as preliminary design and feasibility Software and BIM authoring software. These results suggest a need for cohesion in the usage of software among the different disciplines in the Zambian Construction industry so as to have all proffesions working on a common BIM model.

The results further indicate that BIM was mainly used in the production of; renderings and perspectives, concept design development, construction documents and scheme designs. However, the results also show that BIM was not fully employed on both projects as none of the respondents indicated full use of BIM from inception to project construction. This lack of cohesive use of software made it impossible for project team members to produce an intelligent Building Information Model which is the key component of full BIM adoption as highlighted in literature review.

There is also a general belief among respondents on both projects that the use of BIM technology in Zambia will increase in the next 5 years. The respondents also highlighted that the increased BIM usage will make collaboration among project team members more efficient thus making the management of projects more efficient.

From these results it can be clearly seen that BIM is yet to be fully adopted in the Zambian Construction Industry and there is need for increased awareness and education on the full benefits and capabilities of BIM in the country for it to be fully adopted in the management of construction projects in Zambia.

6.3 Summary

This chapter discussed the results and findings of the interview and questionnaire surveys as well as the case studies. The next chapter presents the conclusions and recommendations and suggests further areas of research.

CHAPTER 7: CONCLUSIONS AND RECOMMENDATIONS

7.1 Introduction

The previous chapter discussed the results and findings of the interview and questionnaire surveys as well as the case studies. This chapter presents the conclusions drawn from the analysis of results. In addition, it presents recommendations directed at increasing the collaboration of BIM in the Zambian construction industry. It further highlights limitations regarding the study and opportunities for further research.

7.2 Conclusions

The conclusions correlate to the objectives of the study and bring up subjects relevant to the aims of the study.

7.2.1 The extent of BIM as a collaboration technique on construction projects in Zambia

The study concluded that BIM as a collaboration technique on construction projects in Zambia is still in its infancy, with most practitioners collaborating at BIM level 1. It was also established that participants on projects collaborated in closed manner while the project governance is hierarchical in the public sector and flat in the private sector.

7.2.2 Perception of BIM adoption in Zambia

Practitioners in the Zambian Construction Industry perceive BIM simply as a 3D modelling software and a digital platform for information exchange. The study also concluded that BIM is yet to be fully adopted as a collaboration technique in the management of construction projects in Zambia.

7.2.3 Challenges and opportunities in the implementation of BIM in the management of construction projects in Zambia

The study established that the prohibitive cost of setting up BIM and a lack of Government will and support as the main challenges in the adoption of BIM in both the public and private sectors of the Zambian Construction Industry. While the Private Sector also identified the lack of local institutions offering adquate BIM training as another challenge preventing the full adoption of BIM in the sector.

It was also established that the benefits of full BIM adoption are that it; allows multiple design disciplines to collaborate at an early stage in the design, enables the client to quickly grasp the concept, feasibility and overall design, allows designers to automatically make low-level corrections when changes are made to the design and with a shared BIM model, there's less need for rework and duplication of drawings for the different requirements of building disciplines.

7.3 Recommendations

From the above conclusions, the following are the key recommendations directed at increasing the application and adoption of BIM as a collaboration technique in the Zambian construction industry and other countries with similar conditions:

a) The government should establish a BIM task group to advance the BIM agender in Zambia.

The Government of the Republic of Zambia needs to take a leaf from the UK, Hong Kong and Singapore Governments and spearhead the BIM agender in Zambia. This can be done by the introduction of policies and laws that will encourage BIM usage. Additionally, the study recommends that the Zambian Government should set up a BIM task group comprising of all key players of the Zambian Construction Industry such as the relevant Government Ministries, Engineering Institute of Zambia (EIZ), Zambia Institute of Architects (ZIA), Surveyors Institute of Zambia (SIZ), Zambia Institute of Planners (ZIP), National Council for Construction (NCC), Zambia Public Procurement Authority (ZPPA), Material suppliers, Educational institutions and the Zambia Association of Manufactures. The aim of this task group should be raise awareness of BIM and to clearly outline ways on how BIM would be fully adopted in the implementation of construction projects in Zambia. Further the task groups out mate goal should be to ensure that construction projects are executed in a collaborative 3D BIM (with all project and asset information, documentation and data being electronic) manner.

b) BIM training must be done locally.

The study also recommends that BIM should be incorporated in the Local school curriculum from an early stage. This will ensure the availability of a local pool of BIM experts who will eventually drive the BIM agenda resulting in the effective and efficient delivery of construction projects in Zambia as collaborated by reviewed literature. BIM software manufactures should also be lobbied to set up local training institutions to provide BIM training locally this will eventually be beneficial to the manufactures as there is a likely hood that the trainees would eventually use their products upon graduating.

c) Industry Regulatory bodies should raise awareness on BIM.

The construction industry through professional and regulatory bodies, such as the Engineering Institute of Zambia (EIZ), Zambia Institute of Architects (ZIA), Surveyors Institute of Zambia (SIZ), Zambia Institute of Planners (ZIP) and National Council for Construction (NCC) should raise awareness of on the benefits of BIM and also incorporate it in their Continuing Professional Development (CPD) events.

d) Lower the Cost of BIM.

As established in the previous section the cost of setting up BIM must be lowered this can only be done if all stakeholders took significant steps towards lowering the cost. The government should remove the taxes on BIM products and the manufactures should come up with BIM products tailored for the Zambian market this can be done by producing BIM software locally.

7.4 Limitations of the study

One of the major limitations of the study was the scarcity of literature on BIM in Zambia, this meant that this research was among the first such investigations to be conducted at this level in Zambia. Unsurprisingly, the results are somewhat mixed due to the fact that respondents represent unique experiences across different stakeholders. This and the modest scale of the sample size, limited time and budget, inevitably meant that there were some gaps in the coverage. Finally, although the study highlighted the extent to which BIM has been used as a collaboration technique in the construction industry in countries like Zambia, the economic and political conditions are different for different countries, the level and extent of BIM adoption on construction projects in other countries is also probably different. The conclusions of this research are therefore limited to Zambia and other countries with similar economic and political conditions. The study offered no opinion whatsoever about the meaning, if any, of the findings of the study in other construction markets of the world.

7.5 Recommendations for future study

From the literature reviewed it can be deduced that there is a lack of significant research on BIM in Zambia. The study recommends that further research should be done in BIM in order to adequately guide current and future BIM investment in the Zambian Construction Industry. It will be necessary to conduct additional more focused studies in key aspects of BIM applications. In order for effective adoption of future research findings on BIM, it is recommended that continuous research should be done by academia with sponsorship from industry practitioners such as government departments and professional bodies of particular disciplines in the construction industry. Some potential research questions for the future are: What is the role of the government and local authorities in promoting the use of BIM? To what extent is BIM being used in sustainable design? How ready are universities in incorporating BIM in the higher education curriculum? Are BIM tools being used in embodied carbon and energy assessments on Zambian Projects? How are early adopters sharing the knowledge they have acquired about BIM use and the benefits gained from the use of BIM.

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APPENDICES

Appendix A: Questionnaire survey

A1: Organisations utilised in questionnaire pre-test

S/No.	Organisation Name	Organisation's Activities
1.	ZEPIU	Quasi Government multi-disciplinary consultancy
2.	Mas Ventures	Architectural firm
3.	Flame Promotions and Procurements Limited	Construction Company
4.	Fair face Enterprise	Construction Company

A.2 Basis of population sample selection for questionnaire survey

S/No.	Profession	Quantity
1	Architects	16
2	Project Managers	8
3	Quantity Surveyors	8
4	Civil Engineers	8
5	Electrical Engineers	8
6	Site Engineers	6
TOTAL		54

A3: Questionnaire survey cover letter

THE UNIVERSITY OF ZAMBIA
School of Engineering
Department of Civil and Environmental Engineering
P.O Box 32379, Lusaka.

18th July, 2017

Dear Sir or Madam,

Questionnaire Survey - Evidence of BIM collaboration in Zambia- a comparative study

I am currently pursuing a Master of Engineering in Project Management offered by the University of Zambia. I am in the final stage of the programme and doing research work. The research topic is: "**Evidence of BIM collaboration in Zambia- a comparative study"**

Building Information Modelling (BIM) is defined as a process for creating and managing information on a construction project across the project lifecycle, with one key output of this process being the BIM model, which is a digital potrayal of every aspect of the construction project created from information assembled and updated collaboratively at key stages of the project. BIM is all about collaboration in a three-dimensional environment between Engineers, Owners, Architects and Contractors, it allows design and construction teams to communicate about design and coordinate information across different levels. The research seeks to investigate the evidence of BIM collaboration in the Zambian construction industry by conducting a comparative study of the private and public sectors of the industry.

Your views and opinions based on industry experience, are therefore sought. Your responses will be anonymous and the information provided will be used solely for academic purposes.

Yours Sincerely,

Muhetu Wachata (Meng Student-UNZA)

A4: Questionnaire

PART ONE: RESPONDENT'S DEMOGRAPHICS

1. What is the name of your company? ……………………………………………………………
……………………………………………………………………………………………………..

2. Which sector of the construction industry do you work in? **(please tick in relevant box)**

- ☐ Private sector
- ☐ Public sector

3. What is your professional involvement on the project? **(please tick in relevant box)**

- ☐ Project Manager
- ☐ Architect
- ☐ Quantity Surveyor
- ☐ Civil Engineer
- ☐ Electrical Engineer
- ☐ Other (specify)…………………………………

4. What's your gender? **(please tick in relevant box)**

- ☐ Female
- ☐ Male

5. What is your highest academic qualification? **(please tick in relevant box)**

- ☐ O'level
- ☐ Certificate
- ☐ Diploma
- ☐ Bachelor's Degree
- ☐ Master's Degree
- ☐ Doctorate

6. How long have you worked in the construction industry? **(please tick in relevant box)**

- ☐ None
- ☐ Less than 5 years
- ☐ Between 5 – 10 years
- ☐ More than 10 years

PART TWO: PERCEPTION OF BIM

7. How would you define BIM? **(please tick all that apply)**

- ☐ a 3D design and modeling software
- ☐ a digital platform for information exchange
- ☐ a process of managing and collecting building data
- ☐ am not sure
- ☐ Other(Specify)……………………………………….

8. Did you use any form of BIM software on the project? **(please tick in relevant box)**

- ☐ Yes
- ☐ No
- ☐ Not sure

9. Which software did you use during the implementation of the project? **(please tick in relevant box)**

- ☐ Revit
- ☐ Archicad
- ☐ AutoCAD Civil 3D
- ☐ Vector works
- ☐ Navisworks Manage
- ☐ Vico Take-off Manager
- ☐ Other (specify)…………………………………

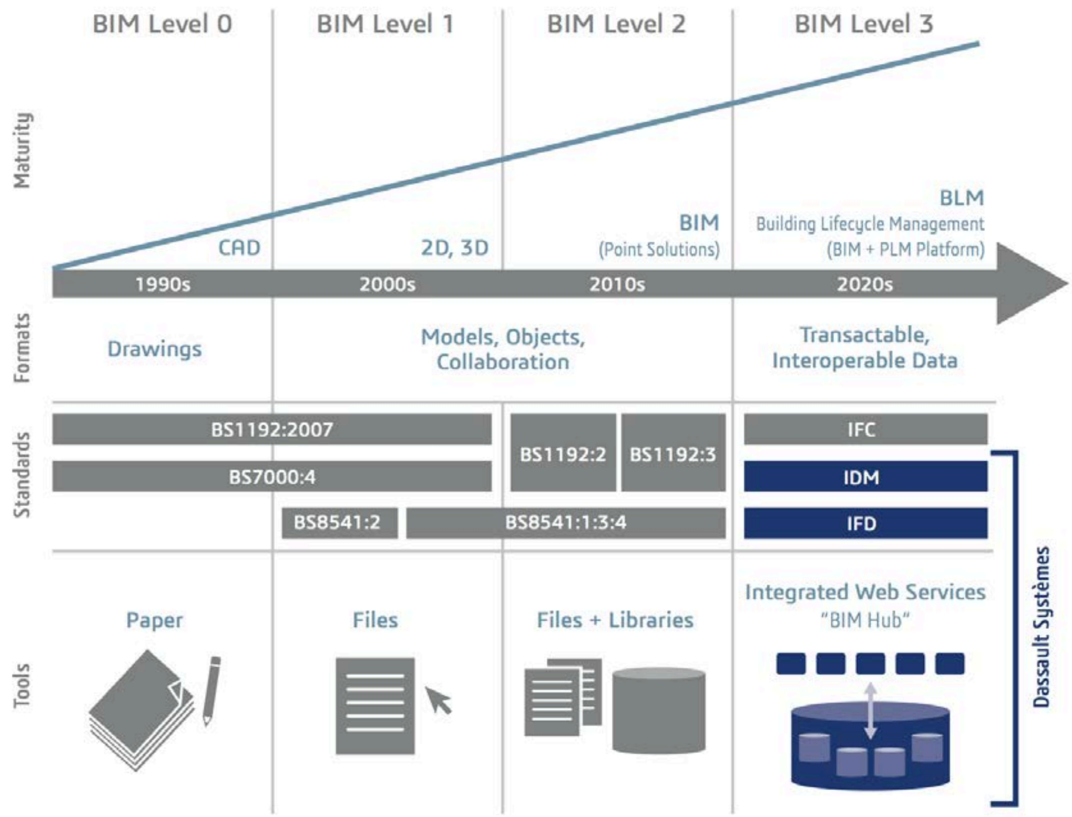
10. In what way(s) was BIM software used in the implementation of the project? **(please tick all that apply)**

- ☐ Concept Design Development
- ☐ Production of renderings and perspectives
- ☐ Production of Scheme designs
- ☐ Production of construction documents
- ☐ Development of design and build documents
- ☐ Fully Integrated Use (From Initial Concept to Construction)
- ☐ Am not sure
- ☐ Other (specify)…………………………………

11. Are you aware of the different levels of BIM?

- ☐ Yes
- ☐ No
- ☐ Not sure

12. Referring to the diagram below, in your opinion, at what level of digital technology do team members involved on the project work? **(please tick in relevant box)**



The BIM Maturity Model by Mark Bew and Mervyn Richards adapted to reflect BLM's relationship to Level 3.

- ☐ **Level 0**: Project data is mostly exchanged either in printed form or digital files such as PDF.
- ☐ **Level 1**: This typically comprises a mixture of 3D CAD for concept work, and 2D for drafting of statutory approval documentation and Production Information.
- ☐ **Level 2**: Design information is shared through a common file format, which enables any organisation to be able to combine that data with their own to make an amalgamated BIM model.
- ☐ **Level 3**: Currently seen as the "holy grail", this represents full collaboration between all disciplines by means of using a single, shared project model which is held in a centralized repository. All parties can access and modify that same model, and the benefit is that it removes the final layer of risk for conflicting information.

13. Do you think the use of BIM improves collaboration among project team members? **(please tick in relevant box)**

- ☐ Yes
- ☐ No
- ☐ Not sure

PART THREE: CHALLENGES AND BENEFITS OF BIM IMPLIMENTATION

14. The statements in the table below outline the benefits obtained from BIM implementation, to what extent do you agree with the statements with respect to your experience in the Zambian Construction Industry? **(please tick in relevant box)**

	Strongly agree	Agree	Neutral	Disagree	Strongly disagree	Don't know
BIM enables the client to quickly grasp the concept, feasibility and overall design						
The use of BIM allows multiple design disciplines to collaborate at an early stage in the design						
BIM allows designers to automatically make low-level corrections when changes are made to the design						
With a shared BIM model, there's less need for rework and duplication of drawings for the different requirements of building disciplines.						
BIM allows for the extraction of cost estimates during the design stage						
When the design is completed, the BIM model is the ultimate communication tool to convey the project scope, steps, and outcomes.						

BIM enables the production of geometrically accurate and consistent 2D drawings at any stage of the design						

15. The statements in the table below outline the challenges of BIM implementation, to what extent do you agree with the statements with respect to your experience in the Zambian Construction Industry? **(please tick in relevant box)**

	Strongly agree	Agree	Neutral	Disagree	Strongly disagree	Don't know
There is a lack of a technical pool of skilled of BIM personel in Zambia						
There is a lack of Government will and support in the adoption of BIM in Zambia						
BIM technology is not necessary or applicable for the nature of projects undertaken in Zambia						
Zambia doesn't have institutions offering adquate BIM training						
The cost of setting up BIM is too high						
There is no demand for BIM in Zambia						
The current ICT systems sufficiently carter for the management of construction projects in Zambia						

PART FOUR: PERCEPTION OF THE COLLABORATIVE ENVIRONMENT

16. Below are statements to do with the collaborative environment. How much do you agree with each statement with respect to how teams worked together on the project? **(please tick in relevant choice)**

	Strongly agree	Agree	Neutral	Disagree	Strongly disagree	Don't know
I feel that the project has a clear and defined lead designer						
It is important that the lead designer arranges work in ways that helps each disciplinary group reach their goals						
I trust that the lead designer will safeguard the interest of all disciplines involved in design						
We rarely solve defined problems in collaboration with all disciplines						
There are rarely problems with collaboration in doing inter-disciplinary work						
In most inter-disciplinary work, we rarely agree about priorities						
Professionals from different disciplines are often frustrated with each other						
I get relevant feedback from other disciplines about my team's contributions						
Exchange of information between disciplines is always a problem						
I find that professionals from other disciplines are not willing to listen to me if I have problems						
I find that my teams view is appreciated by other disciplinary groups						
I rarely find that other disciplinary teams understand what my organisation's team is trying to express or report						
I feel that I am not able to make significant decisions without consulting the lead designer						
I can be open about an error that affects other design firm's work as soon as it is recognised						
I feel team members collaborate well when they are all from the same organisation						

The End!

Thank you for your time.

Please return the completed questionnaire to:

Muhetu Wachata (muhetu84@gmail.com),

Cell: 0966571307, MEng Student.

Appendix B: Interview Guide

Appendix B: Structured Interview Guide

B.1: structured interview (open ended questions)

1.0 **Interviewee and Company Details**

1.1 Name of Company………………………………………………………

1.2 Which sector do you belong to (please tick)?

- Consultancy ☐
- Contractor ☐
- Clientele ☐
- Manufacturing ☐
- Supplier ☐
- Other (specify)…………………………………

1.3 Position in Company…………………………………...

1.4 Professional background…………………………………………………..............

1.5 Years of Experience in the Construction Industry…………………………...........

2.0 **Collaboration in the Zambian Construction Industry**

2.1 Collaborative working arrangements in the construction sector take many forms. From your experience how effectively do you collaborate with other project team members?……………………………………………………………………………

…………………………………………………………………………………………

…………………………………………………………………………………………

2.2 Researchers have established that central to a project team's ability to make effective decisions and achieve their goals is the ability for its members to communicate efficiently. How do you ensure that there's effective communication on projects you are involved in?...

....

....

2.3 Do you think project teams collaborate better when they are all work in one organisation or in different organisations?..

....

....

....

2.4 What situations if any frustrated you during project implementation?..................

....

....

....

2.5 How do you perceive project teams collaborate in Zambia?..................................

....

....

3.0 **Building Information Modelling (BIM)**

Building Information Modelling (BIM) is defined as a process for creating and managing information on a construction project across the project lifecycle, with one key output of this process being the Building Information Model, which is a digital potrayal of every aspect of the construction project created from information assembled and updated collaboratively at key stages of the project.

3.1 Have your ever used any form of BIM software on a project?

………………………………………………………………………………………………

………………………………………………………………………………………………

………………………………………………………………………………………………

………………………………………………………………………………………………

3.2 What in your own opinion are the benefits of using BIM on a project?

………………………………………………………………………………………………

………………………………………………………………………………………………

………………………………………………………………………………………………

………………………………………………………………………………………………

3.3 According to your experience, what are the challenges in the implementation of (BIM) in the management of construction projects in Zambia?
....
....
....
....

3.4 How can the challenges be overcome? ....
....
....
....
....

3.5 Do you think the use of BIM can improve collaboration on projects? ………………
....
....
....
....

3.6 How do you perceive the adoption of BIM in the management of projects in Zambia?...
....
....
....

3.7 Presently, the visualization, coordination and management of project life-cycle information in the construction industry has been improved due to the availability of a wide range of BIM applications, do you agree with this statement?

- Yes ☐
- No ☐
- Not sure ☐

3.8 In the next 1-5 years, do you expect your utilisation of BIM to increase?..................
……………………………………………………………………………….....

B.2: List of Interviewees

S/N	Position	Organisation	Construction Sector
1	Director of Projects	ZEPIU	Clientele
2	Principal	Mas Ventures	Consultancy
3	Director	MLN	Consultancy
4	Project Manager	NAPSA	Clientele
5	President	ZIA	Corporate Body
6	Project Architect	Ministry of Higher Education	Clientele
7	Principle Architect	MDS	Consultancy
8	Senior Architect	Ministry of Housing and Infrastructure	Clientele
9	Project Manager	Flame Promotions	Contractor
10	Director	Fair face Enterprise	Contractor