Framework for macro building information modelling (BIM) adoption in Nigeria.

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FRAMEWORK FOR MACRO BUILDING INFORMATION MODELLING (BIM) ADOPTION IN NIGERIA

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FRAMEWORK FOR MACRO BUILDING INFORMATION MODELLING (BIM) ADOPTION IN NIGERIA

BY

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ABSTRACT

The Construction Industry is a vital component of nations' Gross Domestic Product (GDP); it employs skilled and unskilled personnel. The construction industry's productivity depends on many factors, to mention but a few with its stakeholders' relationships, construction processes, the technology used, workflows, project finance, workers' wellbeing, policy etc. The Nigerian construction industry is disjointed; the professional stakeholders operate in silos with a full monopoly of information. As a result, the sector suffers from inefficiencies and poor performance, uncompleted projects and building collapse. These are attributed to a rigid professional structure, poor information management and poor building production management. This research sets an agenda for investigation and development in the area of Building Information Modelling (BIM). The research work intends to explore and assess the current state of BIM, the status of BIM adoption and implementation as well as its potential opportunities while aiming to develop a framework for the effective adoption of BIM in the Nigerian construction industry. Three different sources of data are used, comparative case studies (literature-based), survey questionnaire (primary source, quantitative-based), and a semi-structured interview (primary source, qualitative-based). A purposeful sampling technique was used in drawing the research participants. The respondents came from within the construction professions (i.e. Architects, Builders, Engineers, Project Managers, Quantity Surveyors, and Town Planners). The objectives of this research include the development of a strategic framework for effective BIM adoption and implementation in Nigeria. The comparative case studies set a pace and served as a precedent to learn from. The quantitative data was used on the macro BIM adoption models and established the Nigerian BIM maturity. These models revealed grey areas where attention is needed, and are also used to provide the basis for the development of the BIM adoption framework. The qualitative data was analysed using content analysis (in a sequential mixed method strategy) and used as input to the development of the context-based BIM adoption framework.

The framework has been developed using a template for developing a national BIM roadmap, a six-year timeline with sequential action plans and milestones were generated. The framework suggests a government and industry (push-pull process) driven approach with support by both the government and the industry, and lead by the government with support from the industry at the implementation stage. A partial mandate is recommended with incentives for adopters. The study revealed BIM potential in improving design and construction processes as well as information management. The study recommends practical and full implementation of the framework. However, the sequence may change over time as a result of potential changes accrued in the areas of diffusion dynamics and policy actions requirements. Thus, a periodic macro BIM adoption study is recommended ahead of the implementation of the framework. This research is unique within its context and essential to promote a new process of working in the Nigerian construction industry and to assist government and industry stakeholders to initiate the paradigm shift required for a better construction industry avoid falling behind in a rapidly digitised world and economy.

Keywords: BIM Adoption, BIM Adoption Barriers, BIM Adoption Benefits, BIM Adoption Drivers, BIM Framework, BIM Roadmap, Nigerian Construction Industry

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DEDICATION

With immense superiority that, I dedicate this PhD Thesis to my late Father and Mother of blessed memories, my uncle Professor Hamidu Umar Pindiga and my elder brother Abdulhamid Hamma-adama for their unconditional kindness, and endless support and encouragement. Their sacrifices remain the foundation on which my studies stand and successes recorded; thus, they will never be forgotten!

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LIST OF ACRONYMS

AEC	Architecture, Engineering and Construction
AIA	American Institute of Architecture
ARCON	Architects Registration Council of Nigeria
BIM	Building Information Modelling
BIMMI	BIM Maturity Index
BPP	Bureau for Public Procurement
BPP	Bureau of Public Procurement
CAD	Computer-Aided Design
CMM	Capability Maturity Model
CORBON	Council of Registered Builders of Nigeria
COREN	Council for the Regulation of Engineering in Nigeria
CPD	Continuing Professional Development
DOI	Diffusion of Innovation
GDP	Gross Domestic Products
ICT	Information and Communication Technology
IFC	Industry Foundation Classes
IPD	Integrated Project Delivery.
IT	Information Technology
NBIMS	National BIM Standard
NBPs	Noteworthy BIM Publications
NBS	National Building Specifications
NICE	Nigerian Institute of Civil Engineers
NITDA	National Information Technology Development Agency
NSE	Nigerian Society of Engineers
NVIVO	Qualitative analysis software used for the Interview analysis for the Case study.
PA	Percentage Agreement
PD	Percentage Disagreement
PMI	Project Management Institute

POA	Point of Adoption
RAF	Rank Agreement Factor
RAFmax	Maximum Rank Agreement Factor
RGU	Robert Gordon University
RII	Relative Importance Index
SMEs	Small and Medium Enterprises
SPSS	Statistical Package for Social Science
UAE	United Arab Emirate
UK	United Kingdom
USA	United States of America

CHAPTER ONE: INTRODUCTION

1.1 CHAPTER OVERVIEW

This chapter introduces the thesis, presenting the motivation and the process involved in the research. A summarised literature review is provided that gives a brief definition of Building Information Modelling (BIM) in general, in the study context, and leads to the study gap established within the context of this research. The literature discusses BIM, BIM benefits, and BIM adoption. The aim and objectives are outlined together with an overview of the research design and the scope and boundaries. The chapter is concluded with the originality of the study and a description of the thesis structure.

1.2 RESEARCH BACKGROUND AND PROBLEM

The ICT Development Index (IDI) of Nigeria was 2.60 in 2017, ranked 143rd in the world (amongst 176 countries), and 15th amongst the 38 African countries (ITU, 2016; ITU, 2017). That means Nigeria is low in digital transformation, falling in-between 'watch out' and 'break out' countries. Watch out countries in the digital transformation perspective are countries facing significant challenges in terms of digital transformation, and these countries have a low level of digitalisation considering their low scores in the four drivers of the digital revolution index (Fletcher 2017). On the other hand, the 'beak out' countries are those with low-scoring in their current state of digitalisation but evolving rapidly. The break-out countries are highly attractive to investors due to a high momentum and significant headroom for growth (Fletcher 2017).

The Architecture, Engineering and Construction (AEC) industry is going digital and moving towards a fully integrated work practice. The AEC industry is going through a disruptive technological shift (Owen et al. 2009). However, there is still the need for a significant effort to achieving that goal globally. The AEC industry has a breakthrough since the proliferation of BIM. BIM is amongst the construction industry's developments that are promising to remedy the well-documented fragmentation of the sector (Azhar 2011; Zhao et al. 2016).

BIM is defined as a set of interacting policies and processes being enabled by technologies in generating a methodology to procure building works from inception to completion down to the entire lifecycle of a building in a digital format (Succar 2009). NBS (2016) defines BIM as a way of working and also how everyone can appreciate a building via the use of a digital model which draws on an array of data assembled collaboratively, throughout the stages of procuring a building and its lifecycle.

There are numerous applications of BIM, to mention but a few with, design coordination, energy performance simulation, scheduling and quantity take-off, clash detection and 3D visualisation (Azhar 2011; Bynum et al. 2012; Cao et al. 2014; Eastman et al. 2011; Li, Chan et al. 2012; Monteiro et al. 2014). There are also several reported claims and case studies regarding BIM benefits in recent years. For instance, McGraw Hill Construction (2014) study on Australia and New Zealand reveals the most significant immediate benefits derived from BIM as a reduction in errors and omissions, reduction in rework; and long-term benefits as business reputation, reduction in project duration and cost. Every country has its own challenges, and perhaps unique reason(s) behind its move to adopt BIM, but one fact remains that they have common goals of improving efficiency and productivity (better service delivery) of the industry. Includes, improving the industry's productivity by changing its traditional workflow (BIM Industry Working Group 2011; NATSPEC 2012; Hjelseth 2017; Richard 2017; Musa et al. 2019; Al-Ashmori et al. 2020).

The Nigerian construction industry is fragmented, with all professional stakeholders generating information and managing it autonomously (Onungwa et al. 2017; Amusan et al. 2018). The industry has been described as in disarray, and endlessly facing persistent challenges like project time overrun, cost overrun, and risk/safety management issues (Ugochukwu et al. 2015; Onungwa et al. 2017), and painfully building collapse. These challenges are mainly attributed to corruption, information and communication gaps as well as faulty design (Okolie et al. 2016; Onungwa et al. 2017; Hamma-adama and Kouider 2017). Thus, it is then necessary to proffer solutions to the compounding challenges in the disjointed and inefficient industry (construction sector). This is targeted to be achieved through the development of a roadmap on which effective and efficient process can be built on or facilitated.

BIM adoption is attaining higher rates of adoption in most developed countries; these countries started the BIM adoption journey over a decade, developing guidelines and standards for over a decade (Hjelseth 2017). However, there remains a long way to go in developing countries like Nigeria. Despite several years of deliberations and research in the area of BIM concept and its adoption, the Nigerian construction industry received its first academic paper in 2013 "Readiness of Nigerian building design firms to adopt building information modelling (BIM) technologies" (Abubakar et al. 2013). The study came as an assessment due to a lack of clarity on whether the industry is ready or not to embrace BIM technology; not the process! Thus, this suggests a state of readiness, i.e. "readiness ramp" (Succar and Kassem 2015).

A comprehensive assessment of BIM adoption in Nigeria is growing over time, and the same applies to its implementation. These can be noticed in the eleven available and relevant published works (see Table 2.1 or Appendix - 1). Along the line of publications, there are nine relevant journal articles (Abubakar et al. 2014; Dim et al. 2015; Ugochukwu et al. 2015; Wang et al. 2015; Timothy et al. 2016; Ezeokoli et al. 2016; Ebiloma et al. 2017; Onungwa et al. 2017; Onungwa and Uduma-olugu 2017), one conference paper (Abubakar et al. 2013) and one academic symposium (Kori and Kiviniem 2015). Four years after the first conference paper within the study context, and just before this study commenced, none has carried out a broad evaluation of the industry nor does the combination of the articles do concerning its current status. All the previous research concentrated on trying to assess BIM within a limited profession or location; thus, there was no meeting point into identifying the current state of the key BIM components (Technology, Process and Policy). Therefore, limitations were identified within the study country as such that facilitate an exploratory study. According to Bui et al. (2016), additional research is needed to update and enable the majority to understand and adopt the new methods of working, especially in developing countries.

For about two decades, Nigeria has been facing a lingering menace of building failure and collapse. Moreover, a consistent delay in approvals of additional works and revised specifications are critical to timely completion of the construction project. Consequently, these result in huge cost overrun, inefficiencies, and poor management of construction projects (Ishaq et al. 2019). Most of these challenges are attributed to the poor communication between construction professionals, and poor collaboration during design and construction stages (Tipili and Ojeba 2014).

BIM is a vibrant process currently dominating the construction market; its efficacy has been proven in several countries like the UK, USA, Australia, Singapore, New Zealand etc. Deployment of BIM on a project bridges information gap and brings about cost control mechanism, reduce errors, omissions, as well as conflicts (Ghaffarianhoseini et al. 2017). With these potentials, why BIM couldn't be tried in Nigeria? And how could it be done?

Every construction market is unique on its own; the Nigerian construction industry has some underlying challenges that need to be overcome. The available BIM adoption strategies (from the developed countries) are context-based; as such, do not fully reflect the complete needs of the Nigerian construction market. Some of these fundamental challenges include poor technology infrastructure, low level of BIM awareness, corruption, technology piracy, bureaucracy, poor industry structure, etc.

1.3 RATIONALE BEHIND THIS STUDY

Considering BIM as a paradigm shift in the construction industry (Azhar 2011; Zhao et al. 2016; Onungwa and Uduma-Olugu 2017), and the documented case studies that proved its efficacy in the industry; this study intends to improve the Nigerian construction industry’s efficiency in communication, rich data exchange and collaborative working. This can be achieved once BIM is deployed at the design and construction phases of projects. In reaching the implementation of BIM on projects, this investigation intends to explore the challenges facing BIM adoption in the Nigerian construction industry and subsequently propose an action plan for its practical adoption.

This study aims to develop a strategy that is capable of driving BIM adoption in the Nigerian construction industry. The study has three investigative phases: Exploratory studies; Case study comparative analysis of three countries; and the main study (investigative study).

The exploratory studies were undertaken through a semi-structured interview and two questionnaire surveys to fill in the literature gap in the study market. The case study is a literature-based comparative analysis of three countries (USA, UK and Australia) that set the platform of the strategy development. The investigative study was carried out using a mixed-methods approach (questionnaire survey and semi-structured interview) to develop the final BIM adoption strategy.

1.4 RESEARCH QUESTIONS

This study intends to answer the following questions:

1. How impactful is BIM in the construction industry’s workflow and processes?
2. What are the successful BIM development and adoption efforts potential to learn from?
3. What is the level of BIM awareness, knowledge and adoption in the Nigerian construction market?
4. What is the Maturity level of BIM in the Nigerian construction industry?
5. What are the potential benefits of deploying BIM on construction projects, especially in relation to the current industry’s challenges?
6. How could BIM be adopted and effectively implemented in the Nigerian construction industry?

1.5 AIM AND OBJECTIVES

The research aims to develop an effective method in form of a framework for BIM adoption in the Nigerian construction industry. The objectives of this research are to:

1. Review BIM as an effective design and innovative management system, and its impacts on the construction industry,
2. Explore BIM development and adoption in the countries where BIM is dynamic and its success was proven,

3. Explore BIM awareness, knowledge and adoption in the Nigerian construction industry,

4. Establish the Nigerian construction industry BIM Maturity

5. Identify the potential benefits of BIM adoption concerning the current challenges of the Nigerian construction industry, and

6. Develop a strategic BIM adoption framework for an effective BIM implementation in the Nigerian construction industry.

1.6 THE RESEARCH DESIGN

BIM could only be fully appreciated or implemented when project stakeholders agreed to its adoption and usage. However, BIM adoption by the industry stakeholders in the first instance is critical to its implementation as the Nigerian construction professionals are currently working in silos. Thus, a top-level strategy is necessary, and government involvement is paramount due to the current industry's structure.

In researching the context-based literature, considerable research gap has been discovered. This research gap includes insufficient documentation to fully gauge the industry's state of BIM knowledge and adoption, lack of holistic evaluation of the industry in terms of BIM potentials, and lack of top-level strategy on how BIM could get adopted in the industry.

As a result, this PhD investigation started with bridging the literature gap through exploratory studies that holistically explored the current state of BIM adoption in the Nigerian construction industry. Furthermore, the research sets six objectives in seeking to develop an effective strategy for BIM adoption in the Nigerian construction industry as the overall aim. Figure 1.1 presents the research process loop, from the research aim to objectives and how these objectives are met back to the research aim.

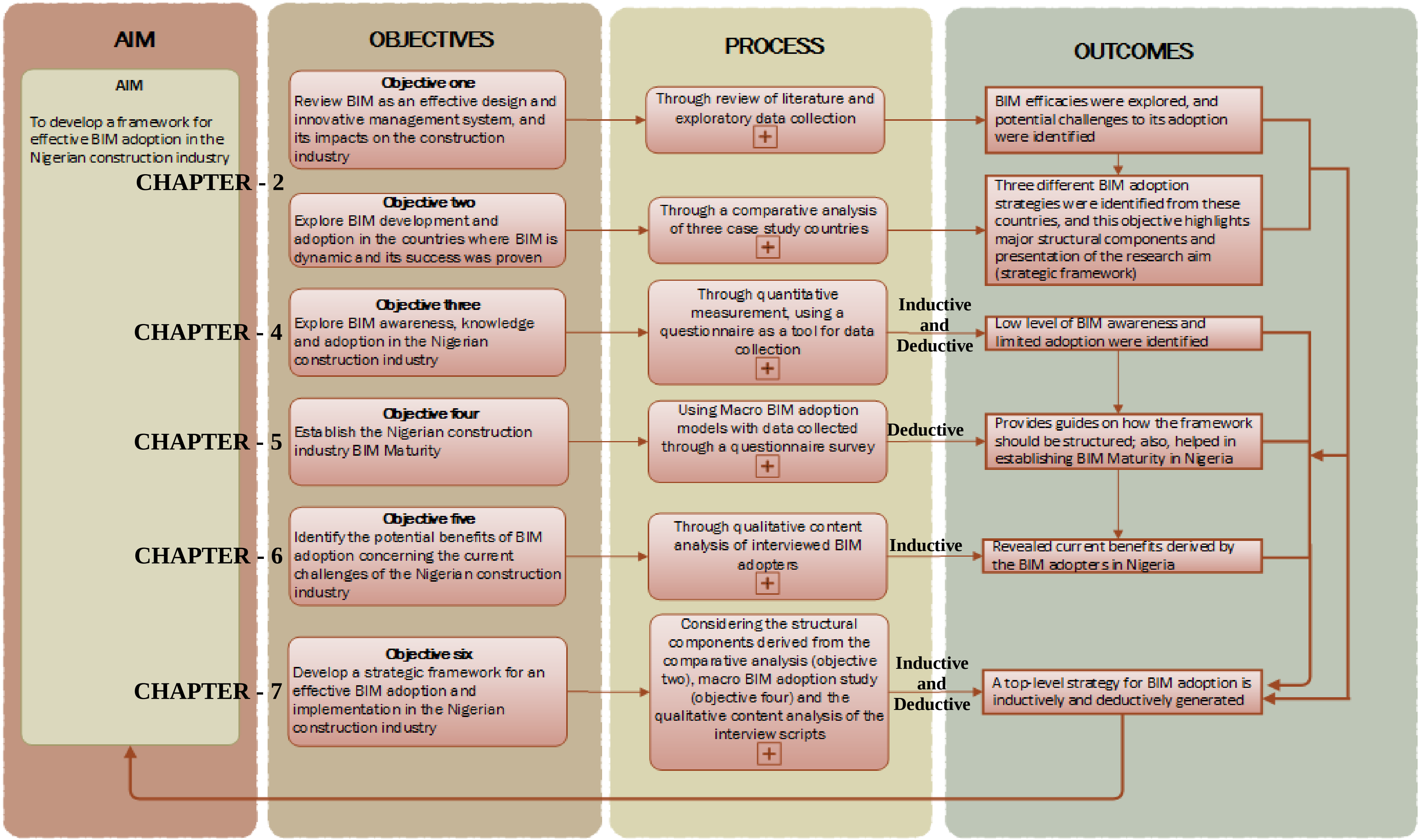


Figure 1.1: The Research Process Loop (Author generated)

The research is designed based on a pragmatism research philosophy, and it involves mixed-method research approached in abductive reasoning (i.e. inductive and deductive approaches) (Bergman 2006; Froise 2014).

1.7 SCOPE AND BOUNDARY OF THE RESEARCH

The scope of this study recounts only BIM adoption within the Nigerian Construction Industry at Macro (country-wide) level. Thus, data collection is limited to data gathered from the Nigerian construction industry professionals; this data was collected using a semi-structured questionnaire and semi-structured interview. The study confines to the three field-types of BIM (technology, process and policy) as a result of the literature confirmation on the strategic macro BIM adoption study (in section 2.3). The formulation of the strategy considers some case study countries (USA, UK and Australia) in addition to the context specifics. Finally, the framework captures contents at a strategic level within the confined BIM field types using the concept of diffusion of innovation as a theoretical framework.

1.8 RESEARCH ORIGINALITY AND CONTRIBUTION TO KNOWLEDGE

The originality of this research includes advancing awareness in the current BIM trend, promoting a new process of working, and facilitating the government and the industry stakeholders to initiate the digital shift in the industry. Moreover, originality of this work is evident with nearly all objectives externally peer-reviewed and published as a journal article or a conference paper (as attached in Appendix 6&7 or p.293 and p.296).

The main contribution to the knowledge of this research is the developed BIM adoption framework. This research also contributes to a broader research domain. For instance, the establishment of Macro BIM maturity of Nigeria and the comparative analysis of three case countries fit into an extensive study on BIM adoption around the world. Only a few countries (mostly developed) were assessed at the macro level, e.g. USA, UK, Canada, China, Australia, Ireland, Spain, Hong Kong, Portugal and Brazil (Kassem and Succar 2017; ChangeAgents 2019). On the other hand, the new information derived from the three case study countries were substantially beyond the use for the Nigerian construction market, that could be used around the globe in search for good practices and learning models.

Succinctly, this study is relevant in setting a pace for the adoption of BIM in the Nigerian construction industry as this is the first effort to doing that. It is the first research that developed a top-level strategy for BIM adoption in Nigeria as no other research with the same country-wide scope has been conducted to date.

1.9 THESIS STRUCTURE

This thesis is organised in accordance with the research design, as revealed in section 1.6. Figure 1.2 illustrates the thesis structure with itemised the major contents of each chapter.

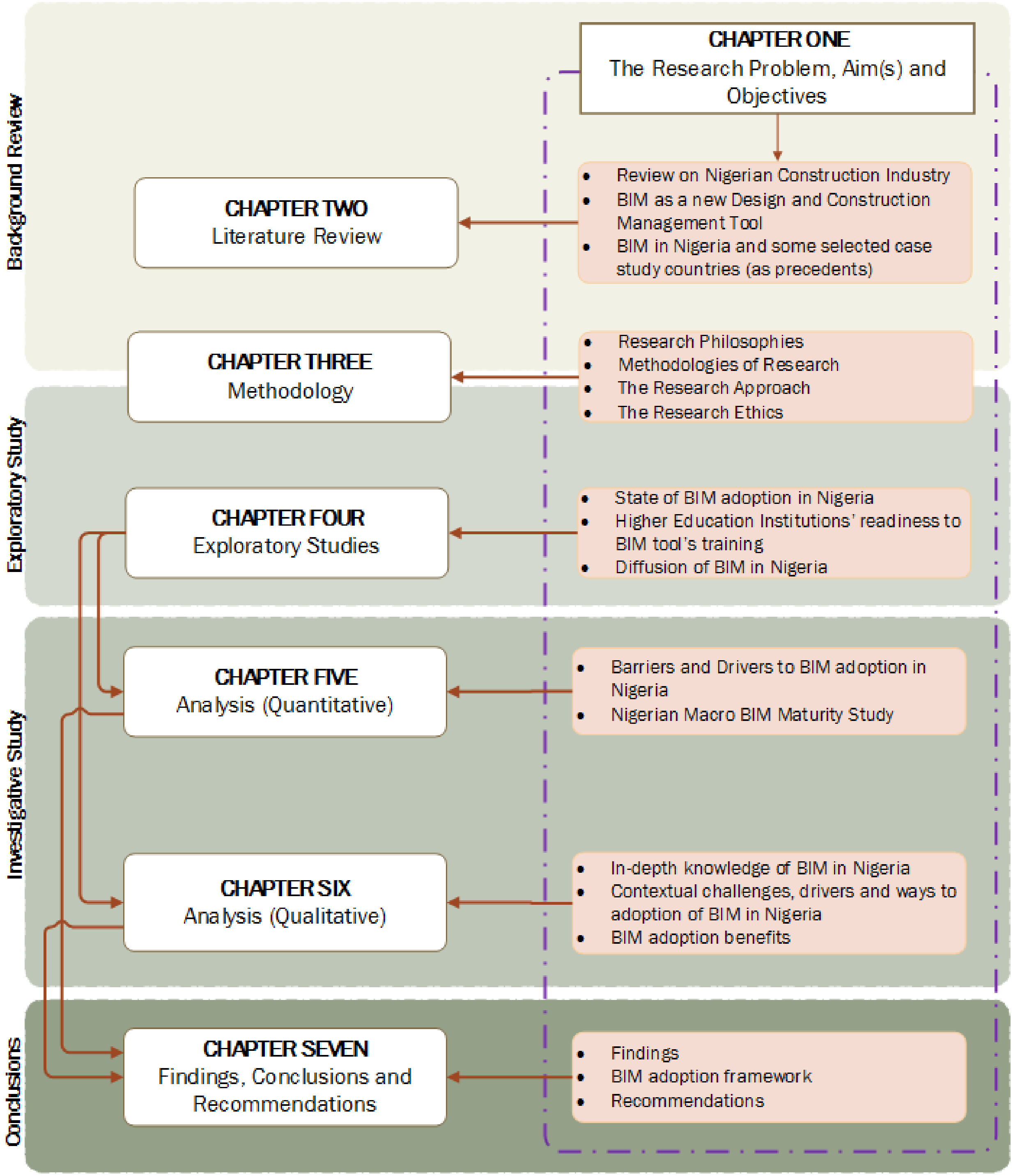


Figure 1.2: The Thesis Structure (Author generated)

1.9.1 Thesis Content

Chapter One: This chapter introduces the thesis, presents the motivation and the research process involved in the study.

Chapter Two: This chapter discusses the literature on BIM and BIM adoption, Nigerian construction industry and its challenges. The chapter also presents a comparative analysis of BIM development and adoption in three different countries where BIM adoption is dynamic. Thus, the chapter is the core component of achieving objectives 1 and 2 (Review BIM as effective design and innovative management system, and Explore BIM development and adoption in the countries where BIM is dynamic and its success was proven) as highlighted in section 1.4.

Chapter Three: This chapter presents the methodology of the research, the philosophy underpinning the investigation, the procedure, as well as the strategy adopted.

Chapter Four: This chapter presents the collected data, the analysis and the results of the exploratory studies undertaken to fill the literature gap observed in the early stages of the research. The exploratory studies involve both semi-structured interview and questionnaire survey sequentially. The fetched data were analysed qualitatively and quantitatively. The results presented an inside into achieving objective 3 (Explore BIM awareness, knowledge and adoption in Nigeria) of this research.

Chapter Five: This chapter presents the analyses and findings of the quantitative data fetched from the questionnaire survey. The quantitative data generated from the questionnaire survey were analysed using SPSS. Significant barriers and drivers to BIM adoption were established based on the BIM adopters and non-adopters' perspectives. The Nigerian Macro BIM adoption maturity is also determined using five macro BIM adoption models. Thus, this chapter deals with objectives 3 and 4 (Explore BIM awareness, knowledge and adoption in the Nigerian construction industry, and Establish the Nigerian construction industry BIM Maturity) of the research.

Chapter Six: This chapter presents the analysis of the coded script under different pre-identified themes. Findings from this chapter formed a significant component in achieving the remaining last two objectives. These include Identify the potential benefits of BIM adoption concerning the current challenges of the Nigerian construction industry and Develop a strategic BIM adoption framework for an effective BIM adoption as outlined in section 1.4, and the entire aim of the study.

Chapter Seven: This chapter brings the findings from chapter five and chapter six, presents the holistic results and draws conclusions and recommendations. The chapter is the last component, and it presents the entire study finding (the aim).

1.10 CHAPTER SUMMARY

This chapter introduces the research and rationale behind it; the aim and objectives; research design as well as its scope and boundary.

CHAPTER TWO: LITERATURE REVIEW

2.1 CHAPTER OVERVIEW

This chapter reviews and discusses the literature on the Nigerian construction industry, BIM in general, BIM benefits, and BIM adoption. The discussion is narrowed towards the Nigerian construction industry and its challenges.

This chapter also presents a comparative analysis of BIM development and BIM adoption in three different countries (the USA, UK, and Australia), where BIM adoption is dynamic and has led to tangible results.

2.2 NIGERIAN CONSTRUCTION INDUSTRY

Construction is considered amongst the world's biggest industries. It is estimated to account for about 6% of world Gross Domestic Products (GDP), while expected to be about 15% of the global gross domestic product by 2020 (Babatunde and Low 2013; Craveiro et al. 2019).

At the end of 2011, the Nigerian construction industry (including infrastructure) contributed about 2% to the country's GDP, which is statistically low compared to its record in 1981 of 5.8% - a difference of 3.81% in 30 years (Abubakar et al. 2014). Despite fluctuating growth (both negatives and positives) of the industry, Central Bank of Nigeria (CBN) reported a 3.7% contribution to the Nigerian GDP in 2018 (CBN 2019). Critically, there is substantial growth compared to 1.99% in 2011. But with today's economic developments in nearly in all sectors, the construction industry is yet to reap the capacities of the present.

The indices of the Nigerian GDP have been changing in the last few years; it has been claimed that the country’s construction industry contributes 3 to 5% to the Nation's GDP (Owolabi and Olatunji 2014). Though, it is determined that the construction industry is a vital sector of every country's economy (Ogunsemi et al. 2008) regardless of the economic development of that country (Owolabi and Olatunji 2014). Moreover, the construction sector is one of the major employers as it employs about 10% of most countries' total workforce (Abdul-Rashid and Hassan 2005). Thus, the construction industry is amongst the essential industries that contribute toward a socio-economic development of any country, particularly emerging economies.

The federal and state public sectors are the primary clients for mega construction projects (both for buildings and infrastructure) in Nigeria. They mostly procure construction works using a "traditional" contract type, and occasionally through design and build (turnkey project) contract (Okunlola et al. 2011; Ruya et al. 2017).

On the other hand, housing sector development is dominated by both the public and the private sectors; they interchangeably supply housing to the Nigerian populace depending on the location (state) in the country (Ogunbayo et al. 2016; Shen et al. 2006; Ikejiofor 1997; Ruya et al. 2017). Furthermore, statistics demonstrate that private property-owners provide the majority of urban housing units for rent in Nigeria.

2.2.1 Procurement of Building Construction works in Nigeria

The procurement of building construction works in Nigeria comes in two to three different ways; public (government), established private developers (registered) and private/owned individuals (unregistered). The government approach is generally via one of these two procurement methods: Traditional or design and builds (Ruya et al. 2017). While the established private developers generally procure building work by design and build or in a novated way, i.e. adopt designs from designers/consultants and take responsibility for construction based on the adopted design. While the private/owned individual operates a sort of direct labour which means the owner takes immediate ownership of every aspect of works (engaging individual workers in every task).

2.2.1.1 Traditional Procurement Route

The traditional procurement route is a method of contracting where a client appoints an architect to lead the design team (consultants) which comprises structural, electrical and mechanical engineers as well as cost consultant or quantity surveyor (QS) (Ruya et al. 2017). In this approach, two different teams are responsible for delivering a project – consultants (designers) and contractor (constructor). The team of designers includes architect, services engineers (electrical and mechanical), structural engineer and quantity surveyor. And, the construction team typically consists of the main constructor and sub-contractors who are selected using a *lump sum competitive tendering* process (Ruya et al. 2017).

A standard form of contract is conventionally used in the built procurement contracts in Nigeria. It is an adopted traditional building contract based on 'joint contract tribunal – JCT' (Okuwoga 1998). This standard form of the contract clearly defines what is to be built, the various parties' roles and the terms of bargain between them. Similarly, it stipulates the requirements by the client, specifies the measures to be taken to guarantee compliance and available remedies to each party in an incident of default (Rwelamila et al. 2000).

On the other hand, traditional contract method has received various criticisms, especially concerning its disjointed deliverables. The technique is not entirely ineffective, and it is just that other procurement methods could be better and suitable when used on some projects (Okunlola et al. 2011).

2.2.1.2 Design and Build Method

The design and build method of procurement is also referred to as integrated procurement approach in which a contracting firm takes obligation for all aspects of the project (Moore and Dainty 1999). Rowlinson (1987) outlines the features of the design and build contract as:

- full documents have defined a contract that is signed before the building,
- a contract in which design is not fully completed before construction commences,
- a contract where the bill of quantities is not customarily prepared, so variations are priced according to a schedule.

The design and build approach to the procurement of construction works uses only one team, the contractor. The contractor takes responsibilities of both the design and the construction; using either their in-house designers or outsource the design to a consulting firm. Most of the construction firms have their in-house architects, engineers (structural & services/MEP), and QS for design and execution of work.

There is a continuous growth of the design and build method of procurement in the UK and some other countries as an alternative procurement method to the traditional one, this is as a result of the new paradigm shift from fragmented team members to an integrated team (Kwakye 2013). There are claims of potential benefits of time and cost overrun, reduction of errors and omissions, less misunderstanding, rapid reaction to scope changes, as well as the production of buildable designs (Kwakye 2013; Molenaar et al. 1998). However, there is also a fear of client reducing his professional representation, which also tends to bring fewer checks on cost and quality (Molenaar et al. 1998). Therefore, the quality assurance in all aspect could be compromised (Al Khalil 2002).

The design and build (integrated), Management, and Co-operative contracts are procurement routes which seem to promote integration (Ugochukwu et al. 2015) due to their natures of arrangement. In such arrangements, the same firm manages the design and construction as such; the constructor is brought on board right from the beginning of the project.

The concluded section (2.2.1) provided an inside of the Nigerian construction industry's procurement route. It informed this study of the industry's current and dominant procurement route as to whether such supports innovative workflow or a different procurement route needs to be considered.

2.2.2 Major Construction Professionals in Nigerian AEC

The profession is considered as a skilled occupation that requires specific education, training and experience (Abdul-Rahman et al. 2010). There are numbers of professionals in the construction industry. The active construction professionals in the Nigerian construction industry are Architects, Builders, Engineers (Civil, Electrical and Mechanical), Estate surveyors and valuers, Land surveyors, Quantity surveyors and Town planners (Owolabi and Olatunji 2014). Similarly, the foremost professionals in the building construction sector are Architects, Builders, Engineers (Civil, Electrical and Mechanical), Land surveyors, and Quantity surveyors. In contrast, the most engaged professionals are Architects, Builders (as project managers or construction managers), Engineers (Civil, Electrical and Mechanical), and Quantity surveyors (Ayokunle et al. 2014).

The construction professionals, including architects, builders, engineers (structural and MEP), and Quantity Surveyors are the leading key players of the construction sector. These professions operate independently as an entity and are regulated by different bodies. The certified professional organisations responsible for the registration and regulation of the professions and their activities, they are:

Architect Registration Council of Nigeria (ARCON) for Architects; Council of Registered Builders of Nigeria (CORBON) for Builders; Council for the Regulation of Engineering in Nigeria (COREN) for all Engineers; and, Quantity Surveyors Registration Board of Nigeria (QSRBN) for Quantity Surveyors.

However, there is no single national agency responsible for the coordination of these bodies and their extended associations (Ruya et al. 2017). Thus, this appears to be a setback to having synergy in the industry. This suggests having a body responsible for harmonising the industry's activities, processes and new standard ways of working.

The construction of buildings requires several workers, including many trades and many professionals. From the project management perspective, realising a project entails having a professional project team. This team constitutes the construction professionals as highlighted above. The required professionals in each aspect of work in terms of design, construction, or both, should be carefully scrutinised as they are responsible for any mischief that may occur within their specific domain during the constructions (Hussin and Omran 2009).

For this study and its context, the following professions are further explained; Architects, Builders (as project managers or construction managers), Engineers (Civil, Electrical and Mechanical), and Quantity surveyors.

2.2.2.1 Architect

An architect is a building industry professional who studied architecture; the architect is involved in the planning, design and construction of a building. An architect collects process and translates a client’s brief into a concept and detailed design of building considering all relevant requirements. Some of these requirements are building regulations, environmental, mental, anthropometrics etc. The professional is the first person of contact by the client, translates the client’s needs and user’s requirements into a detailed drawing with specifications (Oloyede 2008). The architect is considered as the most versatile amongst the building professionals; all the professionals work with an architect’s concept to develop their aspects of work. He is also considered as a prime (lead) consultant at design and execution stages. These professionals are registered and regulated by a government body, Architects Registration Council of Nigeria (ARCON). Also, have a professional organisation or association called "The Nigerian Institute of Architects (NIA)".

The architect has the following roles at both design and construction stages: development of conceptual design base on the client’s needs, detailed design (in drawing and specs), planning, and oversight of building construction (Olatunji et al. 2014). Sometimes, the architect also plays the role of a project manager, and this is just outside of being a construction project leader.

2.2.2.2 Builder

A builder is also a building construction professional mostly involved at construction and maintenance of stages of building. A builder is an academically trained professional up to a bachelor’s degree level on the building production management. This profession was developed initially from Great Britain, started under the centre of the Institute of Building which is later known as The Chartered Institute of Building (CIOB). These professionals are normally being called as Construction Managers in the United Kingdom. The professionals are registerable and regulated by a government body, Council of Registered Builders of Nigeria (CORBON) supported by the Laws of the Federal Republic of Nigeria of 1990 (ACT CAP 40). Also, have a professional body or association called "The Nigerian Institute of Building (NIOB)" (Olatunji et al. 2014).

The builder’s roles are to ensure the buildability of the construction project, to prepare the project quality management plan and ensure its success, to develop and ensure project health and safety plan is followed, and to prepare and ensure construction methodology is followed (Olatunji et al. 2014).

2.2.2.3 Engineers (Civil, Electrical and Mechanical)

The engineering family dominated the design and construction of a building are civil, electrical, and mechanical engineers. The civil engineer is responsible for the analysis and design, as well as construction supervision of all structural components of the building. These components are roof trusses, slab, beam, column, foundation, and even geotechnical investigations. Civil engineering is not just limited to building-related construction but extends to various construction fields, such as roads, bridges, dams, and other infrastructural development. The electrical and mechanical engineers are collectively referred to as services engineers. The electrical engineer is a professional responsible for the design and supervision of electrical-related components of the building. In contrast, the mechanical engineer is responsible for the water and liquid waste disposal systems. The services engineers have other responsibilities outside building-related construction; they are also involved in other infrastructure developments like the power plant, water project, factory building, etc. (Olatunji et al. 2014).

The Council for the Regulation of Engineering in Nigeria (COREN) is a government body established in the early 70s by military rule (decree 55) and later amended in 1992 by Decree 27. The COREN is now under the "Engineers (Registration, etc.) Act, CAP E11 of 2004." COREN is responsible for registering qualified engineers to practise in the federal republic of Nigeria; also, responsible for the registration and monitoring of engineering firms in the country. The professionals collectively have a society called "Nigerian Society of Engineers (NSE)"; and individually have Nigerian Institute of Civil Engineers (NICE), Nigerian Institute of Electrical & Electronic Engineers (NIEEE), and Nigerian Institute of Mechanical Engineers (NIME).

2.2.2.4 Quantity Surveyor (QS)

Quantity surveying is a profession pioneered by Britain. The quantity surveyor (QS) is a construction industry professional that studied quantity surveying. A quantity surveyor is a professional who prepares quantities and prices of proposed building works (Olatunji et al. 2014); he ensures the proper allocation of financial resources and cost management for the best interest of the project/client (RICS 1991). The quantity surveyor can develop cost implication of every component of work and variations effects (Said et al. 2010). The QSs Registration Board of Nigeria (QSRBN) is the government body responsible for the registration and regulation of the quantity surveying professional practice in Nigeria. The QS graduate is registerable to practise by the Nigerian Laws (CAP Q1) of 2004. The professionals established a parallel body to the Royal Institution of Chartered Surveyors (RICS) with the Nigerian Institute of Quantity Surveyors (NIQS).

The QS has several roles from the preliminary stage of a project. The QS roles include cost estimate relating to materials, labour cost, schedule of building materials, value engineering, cost planning, cash flow payment, cost-benefit analysis, Preparing bill of quantity, work variation and cost performance, materials on-site, valuation for payments, and lifecycle costing (Olatunji et al. 2014).

This concluded section (2.2.2) presents the Nigerian construction professionals' educational backgrounds and responsibilities to understand their roles. Construction professions are called with different names in different countries or regions; thus, providing this background is crucial. Moreover, following the professionals' roles would provide a clear picture of the research subjects (respondents and interviewees).

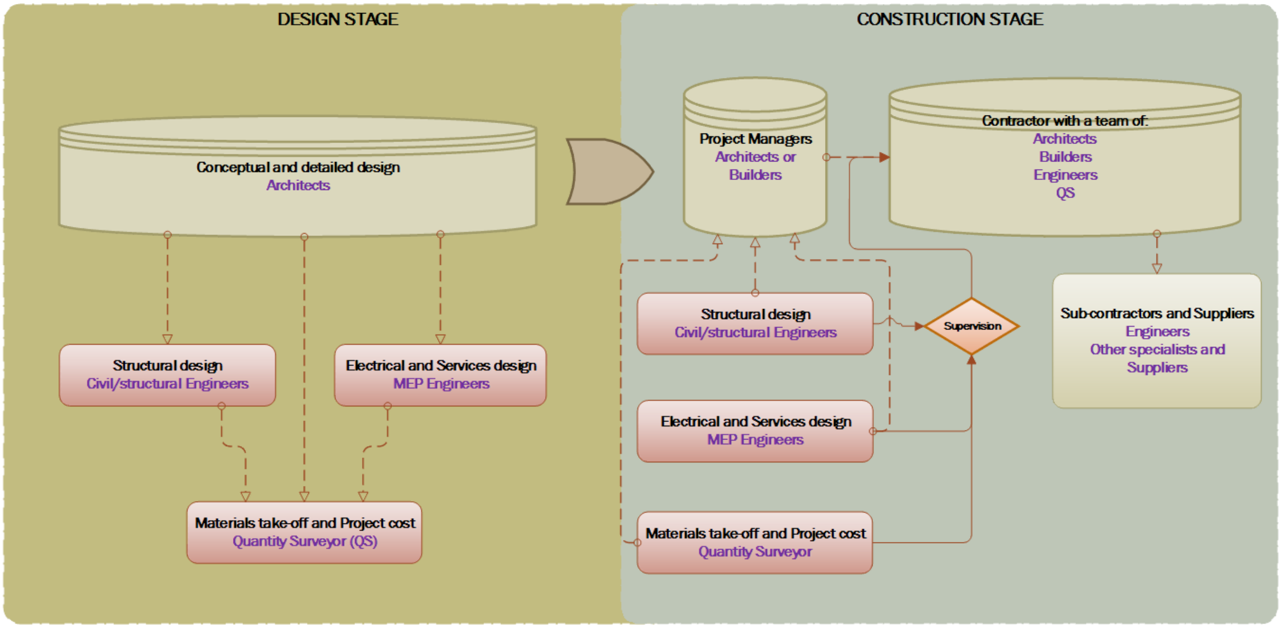


Figure 2.1: Typical working process in a traditional contract setting (Author generated)

Figure 2.1 presents a typical working process of construction professionals in a traditional procurement setting. The professionals are working independently yet to deliver a common goal without collaboration and or integrated information system. This conventional working process described in Figure 2.1 is resented to demonstrate how the professional stakeholders in the industry work in silos; thus, there's a need for a structural change to have a collaborative working environment.

2.2.3 Challenges in the Nigerian Construction Industry

There are several challenges in the Nigerian construction industry; the most dominant and significant ones are poor performance, time and cost overrun, conflicts, and building collapse. These challenges have persisted for over a decade. The building collapse has become a horrible situation that generates fear to the public. Many issues were attributed to the cause of this menace, and this includes the: disjointed teamwork, poor/unsupervised construction, and faulty structural design (Omenihu et al. 2017; Oyedele 2016). For example, Ayedun et al. (2011) compiled ten years (2000 to 2010) incidence of collapsed buildings within Lagos state alone; it was realised that, out of the 54 collapsed buildings, 37 were due to related structural issues. Still, nothing much has been done in tackling these challenges and their ultimate threat (Olagunju et al. 2013).

An effective delivery (on-time and within cost) of a construction project in Nigeria is becoming unrealistic due to poor communication between the construction industry stakeholders. Also, the significant effect of poor or ineffective communication in the industry is time overrun (Gamil and Rahman 2017). The majority of construction projects in Nigeria are delivered late (behind schedule) with rework and above the cost appropriated for (Anumah et al. 2016).

The in-situ or on-site production in the construction brings more waste and compromises quality at the construction stage. It was observed that working with full materials on-site is one of the major sources of waste; things like offcuts, oversupply, and poor recycling are the main sources. Ogunde et al. (2016) demonstrated how effective and fast the use of prefabricated elements is in residential developments. However, from the beginning, there was complaining of high cost, due to the cost of the machinery. Construction and demolition activities generate huge waste annually, estimated to about 30% waste generations Liu et al. (2015) cited Defra (2004). In contrast, Oyedele (2016) discloses that offsite construction is still at a rudimentary stage in Nigeria, and Small & Medium Enterprises (SMEs) who are the majority are not in any way adopting the modern construction methods.

Some of the Nigerian construction industry's challenges are attributed to the country's business environment. Babatunde and Low (2015) undertook a comprehensive study on the Nigerian construction industry, and it reveals overwhelming weaknesses and threats; such as corruption, negligent IP protection, and heavy dependence on the government for major projects. Moreover, the industry suffered an inherent structural problem that is suggested to be its major obstacles to succeed. The structural challenges of the industry may be considered as the cause of its disjointed nature (Babatunde and Low 2015; Onungwa et al. 2017), while the fragmented working brings about poor communication and information sharing, and lack of trust.

Succinctly, building collapse, poor quality project, project delay and cost overrun are the significant lingering challenges of the Nigerian construction industry. These challenges are attributed to fragmented teamwork, poor generation, transmission and management of information. As such, the industry requires a better workflow that would aid collaboration and better information management.

2.3 CONCEPT OF BIM

BIM is considered as a complete 3-dimensional digital depiction of a building system or subsystem, and a sophisticated technology comprising both an accurate building model and incorporated information (in a database) of all building components. BIM requires recognition beyond just a 3D representation of a building; it is an 'information-rich' sample representation of a building or its components (NBS 2012; Memon et al. 2014; NBS 2015). Most importantly, BIM remains the most potential development in the world of the AEC industry (Chan 2014). Furthermore, BIM has gone beyond being just a drawing and a documentation tool; and it is not solely about software, but represents a more collaborative method of working (NBS 2015). It is also considered as a process of transforming the way cities were designed, and life cycle performance of buildings and systems (Beaven 2012). The benefits of using BIM during the building design stage have been well-publicised and are fuelling its adoption rate among architects worldwide. In essence, this has transformed their drawing-based processes to model-based processes.

There are mainly two different BIM models, the UK BIM maturity model and the BIM performance models. The BIM maturity model of the UK was developed by Mark Bew and Mervyn Richards in 2008 (BIM Industry Working Group 2011), it is well-defined for the UK to enable compliance with its requirements. The development of Bew-Richards' maturity wedge in 2008 brings more explanations of the BIM concept not only within the UK but also across the world. There are many forms of this model from different publications, one of which is the one available in the PAS 1192-2: 2013 (BSI, 2013). Figure 2.2 presents the three (0, 1, and 2) defined levels of BIM maturity and one (level 3) that is not fully defined.

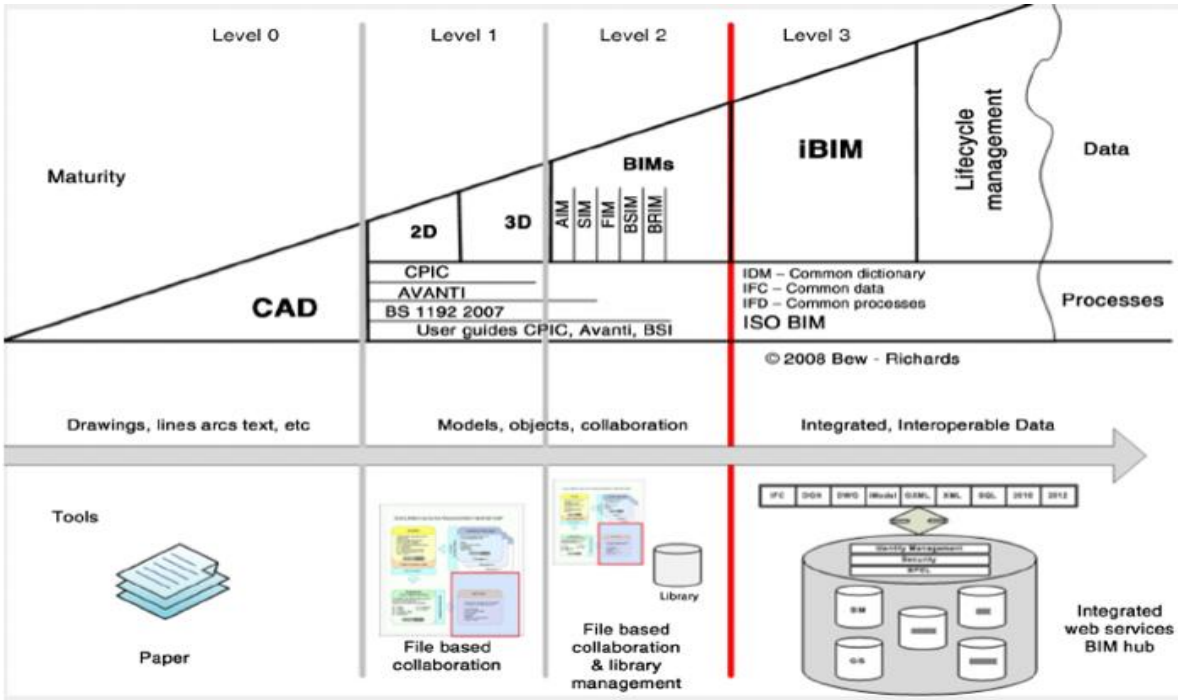


Figure 2.2: BIM Maturity diagram

This maturity model can test organisations and teams against guides; but, cannot evaluate their performance or maturity of a country. Moreover, the model blends the organisational or team performance with a targeted strategy. The conceptual bases of the model development are still unknown and do not fully comply with peer review of academic research. Thus, that remain a setback to the Bew-Richards' maturity wedge. Moreover, the model cannot be applied across countries (i.e. Nigeria), and it is part of a UK-based national strategy.

On the other hand, the BIM Performance Models constitute BIM capability stages, BIM Maturity Index (BIMMI), and Individual Competency Index (Succar 2008). Bilal Succar developed these models in 2008 and continued to refine over the years that lead to the development of five conceptual models for the assessment of BIM at the country level (Macro). The developed models are academically research-based, peer-reviewed and subjected to a sequence of scrutiny. There is also another suggestion closer to BIMMI that, BIM maturity of a firm can be used to support the development of BIM adoption model which is based on the Capability Maturity Model (CMM) (Morlhon et al. 2014).

Succar (2009) introduces the BIM framework; he, therefore, presented it as a tri-axial multi-dimensional knowledge model that comprises: BIM Fields, BIM Stages, and BIM Lenses. These model components harmonised the BIM capability sets; such as implementation maturity, the domain of activities, and the necessary level/scope of capability and requirements assessment.

As this study focuses on the adoption of BIM, which involves professionals and firms involvement aspect rather than the software/technology development aspects; the discussions narrow down to only two of the three knowledge models. The BIM Fields and the BIM Stages are relevant as the adoption is evolving; thus, BIM stages are used as evaluation of the current stage, and the BIM fields are used for both assessment and strategic plan (i.e. in technology, process and policy developments). The third dimension of the multi-dimensional knowledge of BIM model is the BIM lenses; the BIM lenses are strata of analysis to the fields and stages that allow investigations to focus on the area of interest (Succar 2009). This dimension focuses more on methodological screening of data and reducing unnecessary complexity or details. Thus, this research focuses on the Stages (milestones) and the Fields (deliverables and players of technology, process and policy).

Rogers (2003) describes the decision to adopt innovation as one of the two resultants processes of awareness and persuasion stages. BIM as an innovation in the construction industry, its adoption is depending on level awareness and persuasion. The BIM adoption relates to micro (adoption at the firm level) and diffusion to macro (adoption at the national level). At the same time, its implementation is defined as a combination of readiness, capability, and maturity that firm or market should develop to use BIM (Succar and Kassem 2015) successfully. Also, described BIM implementation as a 'three-phased approach' (Papadonikolaki 2017).

On the other hand, some viewed the BIM implementation as to the percentage of projects that involve BIM in a company or industry under consideration (Construction 2014). Moreover, years of BIM experience is directly proportional to the BIM implementation level as well as to the expertise level. Hence, the level of BIM implementation increases with the years of adoption (adoption duration).

2.4 BENEFITS OF BIM

The principles of Constructing the Team (Latham 1994), and Rethinking Construction (Egan 1998) were the first turning points of the UK construction industry. These principles were demonstrated on some projects that proved successful. For instance, the successful (on time and to budget) procurement of Heathrow Terminal Five (T5) revealed a significant difference; though, it can then be argued to be appropriate for big or mega projects (Haste 2002). T5 project, most importantly had the design and construction fragmentation issue resolved. Had the British Airport Authority (BAA) followed a traditional method for T5's procurement, T5 would have ended up 2years late and cost 40% more with six fatalities (Riley 2005). It is, therefore, essential to consider the procurement route as being significant to achieving a successfully integrated workflow. Similarly, BIM can effectively improve tendering and cost estimate (Chan 2014 cited Elbeltagi and Dawood 2011). Furthermore, the application of BIM would effectively improve the accuracy of the cost estimate (Ghaffarianhoseini et al. 2015) and tender.

The manufacturing industry has since realised the benefits of using BIM tools; the automobile industry is a clear example of BIM potentials. The automobile industry recorded significant success from working with BIM technology (Egan 1998). However, the construction industry is generally known to be resistant to changes; and most contractors are not ready for innovations; instead, they persist with the traditional way of working (Egan 1998; Walasek and Barszcz 2017).

There are numerous applications of BIM, such as design coordination, energy performance simulation, scheduling, quantity take-off, clash detection and 3D visualisation (Cao et al. 2014, Eastman et al. 2011, Monteiro et al. 2014). There have been several arguments regarding BIM benefits over the years. Autodesk (2008) claimed a time saving up to 91% on checking and coordination, and 50% on developing a design while using Revit® Architecture software compared with the conventional Computer-Aided Design (CAD). However, different countries have adopted BIM and had individual experiences (in benefits) depending on their level of adoption, and perhaps their specific challenges ahead of the adoption. For example, (McGraw Hill 2014) study reveals the most significant immediate benefit derived from the use of BIM is a reduction in errors and omissions, reduction in rework; significant long-term benefits as business reputation, reduction of project duration and construction cost. Even though, every country has its reasons to adopt BIM; similarly, there are still some common goals amongst countries. These include improving the industry's productivity and unifying its standards by changing its way of working (BIM Industry Working Group 2011; NATSPEC 2012; Hjelseth 2017).

For every innovation, there are some anticipated benefits. These benefits could be financial and or ease of the process and or a better outcome. BIM came with numerous benefits that are probably considered more theoretical than practical due to the diverse construction processes, size and needs/requirements across different markets. For example, several publications bring so much publicity on BIM benefits (Azhar 2011; Parvan 2012; Arayici et al. 2012; Khosrowshahi and Arayici 2012) and its efficacies. However, these appeared only within the literature, especially where the BIM adoption level is significantly low, and case study projects are minimal. Thus, BIM adoption benefits can be presented as a facilitator at the persuasion stage to adopt BIM. The decision to adopt innovation depends heavily on its relative advantage, compatibility, triability and observability; therefore, benefit directly translates to comparative advantage.

BIM can, however, contribute to a more sustainable construction process that may consequently commit to eradicating poverty in developing countries (Bui et al. 2016 cite United Nation Millennium Goals). This claim can be of a keen interest where value for money on a public project is paramount, and more to that reduces corruption. Similarly, there are some setbacks in BIM adoption and implementation in which some argue that "the intrinsic creativity of Architects and Engineers who use BIM is reducing. However, the use of BIM increases creativity in IT" thereby resulting in higher quality and more excellent knowledge or further specialisation (Turk 2016); hence, creating more job opportunities.

The different BIM potentials spanned over the area of structural engineering (i.e. providing rich design information and facilitate offsite or precast fabrication; the area of project management (i.e. scheduling and information management – 4D); and in the area of cost management (i.e. take-off and cost analysis – 5D). Thus, the utilisation of such can bring several benefits potential to tackle the current challenges in the Nigerian construction industry, especially in the areas of building failure and collapse, inefficiencies and project cost overrun. The inefficiencies can be seen from the planning angle, where the execution of planned activities appeared unfulfilling due to the communication gaps or lack of sufficient design/construction details. The 4D BIM scheduling is robust in coordinating and distribution of scheduled activities to respective stakeholders (Kymmell 2007).

Integrating the procurement process remains a key to effective monitoring and evaluation; these include pre-contract and post-contract stages by adopting a concept of BIM process. The abilities of BIM tools and their interconnectivity between stakeholders would, of course, play an essential role for better understanding and monitoring of features, details and specifications. The offsite production of building elements facilitated by BIM concepts would be of significance in controlling quality. Hence, that will improve the product quality and efficiency of the industry.

2.5 BIM FIELDS

The BIM fields is a combination of three essential segments that all contain pairs of components. The segments are, Technology, Process and Policy; and, the pairs of the segments' elements are players and deliverables (Succar 2009). The three BIM fields interact in a circular push-pull complementary behaviour with resultant overlapped in the form of a Venn diagram (Figure 2.3). The BIM field types contained the entire aspects of BIM deliverables and components required for a successful BIM implementation.

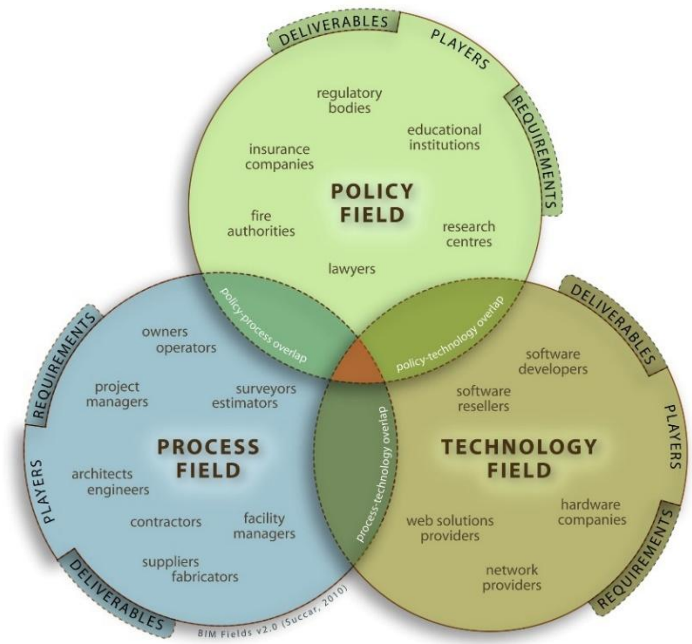


Figure 2.3: Three interlocking BIM Fields — Venn diagram (Succar 2010)

There are intersections of these fields, that is the overlap between process and technology; process and technology; and policy and process. The intersection represents a deliverable that requires input from two or more fields. For example, achieving Industry Foundation Classes (IFCs) require joint efforts of Policy players and Technology players.

2.5.1 Technology Field

The Technology field of BIM is an interactive field of technologies (hardware, software and equipment) enabled by networking systems to support design, construction and operations of a built asset (Succar 2009). The technology field is associated with the technological requirements and needs to deploy BIM, that includes: BIM tool(s) (BIM software), communication systems, model servers, computers, geographic information system, database technology, and internet. And, the players' involved are software companies, hardware companies, and network providers.

2.5.2 Process Field

The Process field is associated with players who procure, design, construct, manufacture, manage and maintain facilities in the construction industry (Succar 2012). The process players components are traditionally the stakeholders; these are

Owner/operators, architects, engineers, project managers, surveyors and estimators, contractors and suppliers, and facility managers (Succar 2010). They work in collaboration aided by the tools (i.e. hardware and software), using services (i.e. network) and platforms (i.e. database) provided by the technology players (software companies, hardware companies and network providers) to deliver construction products and services (Succar 2009).

2.5.3 Policy Field

The definition of policies guides the Policy field as *written rules to guide decision-making* (Ern et al. 2017). The Policy Field is a collection of regulatory bodies, educational institutions, research centres and insurance companies. The organisations do not produce any physical construction product, but they provide specialised services of delivering research, allocating benefits, assigning risks and reducing conflicts within the construction industry (Succar 2009). The policy players are vital from the preliminary stage up to the execution stage. Moreover, their role is essential and thus is required to be considered by any country planning to streamline BIM adoption at a national level (Kassem and Succar 2017).

2.6 BIM MATURITY STAGES

The BIM maturity stages came up to play due to the lack of absolute clarity to the level of BIM implementation and scale of measurement. By knowing the fields of BIM, the maturity stages would identify different levels of BIM implementation. The BIM stages are defined after Pre-BIM phase or immediately after the Point of Adoption (PoA); this is a stage preceding to BIM implementation stage (Succar 2009). The BIM maturity stages clearly describe three fixed starting point with an open-ending point to accommodate future technological developments. The steps develop from one point to the next through advancement in levels, thus changing from one stage to another requires multiple incremental levels (Taylor and Levitt 2005). The three stages are sort of complementary components to the BIM field types that define the stage of BIM adoption or implementation; the stages include:

- BIM Stage 1: object-based modelling

- BIM Stage 2: model-based collaboration
- BIM Stage 3: network-based integration

The BIM maturity stages are further summarised and presented in Figure 2.4 by Succar et al. (2013).

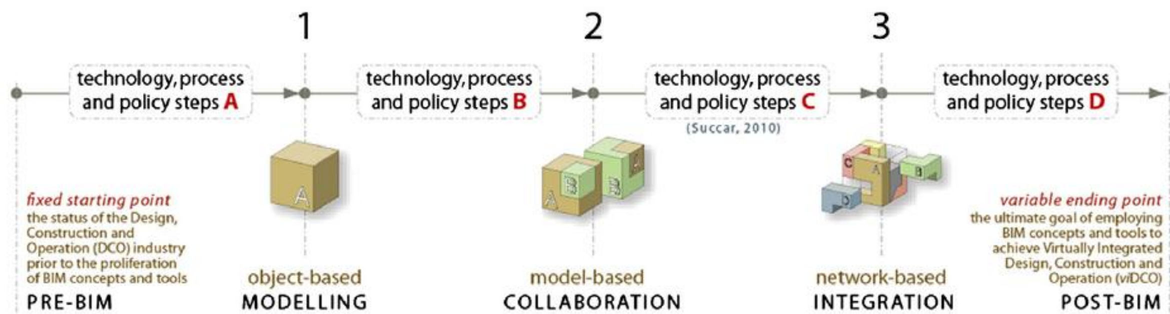


Figure 2.4: Step sets leading to BIM Stages (Succar et al. 2013)

Moreover, there are sequential levels in each BIM stage. For instance, BIM maturity levels of BIM stage 1 are, ad-hoc, defined, managed, integrated, and optimised (Figure 2.5).

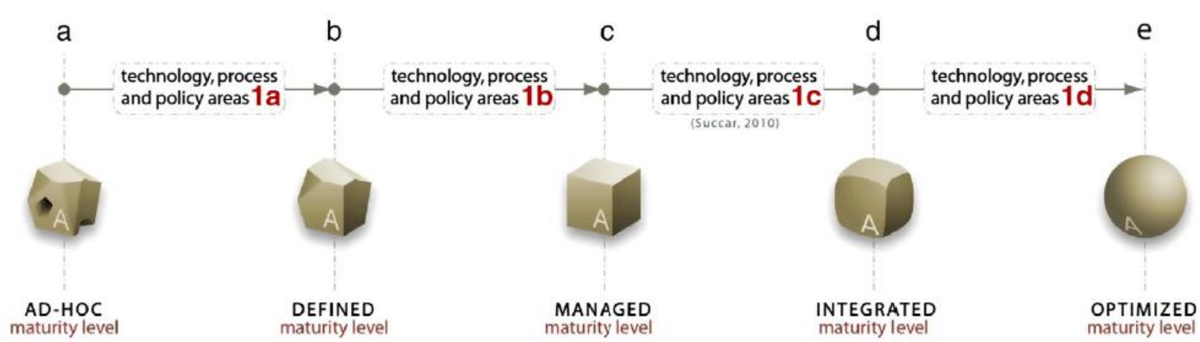


Figure 2.5: BIM Maturity Levels at BIM Stage 1 (Succar et al. 2013)

The BIM maturity levels presented in Figure 2.5 are also utilised in the Macro-BIM adoption study in section 5.3.

2.6.1 BIM Stage 1: Object-Based Modelling

BIM is said to have been deployed when an object-based modelling tool (i.e. Revit, ArchiCAD, TEKLA, BIM360) is used in generating single-disciplinary information-rich model at design, construction or operation stage. The BIM stage 1 involves the utilisation of 3D parametric tools like Revit to create a 3D structure for visualisation and automation of 2D drawings and documentation (Succar 2009). The working process is nearly the same as that of the pre-BIM stage; the information-sharing remains unidirectional. Thus, no collaboration between the stakeholders as the few changes are at the organisational level. However, there is a considerable connection amongst the Design, Construction and Operation phases of a single-disciplinary model.

2.6.2 BIM Stage 2: Model-Based Collaboration

Sequel to achieving the BIM stage 1, advancing from the single-disciplinary modelling to a collaborate inter-disciplinarily model through the sharing of developed models (i.e. between Architect and Structural Engineer). Succar (2010) describes BIM stage 2 as the ability to work by sharing of models (that are IFC enabled), and the interconnection between two project lifecycles (i.e. Design-Design, Design-Construction, and the Design-Operation). This process involves an exclusive 3D rich information model as this will allow semantic to exchange different disciplines. Data extractions, further developments such as 4D (scheduling) and 5D (costing) become feasible. The conventional 2D workflow starts to disappear, and new processes and contract amendments begin to evolve (Succar 2009).

2.6.3 BIM Stage 3: Network-Based Integration

BIM stage 3 is a revolutionised stage of BIM implementation where *semantically-rich integrated models are created, shared and maintained* collaboratively throughout the project lifecycle (Succar 2009). The unique development of this stage is having a single distributed federated database that hosts all information from different professional stakeholders, and the ability to track changes on the developed models. The BIM stage 3 is a shared interdisciplinary nD model (Lee et al. 2005) that allows two-way access by the key project participants, with the ability for several analyses at initial phases of a project. This stage of BIM implementation facilitates changes in the procurement process of the construction works. Such as contract arrangements, risk-sharing, roles and responsibilities as well as deliverables. All these connect to policy change and technology maturity. Figure 2.6 describes the collaborative BIM project initiation workflow, which is different from the traditional workflow.

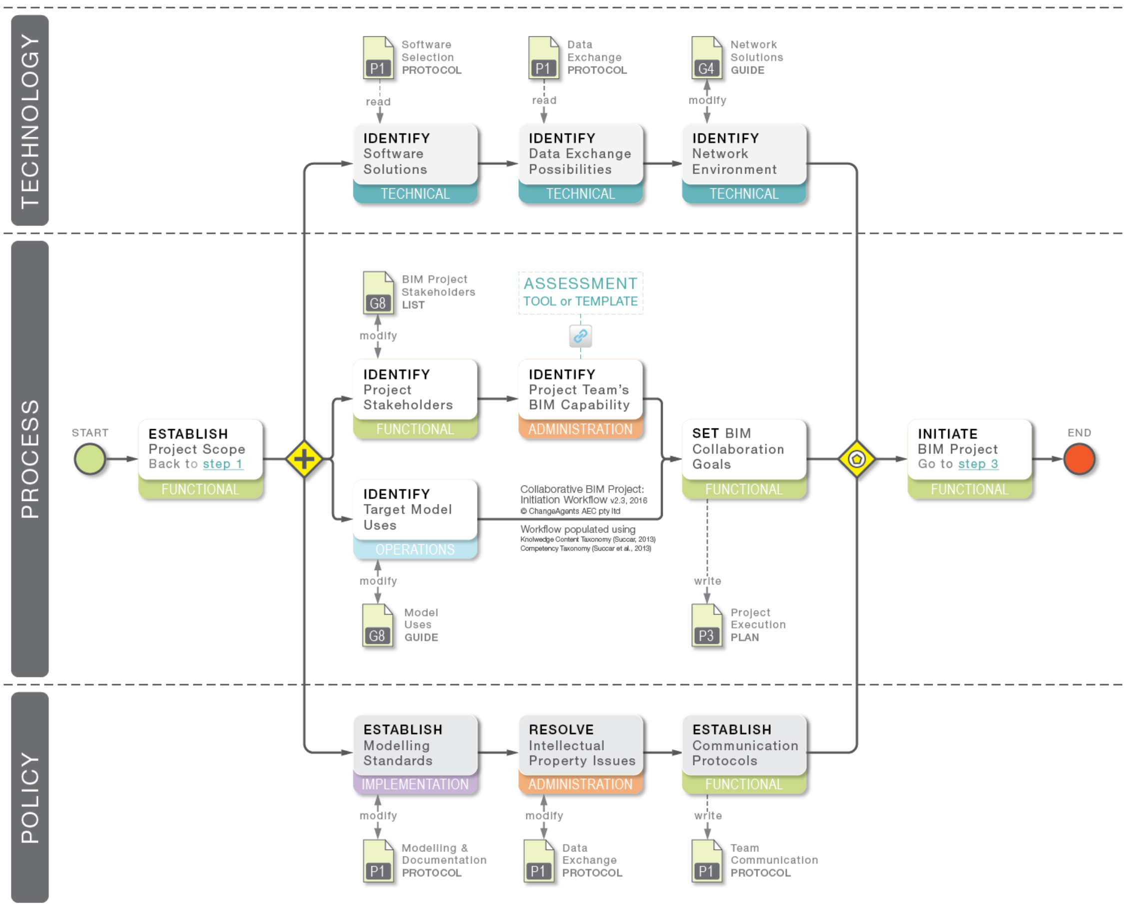


Figure 2.6: Collaborative BIM project initiation workflow(Succar et al. 2013)

2.7 BIM ADOPTION

As described in section 2.3, BIM adoption comes as a result of awareness and persuasion process; it is about perceiving the idea as a new way of doing things. There are three levels of BIM adoption, the Micro (within an organisation), the Meso (within a project), and the Macro (market/countrywide). The Micro BIM adoption relates to organizational (firm) adoption with top management of a firm prescribing the BIM usage (Succar 2010; Papadonikolaki 2018). The Meso level of BIM adoption is adoption based on projects and their teams, the owner and project manager prescribing that (Succar 2010; Papadonikolaki 2018). While the Macro BIM adoption is markets and industries related (country-wide); that involves governments and international institutions (Succar 2010; Papadonikolaki 2018).

A significant BIM adoption is recorded at design and construction stages in some developed countries. United States (US), United Kingdom (UK), Germany and Scandinavian nations are clear examples of that. However, its practical usage is still limping in many countries, and this includes its usage as a platform for facility management which by implication extends to the entire facility life cycle (Beaven 2012).

Despite progressive adoption of BIM in the US, UK and some other developed nations, the construction industry is known to be a very conventional industry that is bound by tradition; it is a group that is rigid to bring together (Walasek and Barszcz 2017). There is, however, a significant development in Hong Kong (developed) construction industry even though it is part of China (developing country). The Chinese government supported BIM adoption and implementation; however, there is still considerably slow adoption of BIM in the industry (Chan 2014). Moreover, Chan (2014) study in China discovered that about 33% believed that lack of training is a significant reason for insufficient use of BIM; two-thirds (67%) felt that use of BIM is not necessary as 2D is sufficient to meet their need. This could be evidently lack of understanding (awareness) of the BIM process.

Similarly, in addressing individual perceptions of this technological process in the UK, some perceived BIM as an unrequited addition to the existing work process (Haward et al. 2017). Thus, considered this as more of remnants to the high initial cost (Walasek and Barszcz 2017). Therefore, the design fee will most likely increase to reward BIM usage; success in terms of a positive return on investment (ROI) also encourages the use of BIM.

Chan (2014) believed that high initial cost and lack of standardisation between BIM platforms are also amongst the main reasons why BIM is not adopted in a country like Hong Kong. Similarly, in the UK, the cost is also a barrier of BIM adoption along with a lack of clarity in the industry; even though those who adopted BIM revealed some of its benefits. These include speedy project delivery, cost competence and information retrieval (NBS 2015). Walasek & Barszcz (2017) argue that the level of design fee needs to be revisited to effectively facilitate the ROI on the use of BIM on the project. On the other hand, Coa et al. (2015) reported a survey carried out on BIM adopters/users from China, where about half (51%) of the respondents disclosed that the costs of BIM in their projects had been passed onto the clients/owners. Some respondents also revealed that some clients allow the inclusion of BIM cost in the bidding price. Therefore, considering the above arrangement or perspective, BIM adoption wouldn’t have been an issue in China. Thus, the cost might not necessarily be of concern in China, but elsewhere. Moreover, some studies like Cao et al. (2015) revealed that the cost of BIM tools would not be an issue to BIM adopters because the client is paying the BIM consultant who provides full IT support.

On the other hand, a study carried out by Azhar (2011) on four successful projects which recorded an average of 634% ROI on the cost of BIM is disclosing enormous benefits of BIM adoption. Moreover, 74% of frequent BIM users in Western Europe perceived positive return on their overall investment (McGraw & Hill 2010). Despite these positive case studies, the UK suffered some level of resistance to adopt BIM especially from those who are using BIM for less than five years as a result of BIM cost distribution (Cusack and Saleeb 2016). However, stakeholders who don’t use BIM are financially benefitting its use by others.

The studies undertaken in the USA, UK and Australia regarding potential benefits of BIM and process of its full adoption indicate that the USA is considered as a country with the highest adoption rate (Construction 2014; Kassem and Succar 2017). McGraw-Hill Construction (2012) reported 71% adoption in the US, whereas UK was at 69% adoption as reported by NBS 2019 survey (this is after the expiration of April 2016 BIM level 2 mandate). The 2015 NBS National BIM Report lamented the limited expertise and resource that can research and educate the industry in this innovative field in the UK. Upon all challenges, more countries are building up to BIM adoption (i.e. Ireland, Germany, Finland, Denmark, Norway, France and Canada); the most recent amongst these is the Republic of Ireland. Ireland (in the last quarter of 2017) released a “Roadmap to Digital Transition” for its construction sector, three years after the National BIM Council (NBC) was formed. The first national survey (for benchmarking) on BIM was carried out in 2015 by Construction IT Alliance (CitA), it reported vast demand for BIM (NBC 2017). The developed roadmap is targeting three key performance Indicators (20% increase in construction exports, 20% reduction in both delivery time and capital cost) by 2021.

Most research focuses on outlining the barriers to BIM adoption and the associated benefits, although the final or primary beneficiaries of BIM adoption are somehow the client and the contractor. The client's intention and action to enforce the use of BIM could be most probably be a quicker solution to adoption and implementation (Zahrizan et al. 2013; Walasek & Barszcz 2017). Some findings associated the downhill situation of BIM adoption in most developing countries with lack of government involvement and consider government involvement amongst the significant driving factor to the speedy adoption of BIM (Zahrizan et al. 2013). On the same trend, Froise & Shakantu's (2014) studies of South African construction industry revealed that lack of awareness and enforcement by the government of South Africa as the contributory factors that slow the BIM adoption process.

The right tools must be available as well as trained personnel (Ghaffarianhoseini et al. 2016) for BIM to be adopted; as such, research often emphasises on the software development aspects of the BIM (Hjelseth 2017) neglecting the training and social aspect of the adoption. This research is also interested in; exploring the necessary changes in the existing working practices. One could foresee successful BIM application as being a fundamental challenge that will demand systematic consideration of interdependencies and effective changes in management to realise its full potentials.

BIM is increasingly being adopted in developed countries, but the picture is different in the developing nations. The absence of BIM national implementation programmes, as well as the scarcity of BIM skilled personnel, are the main reasons for poor adoption and implementation of BIM (Bui et al. 2016; Hamma-adama et al. 2018).

South Africa is amongst African and developing countries with substantial developed infrastructure, and a developed construction sector (Oluwakiyesi 2011). Their level of BIM adoption is higher than any other country in the African continent as a whole (Froise & Shakantu 2014; Hamma-adama et al. 2017). However, the procurement route is found to be the major barrier to its implementation (Froise & Shakantu 2014; Kekana et al. 2014). Research gap has been established in most of the developing countries regarding BIM adoption and implementation, most notably in the area of "technology transfer". This area keeps on receiving diminutive publications recently and also observed that "BIM implementation in the developing country context are rare" (Bui et al. 2016). Amongst other issues, corruption amongst the construction stakeholders is an issue that has deeply affected the construction industry in Nigeria; quick adoption of BIM in Nigeria has the potential benefit of minimising corruption in the sector (Kori and Kiviniemi 2015).

There is limited research on BIM within the study country on a general level beyond a specific discipline and or city in the country. This can be noticed in the eleven compiled published works (refer to Table 2.1) and the more detailed summary in Appendix - 1.

Table 2.1: The Available BIM Publication within Nigeria

S/No.	**Publications**	**Remark**
1	Abubakar et al. (2013)	This study has some limitations, such as Only building designers were considered for the study; The targeted location was only Kaduna & Abuja.
2	Abubakar et al. (2014)	The study focused only on building construction firms, and the primary data were obtained from Abuja and Lagos and also centred on contractors only; therefore, it cannot be generalized.
3	Dim et al. (2015)	This is a literature review-based and uses some case studies from the UK.
4	Kori & Kiviniem (2015)	This research is limited to Architectural firms and is referring to some Architectural consultancy firms in Lagos, Abuja, Kaduna and Kano.
5	Ugochukwu et al. (2015)	The study targets Anambra and Enugu states only; going by the procurement route mostly adopted by the public sector; consultants (designers) should have been amongst the respondents. No evaluation of the respondents' experience. For more clarity, the response by the clients should have been evaluated separately

		from that of the contractors.
6	Wang et al. (2015)	The findings revealed a relatively high level of awareness at the same time, lack of awareness as a barrier to BIM adoption.
7	Ezeokoli et al. (2016)	These findings are limited to a location (Anambra State); only structural engineers were involved out of engineering disciplines in the survey, and only building construction was considered.
8	Timothy et al. (2016)	The findings were derived from Architectural Firms only and targeted Akure only.
9	Ebiloma et al. (2017)	In summary, education and training is the main issue to be handled before serious BIM adoption in the study area. The study covered only one state (Akwa Ibom).
10	Hamma-adama et al. (2018)	Although the survey targets the entire AEC; however, the enquiry is limited to North-west, North-central and Lagos.
11	Onungwa et al. (2017)	The study focused predominantly on the South-Western part of Nigeria, specifically Lagos (75%) with just 6.3% from the South-South region of the country.

Considering the compiled literature on the BIM studies in Nigeria Table 2.1 (as in Appendix - 1), more than three-quarter of the publications (e.g. Abubakar et al. 2014; Ugochukwu et al. 2015; Ebiloma et al. 2017) revealed that lack of trained personnel on the technology as a significant barrier against the adoption of BIM. And, more than half are associated with poor awareness and knowledge of its potentials.

BIM may be referred to as a disruptive technological process that is changing the way construction work is being procured. The Nigerian construction sector is known to be a fragmented industry where professionals have monopolised design and construction information (Onungwa et al. 2017) and work more as a group than a team. BIM is not well established in the Nigerian construction market, but the level of awareness is rapidly progressing. The industry needs this disruptive process (BIM) to improve its productivity and capabilities by integrating the stakeholders' working process. To achieve BIM adoption, an investigation on the maturity of BIM is therefore necessary. Succar and Kassem (2015) developed five conceptual constructs for assessing the adoption of BIM at a country level called "macro BIM adoption model." These conceptual models were then developed further to guide on how the combined models can be transformed into BIM policy roadmap and BIM policy plans (Kassem and Succar 2017). The Macro BIM adoption model is presented in the subsequent section.

The reviewed literature advocates for an innovation adoption to allow the industry prosper, and specifically BIM innovation in this context. The BIM was found to be new in the construction industry, and its need to be adopted requires a streamlined process. Being a new paradigm, methodologies to its investigation is currently evolving. Some methodologies from social research are getting contextualised to investigate the technology shift by the industry. For example, a well-known theory of innovation adoption is the diffusion of innovation, a concept developed by Rogers in 1962 is gaining recognition in this area of research.

The Diffusion of Innovation (DOI) is a theory developed by Rogers in 1962, and it seeks to determine the rate at which new technology or idea spreads (Rogers 2003). DOI was used as a tool to ascertain the phase and level of technology penetration and adoption within the potential population of adopters. The DOI theory outlined five variables that determine the adoption rate, and these are:

- the self attributes of the innovation
- the channels of communication used
- the innovation-decision type, and
- The nature of the social system and the level of change agent's promotion efforts (Rogers 2003).

However, Grunfeld (2011) argued that it is essential for the innovation to be accepted and adopted before it can begin the diffusion. Notwithstanding, several studies still considered the DOI of Information Technology based innovations through using the attributes of innovation as categorised by Rogers (2003). Innovation diffuses and subsequently adopted through the following steps:

1) Knowledge/awareness
2) Persuasion/interest
3) Decision/evaluation
4) Implementation/trial
5) Confirmation/adoption.

The above set of activities are considered in the adoption process. In this case, the diffusion of innovation concept is used in assessing the BIM status quo (at exploratory study) while developing a conceptual framework at the investigative research, specifically, as a theoretical framework.

2.7.1 Macro BIM Adoption

In 2015, Succar and Kassem developed five new conceptual constructs for assessing BIM adoption at a macro (country) level. The developed models were subsequently refined as conceptual tools, extended additional assessment metrics to assist researchers and policymakers in analysing and improving or developing BIM diffusion policies within a market (Kassem and Succar 2017).

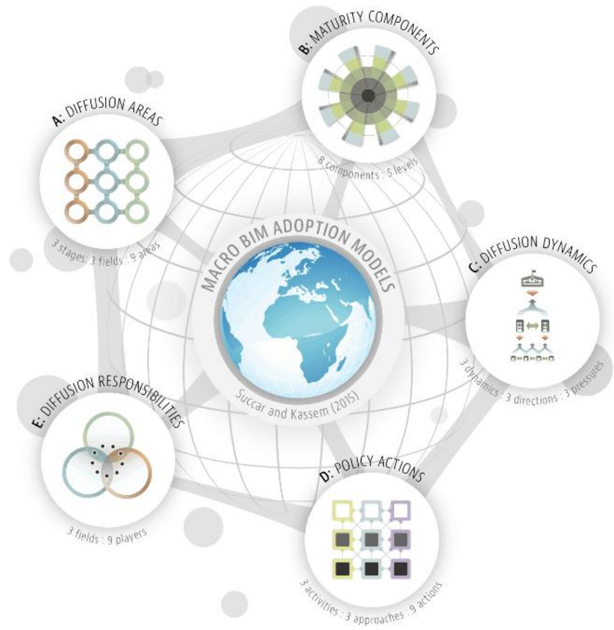


Figure 2.7: Macro BIM adoption models (Succar and Kassem 2015)

The developed macro-BIM adoption models constitute Macro-Diffusion Responsibilities model; Macro-Diffusion Dynamics model; Diffusion Area model; Policy Actions model; and Macro-Maturity Components model (Succar and Kassem 2015). These will be explained in sections 2.7.1.1, 2.7.1.2, 2.7.1.3, 2.7.1.4, and 2.7.1.5. Figure 2.7 illustrates the five developed conceptual models.

2.7.1.1 Model A: Diffusion Areas

The diffusion area model explains how BIM field types (technology, process and policy) relate with the BIM capability stages (modelling, collaboration and integration) to produce nine areas where BIM diffusion occurs (Succar and Kassem 2015). Thus, such areas are for the analysis of diffusion and planning (Figure 2.8). The diffusion areas can be assessed at once from each field type along horizontal (BIM stages) using the same or different methods of assessment, or individually evaluated using the same or different assessment methods (Kassem and Succar 2017).

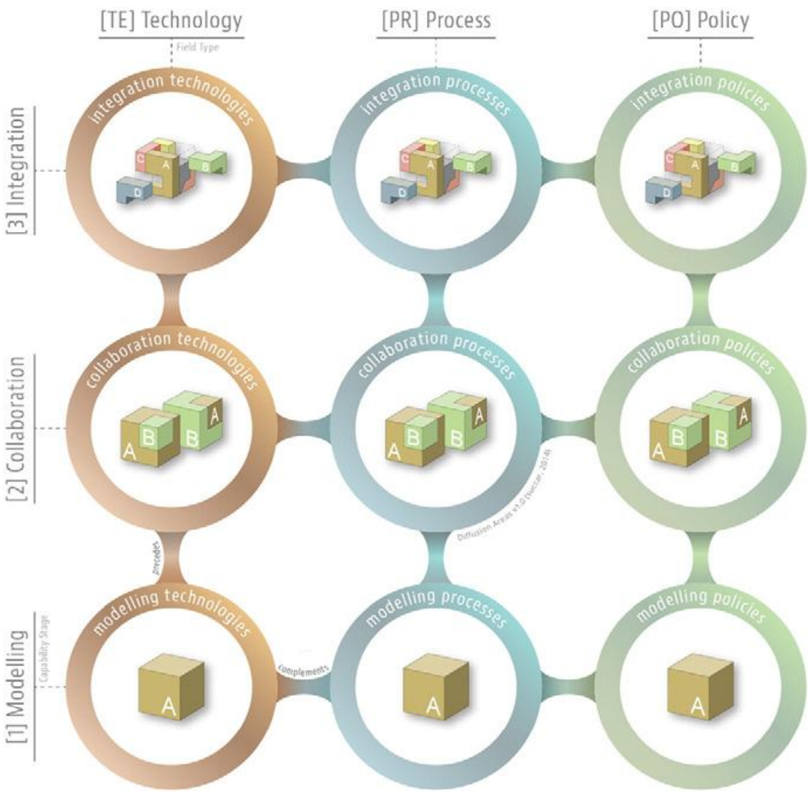


Figure 2.8: Diffusion Areas model (Succar and Kassem, 2015)

The nine diffusion areas provide granular assessment model to evaluate the level of BIM diffusion within a targeted population (specifically, the adopters). The model also allows comparative market analysis from the generated rating of various markets (Kassem and Succar 2017).

2.7.1.2 Model B: Macro-Maturity Components

The macro-maturity components model has eight complementary components that are used to measure and establish the maturity of BIM in countries. These components are Champions and drivers, Learning and education, Measurements and benchmarks, Noteworthy publications, Objectives, stages & milestones, Regulatory framework, Standardised parts and deliverables, and Technology infrastructure. Figure 2.9 illustrates the structured components with five different maturity identification levels. These components are measured using the BIMMI, which has a different maturity level. The scales of measurement from the outer to the inner circle are as follows: ad-hoc – low maturity; defined – medium-low maturity; managed – medium maturity; integrated – medium-high maturity; optimised – high maturity (Fox and Hietanen 2007).

The components converge as they mature from *a* to *e* corresponding to ad-hoc to optimised or low maturity to high maturity. These components and their maturity index set a distinct description of all the eight components within a market. The closer these components are (converging), the mature they are. These components can be assessed on the bases of BIMMI holistically to compare a relative maturity of one component over the other (within the eight maturity components) as prescribed in the Succar and Kassem (2017, table 11). Instead, granularly to evaluate each component using the component-specific metrics (Succar and Kassem 2015, table 3-10). Figure 2.9 illustrates the positioning of the eight maturity components.

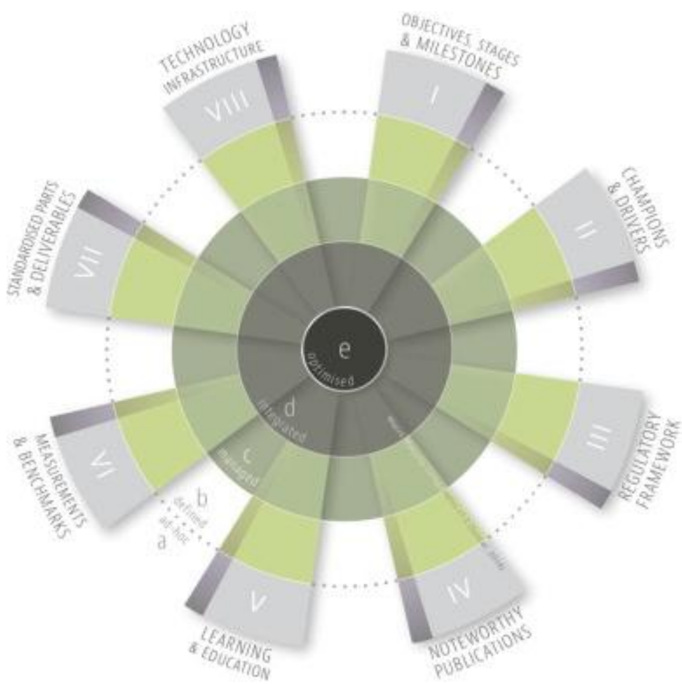


Figure 2.9: Macro-Maturity Components model (Succar and Kassem, 2015)

The champions and drivers are individuals, groups or organisations demonstrating the usefulness of BIM to the construction industry stakeholders. In this context, the availability of these individuals or groups attests to higher maturity compared to an industry lacking the component (Succar and Kassem 2015).

The learning and education represent the component of the educational sector where teaching activities happened whether in higher educational institutions or in the form of continue professional development (CPD) or workshop. It covers the concept of

BIM, the BIM tools and the BIM workflow (Succar and Kassem 2015).

The measurements and benchmarks represent how a particular market acquires metrics for benchmarking project performance and assess the capabilities of individuals, organisations and teams. The availability of this component validates the capacity to evaluate and potentially improve the industry's better performance (Succar and Kassem 2015).

The noteworthy publications represent the relevant documents published (publicly available) to influence the broad industry audience. These documents are mostly developed by influential stakeholders of the industry like government/regulatory bodies, professional societies, industry leader, etc. (Succar and Kassem 2015).

The objectives, stages & milestones represent the availability of policy objectives of BIM and its intermediate capability stages in a country. Also, the presence of milestones and measurement metrics differentiate between the current position and the plan. In the macro maturity context, it describes the achievement recorded from the pre-determined stages and the set milestones (Succar and Kassem 2015).

The regulatory framework is a component that describes the contractual setting, professional indemnity insurance and intellectual property rights underlying BIM-based projects. In the context of macro-maturity assessment, this component's availability intends to address issues of procurement, workflows, deliverables, and stakeholder rights and indicates higher maturity (Succar and Kassem 2015).

The standardised parts and deliverables represent the standardised deliverables, from standardised objects utilisation to model generation; and, the deliverables from generating models to collaborating up to models' integration (Succar and Kassem 2015).

The technology infrastructure looks into how available are the technology deliverables (hardware, software and network systems), their accessibility and affordability within a country. Moreover, it involves the level of usability and connectivity of information systems hosting data-rich three-dimensional models (Succar and Kassem 2015).

2.7.1.3 Model C: Diffusion Dynamics

The diffusion dynamics is primarily meant to assess the adoption trend within a market and compare with the directional pressures to how diffusion unfolds within the construction market. The model comprises three diffusion dynamics, namely: Top-Down; Middle-Out and Bottom-Up (Figure 2.10).

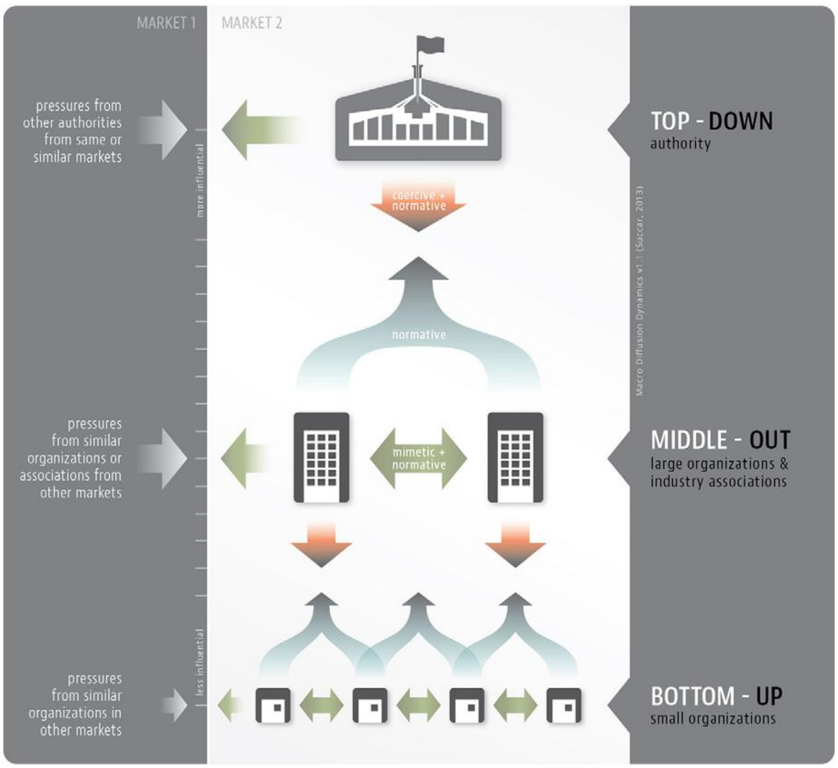


Figure 2.10: Macro-Diffusion Dynamics model

Also, the model sets four directional pressure mechanisms who are laid over the three diffusion dynamics. These include Downwards, Horizontal Downwards, Upwards Horizontal and Upwards Horizontal pressures.

2.7.1.4 Model D: Policy Actions

The policy actions model (Figure 2.11) has nine policy actions generated from mapping the three BIM implementation approaches (passive, active and assertive) and the three BIM implementation activities (communicate, engage and monitor) (Succar and Kassem 2015). Furthermore, the model was developed as an assessment tool to generate activities/tasks to compare policy actions across various countries for structured policy intervention in achieving a market-wide BIM adoption.

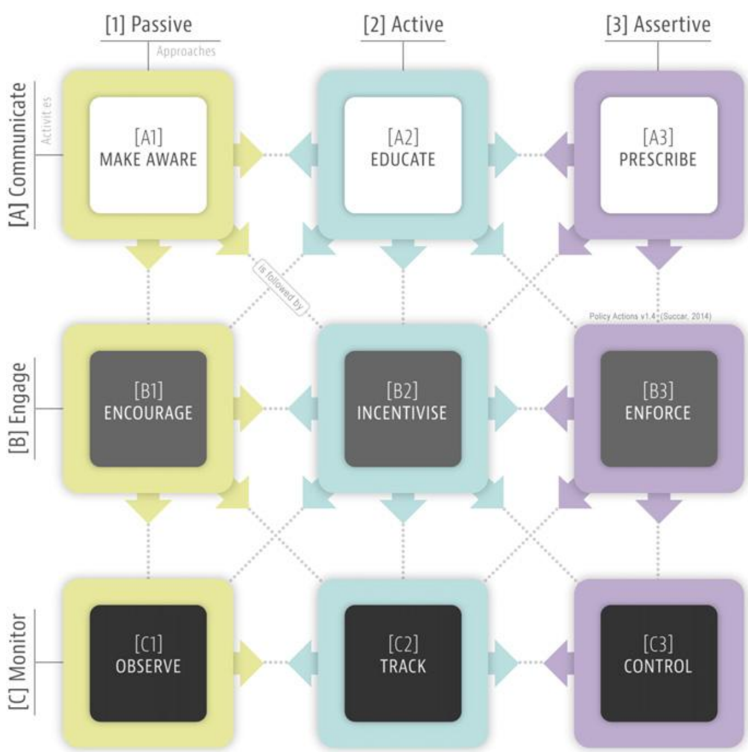


Figure 2.11: Policy Actions Model (Succar and Kassem 2015)

The policy actions present information to the potential BIM adopters, such as advantages of the new process; that may not necessarily speed-up the diffusion, but legislative provision for incentives may encourage the adoption. The model stresses the policy maker's action to influence the wider adoption of BIM.

In the context of macro-BIM adoption, the approaches and activities are used in generating a template for a structure policy intervention or used as a tool in comparing different policy actions across countries.

2.7.1.5 Model E: Macro-Diffusion Responsibilities

The established BIM field types have their respective capability sets (that differs base on BIM stage) as a group of players within the construction industry and across the BIM field types (Succar 2009). This goes into the analyses of BIM diffusion through the players' (stakeholders) roles in the industry as a network of actors (Succar and Kassem 2015).

The macro-diffusion responsibilities model (Figure 2.12) is used in this context (macro-BIM adoption) to compare the BIM diffusion activities of player(s) with a group or different groups, and group(s) within the same country or different countries, as well as the player(s) within a country, or different countries (Succar and Kassem 2015).

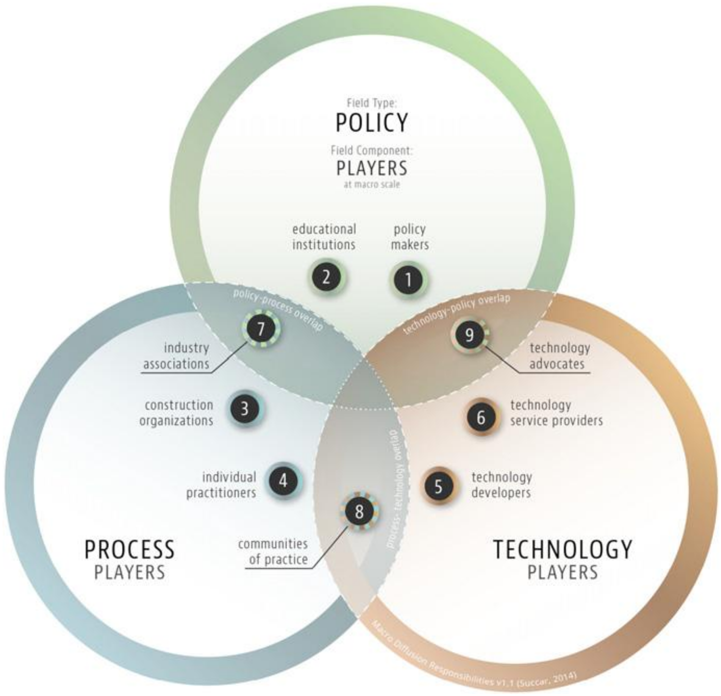


Figure 2.12: Macro-Diffusion Responsibilities model (Succar and Kassem 2015)

Sequel to the completion of the assessment, the concept developed three sequences of activities to realise the intended study aim. These activities are:

- Initiation Phase of the Policy Development
- Consultation Phase of the Policy Development
- Execution Phase of the Policy Development and

The macro BIM maturity models are amongst the most cited and used maturity models (Kassem and Succar 2017; Yilmaz et al. 2017). This set of models were already applied in several countries like Canada, Peru, Latam, Russia, Ireland, Egypt, Spain, Hong Kong and Brazil (ChangeAgents 2019). The macro maturity model is considered as the most viable method to assess BIM adoption at the macro scale.

As part of a process to develop a strategy for effective BIM adoption at a country's level, the construction market maturity should be assessed ahead of policy development. There are several maturity models, ranging from assessment of the derived benefits of BIM utilisation (Barlish and Sullivan 2012) to the 'capability of National BIM Standards model that deals with BIM tools and maturity levels' (National Institute of Building Sciences) and "BIM proficiency matrix by Indiana University" (Smith Dana and Tardif 2009). Despite their derived benefits within their settings, the models do not offer a full understanding of how BIM diffuses at the macro-level or broad macro-BIM adoption (McAuley et al. 2018).

2.7.1.6 Initiation, Consultation and Execution Phases of BIM Policy Plan

The initiation phase is determined to institute "task group" (as a proposal) and the seed BIM Framework that will act as guidance to the National Framework. The following are set as applications of the three models (B, C and D) at the initiation stage. Model B is used in assessing BIM maturity or worldwide efforts. Model C is used to identify the market-specific diffusion dynamic, and model D is used to establish a policy approach to be taken by policymakers.

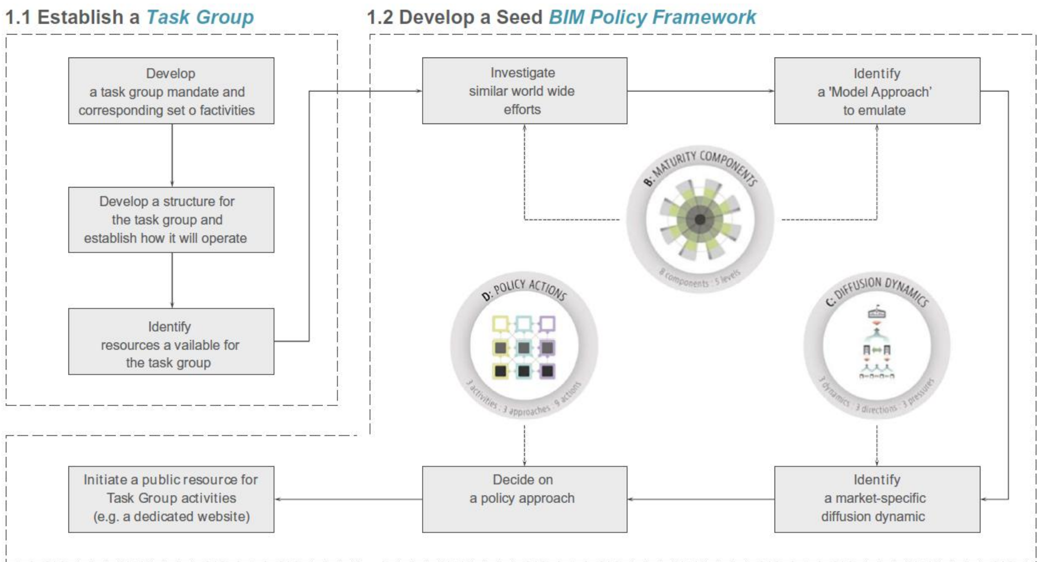


Figure 2.13: The Initiation Phase of the Policy Development Plan (Kassem and Succar 2017)

As illuminated by Figure 2.13, the task group targets the development of a seed BIM policy framework, where this aspect is considered to be achieved quantitatively. The framework development involves investigation into similar efforts around the world and identifies a suitable model approach to domesticate. Findings from the application of macro maturity components model on 21 countries suggest the UK's framework as the strongest (McAuley et al. 2018).

The consultation phase is explained as a stage where seed BIM framework is finally refined and transformed into a roadmap. The roadmap has a set of responsibilities that are assigned to selected stakeholders for action (Figure 2.14). Model E is then deployed with performance indicators and timeframes. The initial stage involves identifying experienced stakeholders and conducting face-to-face interviews as a replacement for the round-table discussions and workshops (Hore et al. 2017). As a result, the process aids the capturing of BIM adoption challenges and recommendation of the stakeholders. Thus, identifying the champions at the BIM implementation stage.

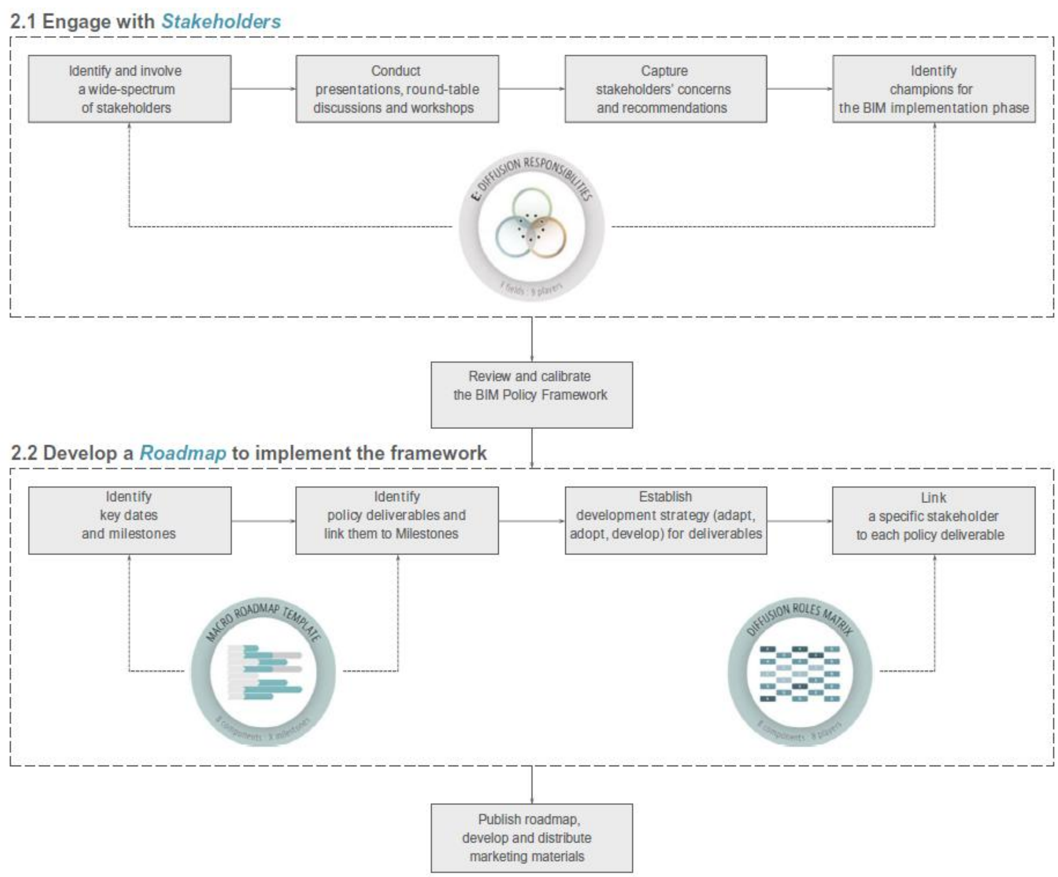


Figure 2.14: The Consultation Phase of the Policy Development Plan (Kassem and Succar 2017)

A roadmap is therefore designed with critical dates and milestones designated and linked to policy deliverables through a Macro Roadmap Template generated in 2017 and explained by Kassem and Succar (2017).

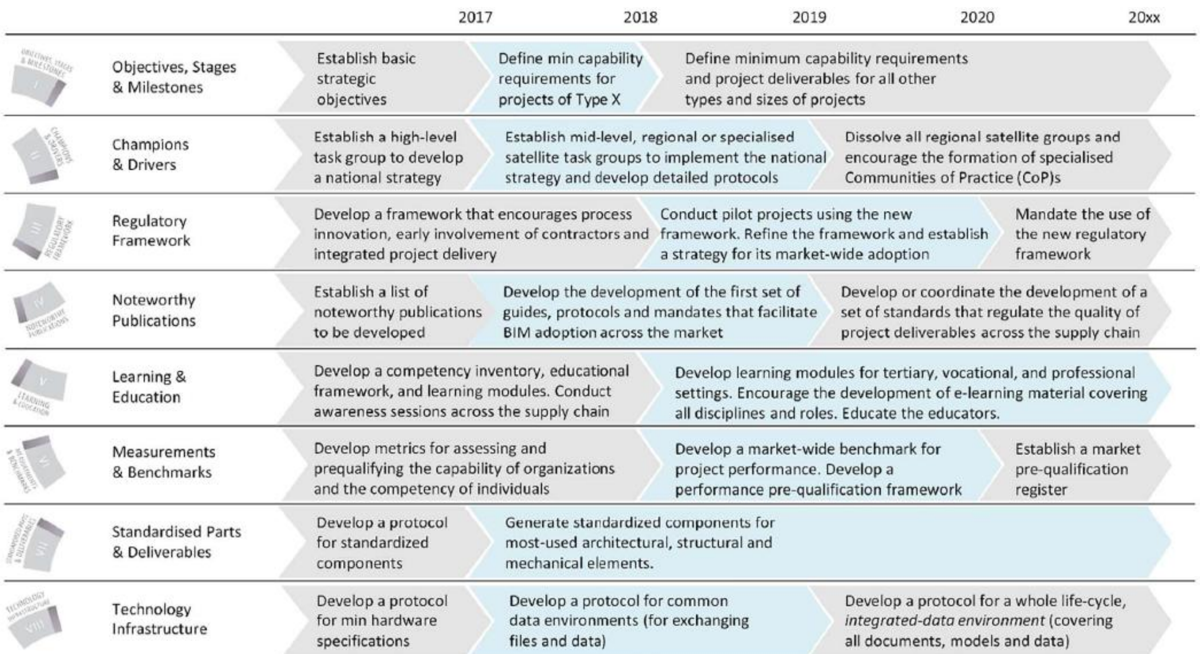


Figure 2.15: Template for developing a national BIM roadmap (Kassem and Succar 2017)

The Consultation Phase targets the industry stakeholders, communicating the mandate of the task group plus the seed BIM framework. The roadmap is developed from the refined seed BIM framework (Kassem and Succar 2017). Every item in the roadmap will be assigned to a stakeholder(s). A template for this is developed and presented in Figure 2.15. This template is not for market specifics, but a guide for any potential adopter country. Thus, development of the roadmap details is based on the country's readiness, level of maturity in all the three BIM fields (technology, process and policy).

2.7.1.7 Use of Macro-BIM Adoption Models

BIM is gradually becoming a norm in the built asset procurement, but its adoption around the world varies significantly. Government effort is playing a significant role in facilitating BIM adoption around the world. For example, UK, USA, Finland, Russia, Denmark, Singapore etc. are some case study countries where government involvement played a significant role in BIM adoption (McAuley et al. 2016; McAuley et al. 2017). Moreover, more countries are keying into this strategy, to mention but a few, such as Canada, Germany, Japan, Ireland, Qatar and Spain. Some of these countries used the developed macro-BIM adoption models to streamline or improve BIM adoption roadmap and guidance for the development of the BIM adoption policy, and such countries include Ireland and Brazil (McAuley et al. 2017; Kassem and Amorim 2015). Other countries that are currently utilising the macro-BIM adoption models include Spain, Canada, Russia, Brazil, Hong Kong etc.

The BIMMI within the macro BIM adoption study rating is utilised in the assessment of the maturity components. It has been considered due to its diversity of usage by several countries (Kassem and Succar 2017), and its ability to be extended for macro adoption planning, unlike other assessment metrics. For instance, the UK BIM maturity model has been developed to clearly define the expected competency level and the supporting standards and guidance notes (BIM Industry Working Group 2011). The model, however, does not provide the guide to develop a strategic framework for the macro BIM adoption.

The first part of the Initiation phase is the establishment of a task group; this includes the development of goals for the group and their corresponding objectives. Considering the Nigerian construction market, is there any organisation matching the responsibilities of the task group? In its absence, the establishment of a task group remains a prerequisite to further actions necessary for macro BIM adoption. Currently, there is no organisation (task group) taking similar responsibility in Nigeria. Thus, Nigeria requires the establishment of a task group if such a structure is to be considered.

2.7.2 Barriers and Drivers for BIM Adoption

BIM is similar to other technologies or innovations; it comes with challenges and barriers while in the adoption and implementation process (McAdam 2010). Barnes and Davies (2014) revealed the most perceived barriers against BIM adoption by organisations as an issue of readiness, high cost of training, and cost of technology investment (hardware and software). This readiness could be the ability to agreeing to change (awareness driven) or technology and workforce readiness. The construction industry is widely known to be conventional and resistive to changes (Walasek and Barszcz 2017); however, this new technological process has come to stay.

BIM is amongst the most discussed subjects in the AEC and perhaps the most discussed area of development in the AEC processes. There are colossal development, research and efforts to implementation of this new innovative process. Hjelseth (2017) compiled five years publications (2007-2017) from Automation in Construction in the BIM field, and his statistics revealed that most research (>70%) were done on the BIM interoperable technology perspective rather than the collaborative processes aspect. Thus, the study suggests more research on a collaborative process to increase awareness of real understanding and how BIM influences AEC activities. On the other hand, some studies lament the concentration of studies on the adopters and non-adopters, investigating the barriers and drivers, and developing models and frameworks (Hosseini et al. 2016). Despite that, there's still an irregularity in the BIM adoption and implementation across the globe (Johnson and Laepple 2003), s well as at different disciplines. Some countries are committed for the BIM implementation, but lack of guidelines hindered their full-blown implementation (Valappil and Saleeb 2016).

There are several investigations and studies on BIM development and usage around the globe. McAuley et al. (2016a) mapped the global overview of BIM adoption; Africa is the only continent that has not been inscribed with adoption value. This is attributed to a lack of clarity in the industry, lack of established studies and low level of the BIM adoption in the African countries. In this perspective, lessons were set to learn at the country level, especially their respective adoption trends. Several countries around the world have been striving to preserve the digital shift; for example, USA, UK, Australia, Singapore, South Korea, Denmark, Russia and Finland to mention but a few are the front runners (McAuley et al. 2016). Some bodies survey the BIM adoption and provide NBPs from many of these countries, to maintain guide and keep track of the BIM progresses. BIM Innovation Capability Programme (BICP) – Ireland; National BIM Reports by National Building Specifications – UK; NATSPEC – Australia; and SmartMarket Report by McGraw Hill Construction – USA are some of the bodies. For a comprehensive assessment of BIM adoption and its business value, McGraw Hill Construction remains the only source of NBPs (McAuley et al. 2016b).

In the recent academic discussion, there are several investigations on the social aspect of BIM adoption, such as readiness, awareness, level of adoption, capabilities (stages) as well as barriers and drivers toward the adoption and implementation

(Ademci and Gundes 2018). Such efforts (by countries and organisations) played a significant role in revolutionising the BIM adoption process (Mustaffa et al. 2017). Subsequent studies conducted regarding the challenges faced while adopting BIM were found to be continuous, starting with Walasek and Barszcz (2017) to Ademci and Gundes (2018), Sun et al. (2017) and Tan et al. (2019).

Wang (2015) also compiled and ranked some of the BIM adoption challenges faced by Mechanical, Electrical and Plumbing (MEP) firms in Nigeria. The study reveals that lack of technical expertise on BIM tools utilisation, lack of awareness of BIM technology as well as high cost of investment on staff training, process change, software and hardware upgrade were the most critical barriers. While Onungwa et al. (2017) study revealed that, lack of skilled personnel, lack of internet connectivity, and the reluctance of other stakeholders to use BIM, lack BIM object libraries and lack of awareness of the technology are the main barriers to BIM adoption. Albeit they citing lack of adequate support or motivation from leaders and political office holders and lack of trained personnel who are abreast of the latest development in technology as the earlier identified challenges, they also lamented the BIM knowledge gap where most Architects learn on the job as no training is mostly offered to them.

Eadie et al. (2014) worked on the identification of barriers to BIM adoption and their order of importance, this study reveals so much to the UK BIM adoption strategy and more importantly directing to the most significant obstacles as to allow adopters pay more attention to them. However, resolving one or more barriers without resolving all will not bring the end to challenges on BIM adoption (Lindblad 2013). Some studies from Nigeria reveal some barriers to adopting BIM (Wang 2015; Onungwa et al. 2017), but not to common professionals or wide market (macro scale).

In NBS report (2018), barriers to BIM adoption are named under two umbrellas, internal (i.e. lack of training, expertise and funds to invest) and external (i.e. lack of client demand and lack of big projects that require BIM). The most recent compiled barriers by Ademci and Gundes (2018) were grouped into five categories; these include personal, legal, management, cost and technical for convenience in the analysis (Sun et al. 2017). Twenty-two compiled BIM adoption barriers were extracted from 62 publications. Table 1 of Sun et al. (2017) [p. 768-770] presents the summary of the barriers; however, that does not necessarily apply to the entire professional fields, organisations and even countries as common. For example, UK reported 18 barriers in their continuous BIM assessment survey (NBS 2018, p. 35), and these barriers are not exactly as those extracted by Sun, Jiang et al. (2017) or those in Wang (2015). However, there are several similarities and common terms across the lists. For example, Khosrowshahi and Arayici (2012) reported many barriers to adoption of BIM across the UK and assert that the barriers are commonly on organisational readiness. Table 2.2 summarises the compiled potential barriers to BIM adoption in Nigeria.

Table 2.2: Barriers to BIM adoption (Compiled by the Author)

S/No.	Barriers to BIM adoption	Reference
1	Lack of expertise within the organisations	Arayici et al. 2009; Yan and Damian 2008; Aouad et al. 2006; Wang et al. 2015; Tan et al. 2019; Jamal et al. 2019; Saleh 2015; Lindblad 2013
2	Lack of expertise within the project Team	Wang et al. 2015; Tan et al. 2019; Jamal et al. 2019; Saleh 2015
3	Lack of standardisation and protocols	Wang et al. 2015; Tan et al. 2019; Jamal et al. 2019; BCIS 2011
4	Lack of collaboration among stakeholders	Wang et al. 2015; Tan et al. 2019; BCIS 2011
5	High Investment Cost	Yan and Damian 2008; Coates et al. 2010; Azhar 2011; Crotty 2012; Efficiency and Reform Group 2011; Thompson and Miner 2010; Giel et al. 2010; Lee et al. 2012
6	Legal issues around ownership, IP & PI insurance	Udom 2009; Oluwole 2011; Christensen et al. 2007; Race 2012; UK BIM Industry Working Group 2011; Chao-Duivis 2009; Furneaux and Kivvits 2008; Jamal et al. 2019; Azhar 2011; Arayici et al. 2009
7	Lack of client demand	Wang et al. 2015; Jamal et al. 2019; Saleh 2015; BCIS 2011; Zuhairi et al. 2014
8	Lack of infrastructure	Wang et al. 2015
9	Lack of government policy	Wang et al. 2015
10	Industry's Cultural resistance	Yan and Damian 2008; Rowlinson et al. 2009; Jordani 2008; Mihindu and Arayici 2008; Watson 2010; Arayici et al. 2011
11	Lack of additional project finance to support BIM	Jamal et al. 2019; Arayici et al. 2009
12	Resistance at the operational level	Jamal et al. 2019.
13	The reluctance of team members to share information	Arayici et al. 2009; Yan and Damian 2008; Wang et al. 2015
14	Return on Investment (ROI) issue	Arayici et al. 2011; Lee et al. 2012; Coates et al. 2010

Lack of expertise, training and cost are consistently remaining amongst the major barriers to BIM adoption across most countries. These challenges have been there for more than a decade (Johnson and Laepple 2003). Countries like the UK (NBS 2018; Richard 2017; NBS 2013), Malaysia (Jamal et al. 2019) and Nigeria (Wang 2015;

Onungwa et al. 2017; Abubakar et al. 2014) are examples of these countries. In the UK, the lack of expertise in the industry is attributed to the underperformance of its Higher Education Institutions (HEIs); and its low level of engagement with the industry (Underwood et al. 2015). While in the Nigerian HEIs, students are generally trained on 'file-based collaboration' – 2D and 3D CAD and HEIs are not technically ready to offer BIM training (Hamma-Adama et al. 2018).

Table 2.3: Drivers to BIM adoption (Compiled by Author)

S/No.	Drivers to BIM adoption	Reference
1	Availability of trained professionals to handle the tools	McDonald 2012; Badrinath et al. 2016; Saleh 2015; Kiani et al. 2015
2	BIM Software affordability	Macdonald 2012; Eadie et al. 2013; Oladapo 2007
3	Enabling environment within the industry	Oladapo 2007; Takim et al. 2013
4	Clients' interest in the use of BIM in their projects	Liu et al. 2010; Eadie et al. 2013; Saleh 2015; Lee and Yu 2013; BCIS 2011; Takim et al. 2013
5	Awareness of the technology among industry stakeholders	Oladapo 2007; Saleh 2015; Zikic 2009
6	Cooperation and commitment of professional societies to its implementation	Oladapo 2007; Becerik-Gerber et al. 2011
7	Proof of cost savings by its adoption	Demirdoven 2015; Saleh 2015; Eadie et al. 2013; Newton and Chileshe 2012
8	Cultural change among industry stakeholders	Saleh 2015; Kiani et al. 2015
9	Government support through legislation	Efficiency and Reform Group 2011; buildingSMART Australasia 2012; Eadie et al. 2013; Saleh 2015; Kiani et al. 2015; Zuhairi et al. 2014
10	Collaborative Procurement methods	Sinclair 2012

The drivers to adopt innovation are merely the facilitators to adopt a new product or process (Saleh 2015). The facilitators are the enablers, as resolving the barriers eases the innovation adoption and the same way that the drivers support the adoption process. Potential drivers mostly fall under empowerment, leadership, and creative culture; and most barriers are interlinked with drivers. In most cases, removing a barrier is creating motivator or motivating to adopt. For instance, solving challenges like lack of experts/trained-personnel on BIM means providing training on BIM usage. Table 2.3 summarises some potential drivers from previous studies.

2.8 BIM ADOPTION PROCESS AND EFFORTS BY THREE CASE STUDIES COUNTRIES

In about a decade, case studies and academic literature revealed some developed countries leading the development and implementation of BIM. The USA, UK and Australia are the developed countries where BIM development and adoption is significantly high, and are resulting in the BIM adoption drive. These three countries are playing a significant role in the BIM implementation at the world stage. This section presents a case study based on secondary data generated from noteworthy BIM publications within selected countries. The USA, UK and Australia are chosen as case study countries for this comparative analysis due to their similarity in construction culture, and their advanced framework for managing construction using BIM. More to their BIM participation at the world stage, availability of national BIM adoption surveys as well as Noteworthy BIM Publications (NBPs) (Kassem et al. 2013). Moreover, these countries have highly established processes, standards and guidelines for BIM adoption and public availability of data for assessment as well (Hill 2014; Construction 2012; Kassem et al. 2013).

The USA and the UK are considered as the leading BIM implementing countries in the world; while Australia is one of the adopter countries whose rapid performance is outperforming the more established countries in terms of BIM guide, Standards, National Specification and corporate research centre (Smith 2014b). Thus, these countries are selected for the comparative case analysis.

A collaborative contracting approach within the USA, UK and Australian construction industries has been well established, and there is substantial literature that set out to demonstrate their main principles, practices and benefits (Kassem et al. 2013; Succar and Kassem 2016). These case study countries have diverse diffusion dynamics and policies associated with their BIM adoption. The diffusion dynamic does not remain constant; it changes from one directional-pressure to another, which depends on who is leading the adoption at a time. For example, the USA was initially middle-out dynamic, but subsequently changing to top-down due to state governments' involvement and the UK was initially bottom-up dynamic but later changed to top-down due to government involvement as well.

2.8.1 Comparative Analysis of BIM Adoption Efforts by Developed Countries as Precedent

This section involves a comparative analysis based on secondary information generated from Noteworthy BIM Publications (NBPs) from within the three case study countries (UK, US, and Australia), to study their BIM development and adoption frameworks for potential contextualisation. The UK, USA and Australia were selected as case study countries due to their construction culture similarity, the similarity in technologies and terminology, availability of national BIM adoption survey as well as NBPs (Kassem et al. 2013). And, their BIM participation at the world stage, i.e. based on BIM leadership (Edirisinghe and London 2015). The comparative analysis was introduced to scrutinise the three case study countries' BIM adoption efforts through the following contents:

- Reasons behind BIM adoption, and the adoption process;
- Structure of the industry vis a vis digitalisation;
- Origin and the method of adoption;
- Enforcement strategy, and Resistance;
- Legislation, Standards, and Guide;
- Technology (infrastructure, manpower and access);
- Education, Training, and Research;
- Success, Challenges, and Return on Investment (ROI).

Building Information Modelling (BIM) adoption is generally assessed through one of the following approaches, a quantitative or qualitative evaluation of surveys and interviews from stakeholders operating within a country or market (refer to Table 2.1) and the use of macro BIM adoption models and metrics (Succar and Kassem 2017). The recent paper "macro-BIM adoption: Comparative market analysis" sets a pace to continuous development of comparative market studies. However, setting a precedent is necessary for constant learning and contextualisation of adoption in BIM evolving fields. A precedent was established through a comparative analysis of BIM adoption trends in the USA, UK and Australia to set a pace for beginners or early BIM adopting countries to learn. This comparative analysis is literature-based, analysed using content analysis. The study collectively reveals the following:

- For a vibrant and even BIM adoption, the government is involved;
- Government mandate facilitates wide BIM adoption and integrates a country's industry to the world;
- The mandate also facilitates BIM research and training that lead to a rise in the country's income by providing pieces of training and workforce export;
- Diffusion dynamic varies at different times, depending on the country's flexibility to the adoption of innovation;
- The dynamic also changes as the industry's culture/regulation changes.

Recommendations are made based on the study findings, especially to the new adopter countries planning to develop a strategy for macro-BIM adoption.

2.8.1.1 Method of Content Analysis

This section adopted comparative analysis as to the categorisation of countries' efforts toward the development, adoption and implementation of BIM. Thus, initiatives, as well as factors that motivated BIM adoption in these countries, were categorised. Reviewed literature used were generated from the various studies under section 2.8 (2.8.1.2, 2.8.1.3, and 2.8.1.4). The comparison aimed to determine the countries' common efforts and otherwise for potential applications in a context where necessary.

2.8.1.2 The United States of America BIM Framework

The General Services Administration (GSA) in the USA launched a national 3D-4D BIM policy program in 2003. This came up in the effort of the government in promoting a digital transition in the construction industry. The policy program objectives were to:

- Establish a policy to additionally adopt 3D, 4D and BIM for all major projects
- Lead 3D-4D-BIM pilot applications and incentives for current and future capital

projects.

- Provide expert support and assessment for ongoing capital projects to incorporate 3D, 4D and BIM technologies
- Assess industry readiness and its technology maturity
- Partner with BIM vendors, professional associations, open standard organisations and academic/research institutions.
- And subsequently, BIM usage was mandated in 2007; the GSA requested the use of the BIM process in all new projects (Wong et al. 2011).

The USA Construction Industry has the following key stakeholders: Architects, Engineers, MEP, contractors, sub-contractors and clients. Architects appear to be a driving force for the adoption of innovation within the USA AEC industry. This can be observed from the nomenclature given to the head of GSA "Chief Architect," Public Buildings Service. Architects have been utilising BIM tools and processes before the 2003 GSA policy.

The digitalisation in the USA AEC industry started since the 1990s with the establishment of the International Alliance for Interoperability (IAI) and later changed to buildingSMART (Edirisinghe and London 2015); while the National BIM policy and mandate were introduced in 2003 and 2007 respectively. The industry in the USA has been operating innovatively. Architects derive the use of Integrated Project Delivery (IPD) and further to BIM utilisation. The American Institute of Architects were actively utilising the BIM concept; thus, that facilitates the central government involvement. The government subsequently legislated it in 2007. The BIM diffusion mechanism in the USA market appears "middle-out" (Kassem and Succar 2017, pp.292) although before then, a sign of "top-down" approach due to the government agencies and large clients' involvement was experienced (Kassem et al. 2014).

The increase in BIM implementation within the USA has been driven by the state governments' mandates (Smith 2014). Contractors reported important realisation of benefits of using BIM concept (Construction 2014); likewise, the rapid rate of adoption was due to the fear of being left behind if one refuses to embrace the BIM revolution. Having the industry relatively developed (driven by the American Institute of Architects) before the governments' policies, it was a bit easier towards a development and enforcement process. The BIM development in the USA was considered a middle-out diffusion dynamic (Kassem et al. 2013) as a result of large organisations and industry associates (i.e. AIA) involvement.

Considering the United States as the first country to adopt BIM, the adoption process was slow and occasionally painful. Still, the USA endured learning from those challenges they faced, building better solutions at the end. Nations that were slower to adopt BIM were able to avoid some of those issues encountered by the USA, hence having a quicker and more efficient process. That has also resulted in some countries having either wedged or even exceeded the USA in BIM utilisation or standardisation (i.e. the United Kingdom).

The utilisation of BIM in the USA lacks a unified national standard for project delivery. Absence of this standard is providing open-deliverables that become dependent on a client-to-client or even project-to-project basis. Various government departments in the USA are producing their standards (independently created) and publishing them in places like the National Institute of Building Sciences (NIBS). These are separately used on projects without connectivity. Some may see this as an opportunity to develop new ideas. For example, Steve Jones, Senior Director of Dodge Data & Analytics see this as a good thing, believing that it would allow fresh ideas to 'problem-solving' contrary to other parts of the world where government standards limit new ideas (Jones et al. 2017). Furthermore, key findings of a recent Dodge Data and Analytics survey on contractors demonstrated an increase ROI from BIM utilisation. Amongst the proclaimed successes include the following:

"A 5% reduction in the final construction costs, a 5% increase in the speed of completion, a 25% improvement in labour productivity, and a 25% reduction in labour" (Analytics 2015).

The policy is seen to have played a role in speedy BIM adoption at the design stage, most importantly the Architects; thus, Architects were found to be championing postpolicy BIM adoption in the USA, while clients lagged (Edirisinghe and London 2015). Notwithstanding, USA contractors are also very advanced in BIM implementation against others around the world (Construction 2014). On the contrary, owners are still the laggards despite the well-established record of BIM in the USA construction industry.

The initiated National 3D-4D BIM Program by the US General Services Administration (GSA) through the office of the chief architect, public building services came immediately after the Autodesk acquired Revit Technology Corporation (2002). Subsequently, the BIM technologies adoption began to spread across the USA; BIM is set as a requirement in all final concept approval for all major projects in 2007. The 3D, 4D, and BIM technology deployment were encouraged in all GSA projects and supported by GSA BIM Guide Series. Two years after the release of BIM Guide Series (2009), BIM adoption almost doubled from the start-up (28%) in 2007. NIBS published many National Building Information Modelling Standards (NBIMS) and specifically on building energy performance (Edirisinghe and London 2015).

The USA is considered as a hub for technology development, the availability and affordability of technology made the USA public and even private sector top in the world. That is what brings about competition and enormous growth in all sectors. Availability of technology infrastructure facilitated a quick development, adoption and implementation of BIM within the industry even before the government mandate in 2007 (Mustaffa et al. 2017). Figure 2.16 presents process toward BIM adoption in the USA.

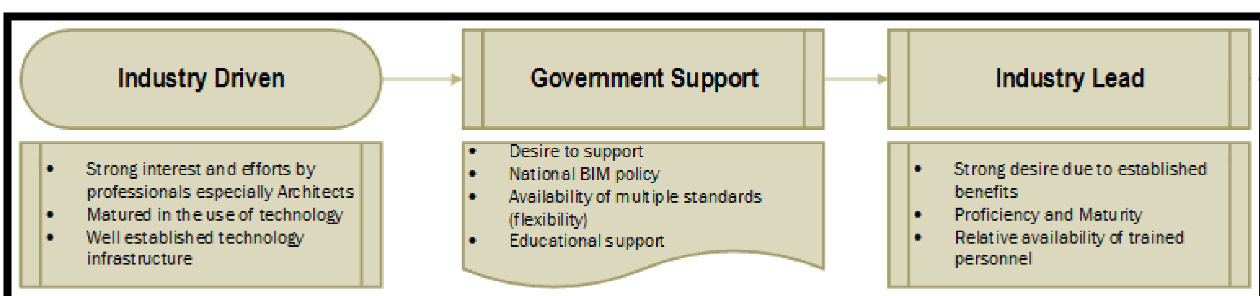


Figure 2.16: The USA process of BIM adoption (Author generated)

BIM education in the USA began since 2002 when many countries have not built up their awareness at the level of the industry. Morse (2009) carried out a BIM teaching survey on USA Academic Institutions, and the result indicated that 82% are providing formal teaching in BIM (Morse 2009). As for research, there is an effort by the GSA, GSA collaborates with International Real Estate Organisations, CAD/BIM Technology Centre and Construction Engineering Research Laboratory to support open standards and guide for BIM software and system in the USA.

2.8.1.3 The United Kingdom BIM Adoption Framework

The United Kingdom (UK) government developed a Task Group to support and assist both government clients and supply-chain contractors in transitioning their work practices to BIM and electronic delivery, as part of an overall digital economy (digital Britain). The overall goal of the strategy is to improve the performance of government estate in terms of reduction in capital costs and carbon performance. Besides, targets to become a BIM world leader (BIM Industry Working Group 2011).

Construction industry comprises of the following key stakeholders: Architects, Engineers, MEP, contractors, sub-contractors and the clients. In the UK, clients are considered as a driving force in the industry. Before the recent development in the industry, clients are discrete and vary greatly; Latham (1994) reveals that individual Government Departments were operating different procurement practices (Latham 1994). Moreover, contracts were mostly running under traditional form involving Standard Forms such as JCT 80 or ICE 5th/6th who are considered unsuitable for collaborative working.

Five different contract strategies are the conventional practice contracts within the UK construction industry; these are: traditional, construction management, management contracting, manage & design, and design & build arrangements. The digital transformation strategy has however favoured one contract over another, and this strategy has a target to achieve this transformation through encouraging the growth of new digital businesses or helping traditional businesses to transform into a digitally-enabled one (Shayesteh 2015).

Bew and Richards (2008) developed a BIM maturity wedge in 2008. The maturity nomenclature starts with level 0 (paper-based) to level 3 (integrated web-based). The most popular amongst these maturity levels is BIM level 2. The British Standards

Institution (BSI) describes BIM Level 2 maturity as a series of domain and collaborative federated models; different parties prepare the models, consisting of both 3D geometrical and non-graphical data, during the project life-cycle within the context of a shared data environment. BIM is highly publicised in the UK due to government interest and involvement. The UK government mandate on all central projects above £5m to be BIM level 2 enabled by 2016 was a long leap taken in 2011. However, 2017 NBS report revealed 62% BIM usage in the UK (Richard 2017). The UK government policy for the 2016 BIM level-2 mandate was a driver for quick uptake of BIM in the UK. A significant development was recorded (from 31% to 62%) within the five years ahead of the mandate deadline (2016). It was noticed that the government policy accelerated the adoption, portraying a clear "top-down" diffusion dynamic (Succar, Kassem 2015) which is now the dominant UK BIM adoption strategy as reported in the report of government construction client group (2011). On a further discovery, the approach subsequently changed (to middle-out) due to higher adoption by bigger companies hence becoming the leaders to moving the adoption further.

BIM implementation strategy in the UK is a "Push-Pull" type where the "Push" is the five years horizon given to the supply side of the industry to having all the players attained BIM level 2. While, the balance "Pull" comes from the client-side to specify, collect and use the generated information (BIM Industry Working Group 2011).

Availability of Noteworthy BIM Publication to achieving the 2016 mandate played a significant role in speeding BIM involvement by owners (Edirisinghe and London 2015). Despite the government mandate, the technical shift encountered some challenges, such as, resistance to changes, lack of experts, investment cost, and feeling at risk of starting something new (Richard 2017). Moreover, Dainty et al. (2017) reported lack of spelt out opportunities in the UK policy on BIM adoption as a barrier to its adoption.

On the other hand, the targeted benefit of this digital shift is to achieve improved efficiency, reduction in total life cost assets, reduction of carbon footprint and capability of construction information storage and management. The investment benefits are somewhat not limited to the above benefits but, extend to a long-term plan of selling expertise and cutting-edge technologies across the world and seize a share of the $15trillion global construction market forecast by 2025 (Shayesteh 2015). Tremendous achievements were recorded in the UK construction industry in terms of BIM adoption benefits. For instance, the construction cost savings of £804m (in 2013/2014) announced by the Cabinet Office was significantly contributed by the adoption of BIM (Shayesteh 2015).

The legislation is introduced to facilitate the BIM adoption; a time horizon was established together with milestones. The British Standards Institute created an information-sharing standard called PAS 1192:2 to delineate a workable explanation of the vital exchange points between client and supply chain at different stages of a building project, specifically on BIM Level 2 technology compliance. The BIM Level 2 suite of documents has been developed to help the Construction industry adopt BIM Level 2. The documents are reviewed periodically to meet the requirements and needs of the industry. The following sets of standards are a trend from where BIM standards begin and continuously developed:

- BS 1192:2007+A2:2016: Collaborative production of architectural, engineering and construction information
- PAS 1192-2:2013: Specification for information management for the capital/delivery phase of construction projects using building information modelling
- PAS 1192-3:2014: Specification for information management for the operational period of assets using building information modelling
- BS 1192-4:2014: Collaborative production of information. Fulfilling employer's information exchange requirements using COBie
- PAS 1192-5:2015: Specification for security-minded building information modelling, digital built environments and smart asset management
- BS 8536-1:2015: Briefing for design and construction. Code of practice for facilities management (Buildings infrastructure)
- PAS 1192-6:2018: Specification for collaborative sharing and use of structured

Health and Safety information using BIM.

Following the recommendation of BIM level 2 as standard practice from 2016 and the establishment of the BIM level-2 mandate, the BIM Industry Working Group (2011) recommends a collaborative form of contract (i.e. NEC), guideline and protocols to avoid ownership and responsibilities issues. Upon all these, the group did not perceive copyright and IP issues as significant to act as barriers to BIM adoption (Jones et al. 2017).

The technology infrastructure supporting this digital process is not a big issue in the UK has transformed the publishing, retailing, financial and travel services in the same way (Shayesteh 2015); the same applied to the technology accessibility. This kind of system has been in use within the UK public sector, such as planning portal, OCG procurement systems and paperless open borders systems; these were deployed for more than a decade ago (BIM Industry Working Group 2011).

Despite the government efforts, however, the digitalisation process faces numerous challenges, rating the top barrier amongst which is a shortage of BIM technology experts (Richard 2017). That has come despite various efforts to benefit from the UK educational programs like BIM for education, BIM for SMEs etc. Upon these, education and training are still lagging; and the main drivers in academia are the individual academics and or departments that particularly have interest (Rooney 2015). Underwood et al. (2015) described Architecture and Construction related subjects as dominants to incorporating BIM in their teaching. However, the rest of the built environment-related disciplines are low interested parties. Architectural schools are ahead of all other built environment disciplines on BIM education.

The industry and educational institutions are dominated with the following BIM software: Autodesk Revit (Arch, Struct, MEP), Navisworks and Sketch Up. Furthermore, in the whole Built Environment disciplines, there are generally low levels for BIM maturity awareness; hence, higher education institutions (HEIs) were mostly underperforming (Underwood et al. 2015). That is what attributed to the lack of BIM expertise in the UK construction industry. Consequently, this high level of detachment has been an obstacle to the full implementation of BIM in the UK. Figure 2.17 presents efforts/process toward BIM adoption in the UK.

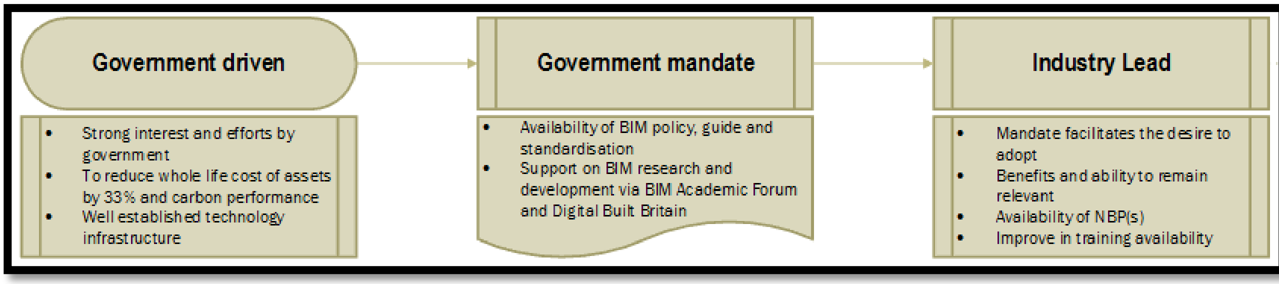


Figure 2.17: The UK process of BIM adoption (Author generated)

BIM Academic Forum (BAF) was established in late 2011 with the mission to develop and promote teaching and learning with the research aspect of BIM through cooperation and collaboration. Many UK universities are represented in the forum, which serves as a conduit between industry's needs and BIM training within the higher educational institutions. Succinctly, the forum is to promote the academic prospect of BIM in the UK (Underwood et al. 2015). This has furthermore increase BIM awareness, facilitates research and development in the area of BIM adoption and implementation that lead to the development of several NBPs. Other organisations/ professional societies that promote BIM training through short courses programmes include:

- Institute of Civil Engineers (ICE),
- Building Design (BD),
- Construction Industry Training Board (CITB),
- Building Research Establishment (BRE), and
- Building Services Research and Information Association (BSRIA).

BRE (2016) discovered only about 10% of those who got trained on BIM go for training or getting taught in Universities and colleges while the remaining 90% got trained from other places (i.e. training providers, software vendors etc.). Thus, higher education institutions are not producing sufficient BIM skilled candidates as needed by the industry. SMEs occupy 98% of the construction sector in the UK (Shelton et al. 2016), and lack of BIM trained personnel is mostly affecting the SMEs in the adoption process. That is also coupled with a lack of funds to train their employee, and this suggests SMEs as the immensely beneficiary of 'BIM ready' graduates from higher education institutions.

2.8.1.4 The Australia BIM Framework

To increase the productivity of asset management in the built industry, the National Building Information Modelling Working Party was established to report to the Built Environment Industry Innovation Council (BEIIC) on BIM activities. NATSPEC (National Specification) National BIM guide is a body under NATSPEC Construction Information maintained by the government and the industry that was developed in 2011 to establish a standardised practice for digital building information exchange in Australia. These include documents for guides to BIM implementation on projects, open BIM object standard (OBOS) and object properties standardisation tool (NATSPEC 2012). The National policies and standards played an essential role in the Australian construction industry for their vibrant BIM adoption.

During a series of buildingSMART MESH conferences in early 2011 sequel to the suggestion from the productivity in the Buildings Network report, the buildingSMART Australia held a stakeholder's consultation workshops in early 2012 across Australia. The workshop recommends the need for national action on some identified areas as a matter of priority to facilitate BIM adoption in the Australian construction industry. Seven key areas of priority were considered, these are:

- Procurement contracts that support collaborative BIM processes
- BIM Guidelines
- BIM Education
- Product Data and BIM Libraries
- Process and Data Exchange protocols
- Regulatory Frameworks
- Pilot Projects (Australasia 2012).

The Australian construction industry stakeholders recommended contract that supports the collaborative working process. However, there is still no published contract form incorporating the BIM process in the Australian market other than a bespoke agreement which is conventionally adopted even at the highest of the most broadly used levels of BIM (level 2) (Mustaffa et al. 2017).

Subsequently, ACIF-APPC BIM framework was released in 2014 (Edirisinghe and London 2015), and the New South Wales' Health mandates BIM deliverables on all projects over $30 million (McAuley et al. 2017). This action significantly raised the BIM adoption level in Australia, although there is still no BIM mandate at central government level. Thus, the New South Wales' Health BIM mandate inscribed Australia as a country with a "restricted mandate" (McAuley et al. 2017). Succinctly, the Australian government did not mandate BIM on public projects (Reza et al. 2018) as such the government and non-profit organisations help in providing a levelled ground (guide) but did not impose BIM on public projects.

Australia appears to have an industry-driven BIM adoption. Albeit there are recommendations by the Australian construction industry stakeholders to mandate BIM, so much heated scrutiny on the plan. However, the Australian government did not mandate BIM on public projects (Reza et al. 2018).

The essential resources gap between SMEs and large companies is the soul challenge to mandating the utilisation of the country's BIM framework. Consequently, the top-down BIM diffusion mechanism will appear extreme (Succar and Kassem 2015) within the country's construction market.

Hosseini et al. (2016) study reveal a fear of 'risk' associated with ROI on BIM as a significant barrier to BIM adoption by Australian SMEs, replacing the previously known 'lack of experts and knowledge on the innovation' as the significant barriers. Thus, 'Pilot Projects' is recommended in the report of DIISRTE and such can go a long way to clearing the ROI issue and remove that as a barrier.

The Australian Institute of Architecture (AIA) and Consult Australia established an industry-academia BIM working group in 2011; it was on this basis that a foundation was set with a series of Noteworthy publications in 2012. The Australian Government

Office for Learning and Teaching (OLT) supported a project on BIM technologies known as 'collaborative design education - CODE BIM' that engages three universities (the University of South Australia, University of Newcastle and University of Technology Sydney). A developed complementary framework is now out to help Academics to implement BIM training. On the other hand, poor implementation of BIM education was mainly associated with curriculum issues, cultural resistance (afraid of trying new things) and class size (population) (Rooney 2015).

Subsequently, a joint research centre for BIM was formed for sharing knowledge amongst researchers, engineers and innovators achievable through collaboration between Huazhong University of Science and Technology and Curtin University. Furthermore, the buildingSMART's BIM initiative in moving the industry forward is a strong desire to a 'multi-disciplinary BIM education'. Figure 2.18 presents efforts/process toward the BIM adoption in the Australian AEC industry.

Figure 2.18: The Australia process to BIM adoption (Author generated)

Despite the provision of BIM training by the higher institution within the countries where BIM is dynamic, the training moves at a slow pace (Rooney 2015). The slow pace of BIM training is due to challenges in terms of overcrowded modules (as no space to introduce new ones) as well as remodelling of the lecture-based modules to smaller multi-disciplinary teamwork-based modules.

2.8.2 Discussions

Table 2.4 presents each country's framework concerning different sections of BIM fields (Process, Technology and Policy). In contrast, Table 2.5 shows the BIM Adoption guide and standards developed by the selected case study countries. There is a commonality between countries in the availability of BIM technology (Kassem et al. 2013); therefore, the categorisation will instead focus more on the technology infrastructure and training in the technology field. On the contrary, policy and process fields differ amongst countries and require contextualisation.

Table 2.4: Categorisation of efforts by the USA, UK, and Australia in adopting BIM concept (Compiled by the Author)

	BIM Field Type	United States of America	United Kingdom	Australia
Reason for BIM adoption	**Process**	To improve the productivity and performance of the government-built asset.	To improve the performance of the government estate in terms of reducing capital costs and carbon performance. "*Government has the vision to reduce whole life costs of assets by 33% by 2025"*	The initiative aimed to increase productivity and improved asset management in the built industry. Value for money, procurement transparency and emission reduction (buildingSMART 2016)
Digitalisation	**Technology**	Digitalisation started in the USA since the 1990s with the establishment International Alliance for Interoperability (IAI) and later changed to buildingSMART (Edirisinghe and London 2015); while National BIM policy and mandate were introduced in 2003 and 2007 respectively.	The UK has successfully transformed its publishing, retailing, financial and travel services (Shayesteh 2015); thus, the technology for digitalisation is available and open to the construction industry. These kinds of system have been in use within the UK public sector for over a decade, such as planning portal, OCG procurement systems and paperless open borders systems (BIM Industry Working Group 2011). However, the industry's digitalisation big challenge is the shortage of BIM technology experts (Richard 2017).	Construction is one of the sectors where Australia led in physical capital investment in the year 2010 (Organization for Economic Cooperation and Development, OECD 2013); this may be attributed to its significant lags in knowledge capital investment (Lev, 2001). However, with a clear record of capital investment in engineering and some sectors, Australia is considered medium amongst its counterpart in innovation (pwc 2014).
BIM Initiation and Adoption Method	**Policy/Process**	BIM adoption in the USA started as a middle-out diffusion process, driven by Architects. BIM adoption initiated by Architects and then followed by the US government initiatives for the BIM technology deployment and Building Energy Performance (BEP). The BIM diffusion in the USA market is changing from **Middle-Out** dynamic to the Top-Down approach.	BIM adoption in the UK started as a bottom-up diffusion process, driven by designers. The UK government-initiated BIM adoption journey back in 2010; and the subsequent release of the BIM level 2 mandate (in 2011) on all public projects by 2016. The BIM diffusion dynamic within the UK market has changed from Bottom-Up to **Top-Down** dynamic and now changing to Middle-Out.	BIM is being move by both the government and industry stakeholder; the move is in collaboration between the government and non-profit organisations through the development of national specification (NATSPEC) in 2011 and the subsequent released of first BIM framework in 2014 by ACIF-APPC. No mandate in general, however there is a restricted one from New South Wales' Health on project in excess of $30 million and the effort by Australian Department of Defence as well. The BIM diffusion dynamic in the Australian market is currently **Bottom-Up**

				diffusion dynamic.
Development and Challenges	**Process**	BIM started developing from professionals in the industry and the states before the federal government. The industry is facing challenges of regulation and standards where multiple agencies having their own rules and requirements.	The BIM development in UK is an exclusive commitment of the UK government. An extension to the digitalisation process of the country's systems. Absence of defined opportunities of adoption of BIM in the UK policy is one of the considered a barrier to its adoption (Dainty et al. 2017). Moreover, lack of clear understanding of BIM by clients and BIM experts' deficit were amongst persistent challenges of BIM utilisation.	buildingSMART Australia was the motivator, buildingSMART organised a workshop for the industry stakeholders to accelerate the BIM adoption in Australian AEC market. Standards and guides were developed and available for use. However, there is significantly low adoption by SMEs who are about 98% of the construction sector and more than 70% of them are non-adopters (Dainty et al. 2017). Mostly due to lack of investment cost and lack of evident ROI.
Policy Initiative and Standardisation	**Policy**	National 3D-4D BIM policy program was initiated in 2003, and mandated on government projects in 2007. There are standards published by the National Institute of Building Sciences (NIBS). Various government departments are producing standards and publishing them in NIBS, and these are independently used on projects – opened BIM standard. Thus, no unified standard adopted and imposed at national level.	There is comprehensive government policy; mandate released in 2011 to be complied in 2016 for all public projects in excess of £5m. UK is widely recognised as a world leader in BIM standards and guide. In 2007, BSI, together with business organisations, researchers and industry bodies embarked on the development of BIM standards as well as necessary guidance for implementing the BIM (Richard 2017). These include the following development: BS 1192:2007+A2:2016; PAS 1192-2:2013 PAS 1192-3:2014; BS 1192-4:2014 PAS 1192-5:2015; BS 8536-1:2015 and PAS 1192-6:2018.	The Australian BIM initiative lack policy backing for now as there is a heating scrutiny on plans to pursuing a BIM mandate (Hosseini et al 2018). National BIM guide was first published in 2011, reviewed and reconfirmed in 2016 based on NATSPEC construction information. There are also standards for all the professional parties including the client (NATSPEC construction information). buildingSMART Australia committed to ensuring the development of some specifications like: IFC (ISOPAS 16739), IFD (ISO 12006-3:2007) and IDM (ISO/DIS 29481-1).
Technology (Infrastructure, man-power and accessibility)	**Technology**	USA may be considered as a centre for Technology development; the availability and affordability of technology made their public and even private sector top in the world. This is what brings about competitiveness and enormous development in all sectors. The availability of technology infrastructure is moreover facilitated a quick	The technology infrastructure supporting digital processes is readily available in the UK; having digitally transformed many sectors of the economy and services (Shayesteh 2015). The technology infrastructure and their accessibility are magnificent for usage; without doubt, '*UK continues to be an innovative developer and adopter of*	Australia is considered medium amongst its counterpart in innovation (pwc 2014). There was a great move in BIM technology accessibility and its development by buildingSMART. "Open BIM Alliance of Australia" was established by buildingSMART and is amongst its great roles that brings alliance with software vendors who promoted "Open BIM"

		development, adoption and implementation of BIM within the industry even before the government mandate in 2007 (Mustaffa, Salleh et al. 2017).	*technology*' (Richard 2017). These kinds of system have been in use within UK public sector, such as planning portal, OCG procurement systems and paperless open borders systems were since deployed (for more than a decade) (BIM Industry Working Group 2011). However, in construction industry digitalisation process, deficit of BIM technology experts is considered amongst the barriers to the speedy adoption BIM (Richard 2017).	concept (Smith 2014a).
Education, Training and Research	**Policy**	Educating students on BIM in the US began since 2002 when many countries hasn't built up awareness on BIM even at industry level. Morses (2009) carried out a survey on USA Academic Institutions that indicated 82% providing formal teaching in BIM. As for researching, GSA collaborates with International Real Estate Organisations, CAD/BIM Technology Centre and Construction Engineering Research Laboratory to support open standards and guide for BIM software and system.	BIM Academic Forum (BAF) was establishment in the late 2011, this was considered very promising seeing its mission to develop and promote teaching and learning with research aspect of BIM. The forum serves as a conduit between industry's needs and BIM training in higher institutions. Succinctly, the forum is for the promotion of academic prospect of BIM in the UK (Underwood et al. 2015). There are some educational programmes plan for BIM training in the UK, this include BIM for education and BIM for SMEs. On the other hand, there is overall low levels for BIM maturity awareness within the entire disciplines thus, higher education institutions (HEIs) are generally underperforming (Underwood et al. 2015). Consequently, resulted in shortage of BIM experts in the market (Richard 2017) this is reported as a top ranked barrier to utilising BIM (Richard 2017). Some organisations and professional	The Australian Government Office for Learning and Teaching (OLT) supported a project on BIM technologies known as 'collaborative design education - CODE BIM' that engages three universities (University of South Australia, University of Newcastle and University of Technology Sydney). A clear framework was developed to help Academics implement BIM training. On another effort, the Australian Institute of Architecture (AIA) and Consult Australia established an industry - academia BIM working group in 2011; it was on this base that a foundation was formed with series of Noteworthy publications in 2012. Subsequently, a joint research centre for BIM was formed for sharing knowledge amongst researchers, engineers and innovators to be achieved through collaboration between Huazhong University of Science and Technology and Curtin University.

	societies are offering BIM training. BRE (2016) discovery reveals that higher education is not producing skilled candidates on BIM as needed by the industry.	

Table 2.5: BIM Adoption guide and standards by the USA, UK, and Australia (Compiled by the Author)

	Organizations	**Role and year**
United States of America	General Services Administration (GSA).	Formation of National 3D-4D BIM Program in 2003. General guidelines for GSA associates and consultants engaging in BIM practices (2010). Sets requirement of BIM in all final concept approval for all major projects and the development of BIM Guide Series in 2007.
	AGC - Consensus Docs 301 BIM Addendum.	Development of standard contract documents for legal and administration issues associated with using BIM (2006).
	USACE, BIM Project Execution Plan, ver 1.0	Protocols for implementing BIM in the U.S. Army Corps of Engineer's civil works and military construction processes with a focus on operation phase (2006)
	National Institute for Building Science (NIBS).	Development of National Building Information Modelling Standard (NBIMS) on Building Energy Performance as well as publishing BIM standards from various government departments.
	States Protocols and Guidelines.	State of Ohio developed BIM general guidelines for building owners (requests for qualifications, agreements, bidding requirements, and contracts) in 2010. And, New York city council developed basic guidelines for the use of BIM for the municipal agencies in 2012.
United Kingdom	UK government	Development of BIM level 2 mandate on public projects in 2011 and the committed to the achievement recorded in the 2016.
	BIM Task Group	Provision of support and assistance in the BIM adoption journey. Presented the utilisation of Information sharing environment known as Construction Operations Building information exchange (COBie) in 2011.
	AEC (UK) committee.	Integrated standard for the AEC industry CAD & BIM in the UK.
	British Standards Institute (BSI).	Development of Information sharing standards created (i.e. PAS 1192:2, PAS 1192:3, BS 1192:4, PAS 1192:5 etc.). BSI started developing BIM standards since 2007.
Australia	Built Environment Industry Innovation Council (BEIIC).	BEIIC is responsible for National Building Information Modelling initiative since 2012.
	CRC-CI national guidelines for digital modelling.	Guidelines for creation, maintenance, modelling procedures and implementation on large projects (2009).
	Department of Planning, Transport and Infrastructure (DPTI)	Developing guidelines for government agencies, consultants and contractors
	NATSPEC.	NATSPEC developed National BIM Guide in 2011.
	Australian Construction Industry Forum (ACIF).	Development of BIM Knowledge and Skills Framework in 2014.

2.8.3 Strengths and Weaknesses of BIM Adoption Efforts by USA, UK, and Australia

Several common drivers ease innovation adoption for these three countries. For instance, technology infrastructures, availability of software and hardware as well as enabling policies to speed up the diffusion are quite clear in context. These set of advantages utilised by the countries are an essential backbone to soften resistance and critical factors to drive and move the industry together. Availability of NBPs also played a significant role in providing awareness, and streamlined guide across all professionals wish to adopt BIM in these countries. The NBPs aimed to encourage BIM understanding, regulate its implementation or mandate, and they are developed by:

- government agencies (i.e. USA, UK)
- government mandate (i.e. UK)
- industry/professional organisations (i.e. Australia and the USA) or
- academic entities (i.e. USA, UK and Australia).

Nonetheless, there is some dissimilarity amongst them in terms of the guide by countries. The open guide is demonstrated in the USA, where agencies use or develop their guides, and this allows flexibility and speedy adoption/implementation. On the contrary, the UK illustrated closed guide that facilitates a substantial number of NBPs from the government but with less adoption rate. Despite the low adoption rate compared to the USA, this strategy positioned the UK at world leadership stage in providing standards, guides and protocol to adopt BIM. At the same time, Australia demonstrated a combination of the two approaches from the USA and the UK. Government and non-profit organisations deliver standards and guidance on BIM, and this provides a balance of flexibility and government input while maintaining a partial (restricted) mandate.

2.8.4 Conclusions

This aspect of study attempts to compare both the process and legislative efforts of the USA, UK, and Australia on BIM adoption and implementation within their respective construction markets. Considering the considerable literature availability and NBPs, it is evident that these countries are leaders in BIM implementation. The generated middle-out diffusion dynamic by the USA shows the proactive nature of their construction industry and the government flexibility as to the adoption of innovation. On the other hand, the UK and Australia began with bottom-up diffusion dynamic due to the level of control by the government on innovation adoption. The UK subsequently changed as the mandate came into play in 2016 to top-down dynamic. Although the dynamic is changing to middle-out as the more prominent firms are taking the lead. A multiple and concurrent diffusion dynamic reveals higher diffusion and adoption rate.

Despite the similarities in the availability of technology infrastructure, hardware and software (BIM tools) amongst these countries, availability of experts on BIM still differs. Thus, there is variation in BIM experts' availability within these countries. Similarly, developing the teaching in BIM is one of the keys to its acceptance; thus, the USA takes that advantage and built-up its manpower against experts' shortfall and possible resistance. The architects are at the forefront of BIM adoption and even training across the three countries. The government involvement is playing a pivotal role in BIM adoption, and most importantly enacting a policy (mandate) on its usage. Despite considerable development of BIM in Australia, the adoption is not as wide as the USA and the UK; hence, a mandate may play a role in wider BIM adoption and acceptability. Mandating BIM can go a long way to integrating a country's construction market to the rest of the world in market and technology.

It is recommended that new adopter countries require appreciable technology infrastructure, availability of hardware and software to drive BIM adoption further effectively. Mandating BIM to a certain level speeds up adoption, also alleviates education and training challenges in support to up-skill AEC professionals. A multiple and concurrent diffusion dynamic is also recommended especially at the early stage of BIM adoption.

2.9 CHAPTER SUMMARY

This chapter reviewed the literature on the Nigerian construction industry and its challenges. Furthermore, the concept of BIM was discussed, and the benefits associated with its adoption were reviewed. The idea of BIM realises two significant components with sub-components: BIM fields as substantial areas of a BIM framework, and macro-BIM adoption, which involved all aspects of a BIM framework. Similarly, all components of a BIM framework were deduced under the three pre-identified BIM field types (Technology, Process and Policy).

Model A (diffusion areas) provides granular assessment model to evaluate the level of BIM diffusion within the potential BIM adopters. Taking the assessment into account, Model B (maturity components) allows a study to undertake a comparative analysis of other construction markets to identify "model approach" to emulate. Thus, this facilitates comparative analysis conducted in section 2.8.1.

Model C (diffusion dynamics) informs a study those are pushing the adoption (i.e. top-down, middle-out or bottom-up). Hence, that gives an idea of where actions should be concentrated to, or where support is required.

Model D (policy actions) informs the next policy approach (i.e. Passive, Active or Assertive) to be considered to speed up the adoption.

Model E (macro-diffusion responsibilities) firstly determines the industry's champions. Furthermore, it facilitates and allows to engage the stakeholders who are of better knowledge of BIM (e.g. champions) to disclose their concerns and recommendations. Thus, this allows the study to go further with interviews as the second segment of data collection. It has also summarised the players involved in the BIM process, the tools needed, and the policies related to BIM adoption and implementation. The review suggests that the market needs to be assessed based on the macro maturity study models. And, those who are experienced in the industry (BIM-related) need to be involved in domesticating any potential framework. On the other hand, case study market is necessary to learn from and have a foundation to build on.

Explore BIM development and adoption in the countries

This section of research explores BIM development and adoption within the three developed countries, as such addresses the second objective is this PhD research. The comparative analysis of the USA, UK and Australia revealed three different approaches to BIM adoption and implementation. The USA BIM adoption is an industry-driven with government support, and the industry continues to lead the adoption and implementation. The UK BIM adoption is a government-driven process, push and supported by the government, but with realised benefits, the industry is pulling and taking the lead. The industry drives the Australian BIM adoption with support from the government and organisations; the government and the industry are collaboratively leading the BIM adoption.

On another note, the level of BIM awareness, the BIM diffusion and adoption in the Nigerian construction industry are not very clear within the available literature (see Appendix - 1) as such, further study 'exploratory studies' is necessary to build this research on. Exploratory studies were carried out and presented in sections 4.3, 4.4, and 4.5.

To keep track of this research and its originality, the reviewed literature and the comparative analysis of the case study countries were peer-reviewed and published as journal articles (see Appendix – 7).

CHAPTER THREE: METHODOLOGY

3.1 CHAPTER OVERVIEW

The previous chapter examined the construction industry in general and its challenges in the context of Nigeria. BIM was discussed in generic and in specifics; its potentials and its difficulties to adoption were critically reviewed through some case study countries. Consequently, BIM adoption strategies were identified.

This chapter introduces the methodological framework and the theoretical underpinning of the primary studies. It presents the research philosophy, research methodology, and instrument of the research.

The research approach(es) is discussed, and the philosophy underpinned the research approach adopted is presented. That includes the ethical considerations under the University's research ethics policy.

3.1.1 Theoretical Framework

A theoretical framework in research is a generic academic system that involves concepts and assumptions, as well as theories specific to the topic of investigation (Neuman 2006).

A project-based industry may be considered unique, and the construction industry is dominantly project-based (Morris, 2004). As such, it is unique. Construction projects require diverse professions/professionals for complete delivery, thus considered highly heterogeneous and complex. For Rogers et al. (2005), heterogeneity is essential to the theory of innovation diffusion, and that influences the heterogeneous contexts in macro-scale phenomena which are promising to deliver innovation in a complex construction project network (Papadonikolaki 2017).

The five reported steps for innovation diffusion in section 2.7 are grouped under three stages of drivers, supporters and leaders as a theoretical framework of this research. The first two steps (i.e. knowledge/awareness and persuasion) are grouped as "initial stage"; the third step (decision/evaluation) as "critical mid-stage" to adoption; and the last two steps (i.e. implementation/trial and confirmation/adoption) as a "confirm the adoption" stage. This grouping is illustrated in Figure 3.1.

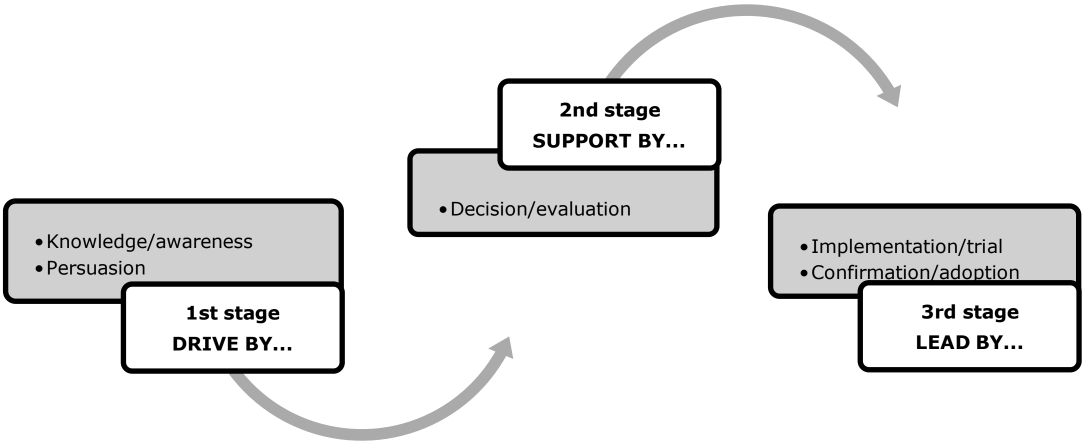


Figure 3.1: A simplified theoretical framework (Author generated)

Subsequently, the theoretical framework is considered viable to use as a template to enhance and facilitate the innovation diffusion in the construction industry (i.e. BIM adoption and diffusion). Moreover, the essential parameters to this theory are embedded under the first three steps (Knowledge/awareness, Persuasion, and Decision) in the 'decision to adopt' an innovation, and these are summarised and illustrated in Figure 3.2.

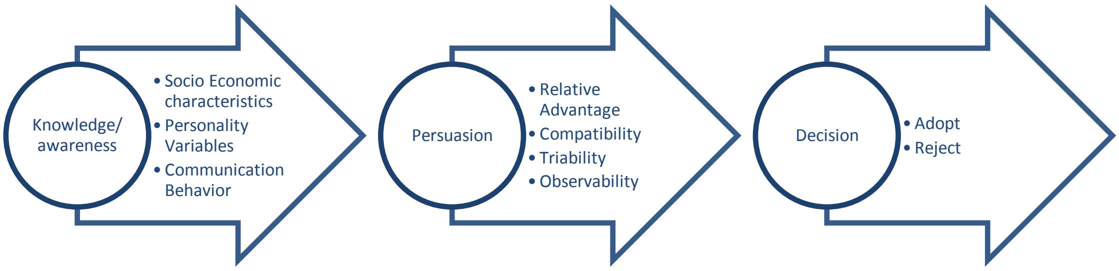


Figure 3.2: Essential parameters to innovation adoption (Author generated, adopted from DOI)

Essentially, the diffusion of innovation theory by Rogers et al. (2005) sets the steps and processes that innovation diffuses and subsequently gets adopted within a potential group of adopters.

3.1.2 Conceptual Framework

The conceptual framework forms a basis for the methodology of research and guides the practical approach. It thus connects the literature review findings to the research procedure. The reviewed literature revealed the level of fragmentation of the Nigerian construction industry and the challenges faced as a result of that. Review of BIM reveals its potentiality of integrating the construction industry, and the case study countries elucidated potential strategies to development and adoption of BIM. The conceptual framework (developed from the case studies) presents the major steps to BIM adoption at the Macro level, and it is the case study framework to be contextualised. The developed case studies' BIM adoption efforts are combined together and presented as a conceptual framework illustrated in Figure 3.3. The sequencing in the case studies presentation helped in generating sequence in the framework development, and the items/activities under the three headings options potential to be utilised based on the context findings.

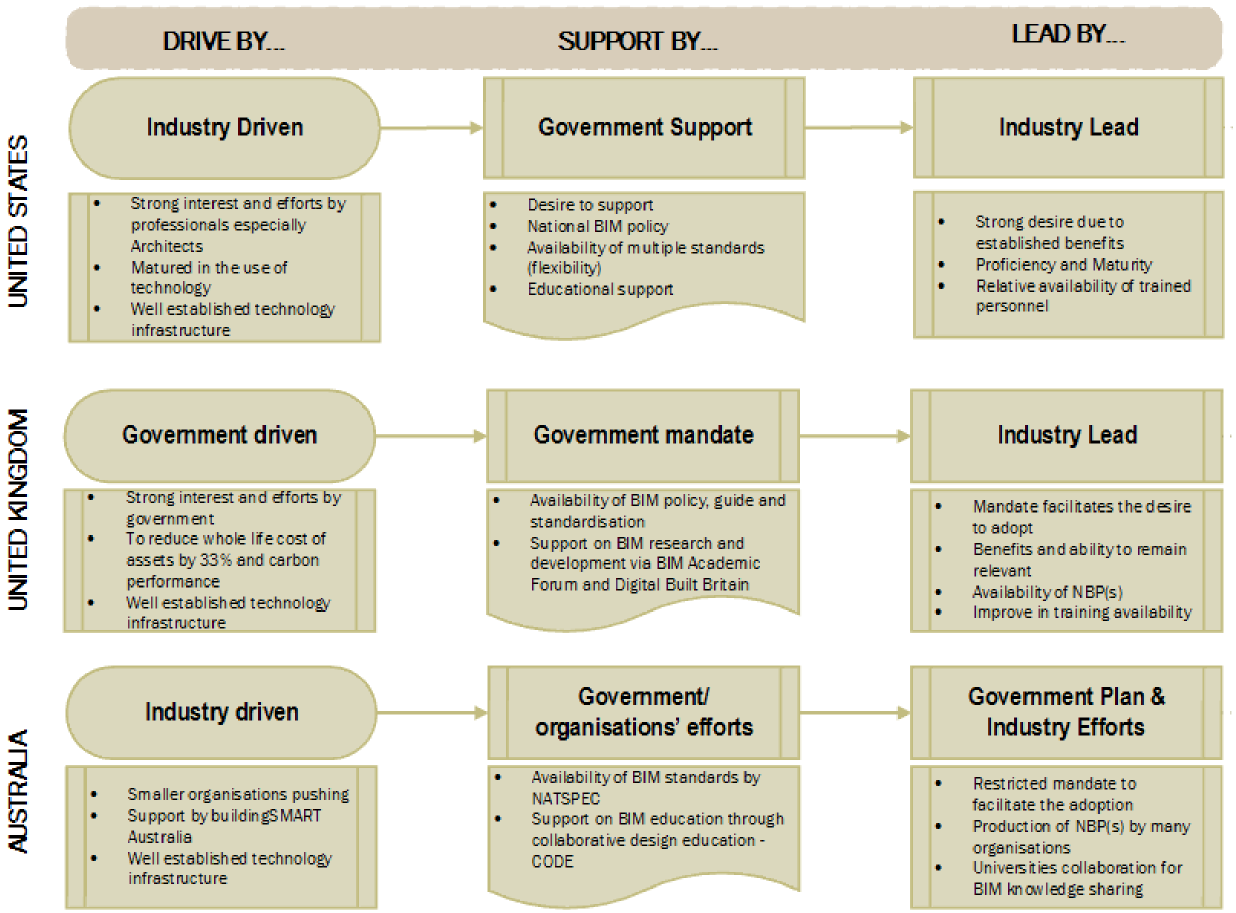


Figure 3.3: Case studies efforts on BIM adoption as a Conceptual framework (Author generated, adopted from Hamma-adama and Kouider 2019)

The concept of this research is to develop a strategic framework for effective BIM adoption. The reviewed literature demonstrates how BIM adoption is insignificant, with a low level of uptake in Africa and Nigeria in specific. The methodology of the research addresses the current state of BIM adoption and usage; established the BIM maturity level; and how BIM drivers or supporters, and views from early BIM adopters can be analysed to contextualised BIM adoption framework.

The study problem is initially considered technical, as the investigation intends to deal with challenges faced in procuring construction works, and perhaps the use of technology at design and construction stages. On the other hand, it is also a social issue, as it involves the innate industry's culture in terms of it processes and protocols; it addresses an innovation diffusion and innovation adoption.

3.1.3 Research Philosophy

A research philosophy addresses fundamental assumptions regarding beliefs like social reality, referred to as 'Ontology', and the relationship between an observer (knower) and observed (known), which is referred to as 'epistemology' (Neuman 2006). In a generic term, Neuman (2006) describes research philosophy as beliefs that deal with assumptions about methodologies adopted in the research. There are several research philosophies presented by Saunders et al. (2012), in their model called 'research onion'. To mention but a few with positivism, realism, interpretivism, objectivism, subjectivism, and pragmatism. While other schools of thought concentrate on three different philosophies (Neuman 2006) that give birth to only five philosophies presented in the research onion by Saunders et al. (2012). The three underpinning philosophies are ontology, epistemology, and pragmatism. Subjectivism and realism are classified under ontology, and epistemology goes with positivism and interpretivism. On the other hand, pragmatism is a foundation of mixed-method research that integrates quantitative and qualitative approaches (Ivankova et al. 2007). Figure 3.4 illustrates the branches of research paradigms and approaches involved under them.

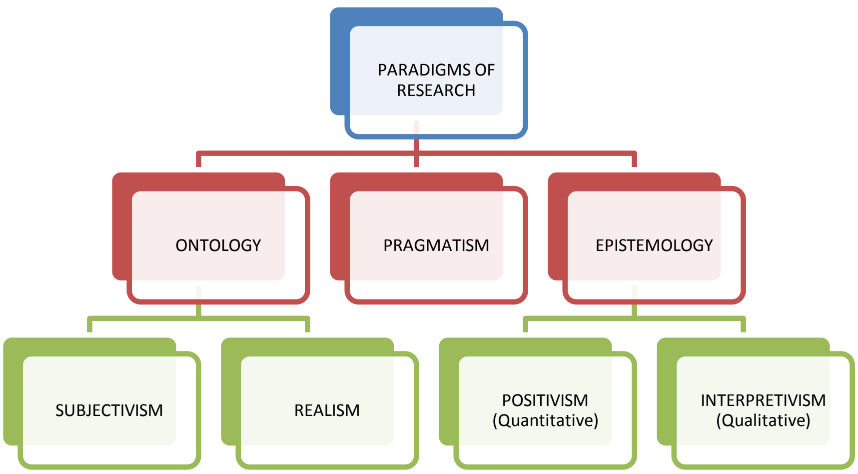


Figure 3.4: Paradigms of research (Ivankova et al. 2007; Summarised by the Author)

3.1.3.1 Ontology

Ontology is a research paradigm that deals with a philosophical belief regarding the existence of social reality (Neuman 2006). It constitutes subjectivists and realists' philosophical approaches. The subjectivists' philosophy believes in the existence of social realism as a formation, or ledge of the investigator's cognition and consciousness (Gill and Johnson 2010). In contrast, realists believe that social realism is autonomous of the investigator's reasoning structure (Nieuwenhuis 2007).

3.1.3.2 Epistemology

Epistemology is the criteria for knowing what constitutes scientific knowledge (Grill and Johnson 2010). The epistemology has two leading schools of thought, positivist and constructionist or interpretive (Bergman 2008). These two approaches are used to discover scientific knowledge (Neuman, 2006). Positivist belief is an approach to the discovery of knowledge through a scientific method, that reality is found with empirical evidence, and or via deductive reasoning (Neuman, 2006). While constructionist belief is an approach where research is undertaken, and the reality is discovered through peoples' experiences (Nieuwenhuis 2007). On another understanding of uncertainty, Babbie (2007) believes that no observation can be free from the researcher's consciousness (neutral); thus, all perceptions are subjective.

The two approaches of investigations discussed above (positivist and interpretive) are imperative to the selection of research approach, which in many times referred to as 'research method'. The positivist approach involves a quantitative method, while the interpretive involves a qualitative method of research (Saunders et al. 2012). Table 3.1 outlines the taxonomies of research methodologies for the positivist and interpretivist beliefs.

Table 3.1: Taxonomies of research methodologies (Galliers, 1991, p.149)

Positivist/Scientific	Interpretivist/Anti-positivist
Laboratory Experiments	Subjective/Argumentative
Field Experiments Reviews	Reviews
Surveys	Action Research
Case Studies	Case Studies
Theorem Proof	Descriptive/Interpretive
Forecasting	Futures Research
Simulation	Role/Game Playing

3.1.3.3 Pragmatism

Bergman (2008) asserts that social and behavioural scientific researches are increasingly using the combination of quantitative and qualitative approaches (mixed method). Pragmatism is a philosophical foundation considered best for mixed research methods (Ivankova et al. 2009). And, it is deemed to be compatible with multi-strategy research (Brannen 2008). The pragmatists believe that investigation is achieved from 'what works' for a specific investigation scenario. Moreover, a complete understanding may be achieved if quantitative and qualitative methods were deployed in research. However, deployment of both methods is subject to the 'workability' theory, its relationship with the purpose of the investigation (i.e. study questions) (Gill and Johnson 2010).

The six objectives of this research are grouped into three (i.e. objectives 1 and 2; objectives 3 and 4; and objectives 5 and 6). The objectives 1 and 2 are literature-based where only secondary data are involved. Moreover, objective two went further with a comparative analysis of the three case study countries (refer to section 2.8.1). In the process of identifying and defining a suitable research method, the main questions asked in chapter one were considered. These main questions are directly connected to the two remaining grouped objectives (objectives 3 and 4; and objectives 5 and 6), the questions are:

'What' is the level of, awareness, adoption, and maturity of BIM?

'How' can BIM be effectively adopted in the Nigerian AEC industry?

The objectives 3 and 4 are grouped due to the similarities in their data and method of the collection. The potentiality of knowledge discovery (what is the level of…) through empirical evidence using deductive reasoning suggests a positivist approach. Thus, it involves a quantitative approach to meeting the second grouped objectives (Neuman 2006; Grill and Johnson 2010). To address the first set of questions which consists of the level of BIM adoption; and its maturity with the adopters (objectives 3 and 4), a survey using questionnaire was conducted on the Nigerian construction professionals who are at least aware of BIM. Their level of BIM utilisation, barriers and drivers to adoption of BIM were simultaneously examined (refer to Appendix - 9). In the process of establishing the level of BIM adoption and BIM maturity, it requires knowing 'how many' firms adopted that; and findings are deduced with the aid of the macro BIM adoption models (McAuley et al. 2018; Murguia 2019) in a quantitative-based approach.

Objectives 5 is deduced from the available literature (potential benefits of BIM adoption) and contextually affirmed through interviews (BIM benefits concerning the current challenges in Nigeria). On the other hand, objective six is achieved primarily through interview using the template for the development of Macro BIM adoption roadmap with the aid of macro BIM adoption models (Kassem and Succar 2017).

The last set questions are: 'what are the potential benefits…' and 'how can BIM be effectively adopted…'; thus, they involved 'what' and 'how'. As such, these relate to the industry's culture and current level of the BIM sophistication. The reality can only be discovered in this context through the people's experiences; thus, the interpretivist approach is deemed appropriate (Neuman 2006; Nieuwenhuis 2007). Ultimately, the combination of these approaches to deliver the set objectives is a clear indication of the deployment of a pragmatic philosophy (Ivankova et al. 2007). The industry practitioners have diverse experiences and as such, may perceive and respond to questions differently. Their knowledge of BIM deployment on project and challenges faced during the adoption is of importance; as such interviewing them can suggest an appropriate approach to effective BIM adoption as demonstrated in Gu and London (2010); Valappil and Saleeb (2016). Furthermore, to examine the culture of the industry processes and the in-depth investigation of a questionnaire survey, a semi-structured interview was deemed appropriate (Creswell 2015).

Succinctly, the methodology of this study is of a conciliatory (multi-method) where diverse methods were deployed to examine the research problem. Exploratory studies were first implemented to explore the current country's stand and to fill the literature gap that was identified in the literature. A convergent mixed method was used for exploration or exploratory studies. Secondly, a questionnaire survey (quantitative research) is used in gaining a comprehensive knowledge of BIM adoption and usage levels, as well as BIM maturity. Thirdly, a semi-structured interview was used as a tool for data collection, and qualitative content analysis is used as a method of analysis. A combination of second and third investigations as explanatory sequential (mixed method) is used to provide answers to how BIM can effectively be adopted in the Nigerian construction industry. Thus, the approach is abduction reasoning, i.e. the combination of inductive and deductive approaches (Saunders et al. 2012).

3.2 RESEARCH PROCEDURE

This section outlines the context for this research, data collection steps and methods. To achieve the study aim, and objectives, the following strategies of inquiry were specifically considered Literature review, comparative case studies, and two exploratory studies. This research work uses a mixed (Quantitative and Qualitative) method approach.

Qualitative content analysis is used for the interviews, while descriptive statistics is used with the aid of macro BIM adoption models for the questionnaire survey.

This research consists of three studies; the first study relates to BIM technology adoption in the Nigerian construction industry. To determine the level of BIM utilisation in Nigeria, awareness, knowledge, and technology availability should be ascertained first. The exploratory studies (to fill the literature gap) were carried out through multiple means (interview and questionnaire survey) as described in chapter four (sections 4.3, 4.4 and 4.5 referred).

The exploratory studies were introduced to enrich and complete the literature in the Nigerian context. The study is undertaken through interview and questionnaire surveys. The questionnaire surveys were quantitatively analysed (using simple descriptive statistics), and the concept of innovation diffusion was also deployed. The interviews were analysed using qualitative content analysis. The exploratory investigation discloses a brief level of awareness and diffusion of BIM in the study market (see section 4.5).

The second study has utilised a separate data collection, a questionnaire survey followed by semi-structured interviews. The questionnaire survey is quantitative as it deals with 'How much is BIM being utilised?'; It also involves the application of five macro BIM maturity conceptual models, establishing the BIM maturity within the study context. The questionnaire survey has quantitative questions that are divided into the following:

- What is the level of BIM awareness within the Nigerian construction industry?
- How many firms are using BIM?
- To what level is the adoption (based on the three BIM stages) of BIM?
- What are the barriers and drivers (list compiled from previous studies) to the BIM adoption?
- What are the capabilities (based on BIM fields)?

The five conceptual constructs for assessing BIM maturity at country level are used in evaluating the Nigerian BIM Maturity, aimed to be utilised in the development of National BIM adoption policy (McAuley et al. 2017). That is an absolute way of informing the development of market scale BIM diffusion policies (Succar and Kassem 2015). And, 'comparative market analysis' concept is utilised to evaluate BIM adoption and analyse the BIM diffusion policies across the three chosen countries (the UK, US and Australia) and subsequently the study country (Nigeria). The Kassem and Succar's (2017) benchmarking was considered in the market analysis.

On the other hand, the semi-structured interview intends to gain in-depth knowledge and understanding of the study subject in terms of current BIM process and challenges, and how the adoption can be appropriately structured. Results from the quantitative (questionnaire survey) and qualitative (interviews) studies are considered on the conceptual framework generated from the comparative case studies analysis (in section 2.8.1).

The comparative analysis data is generated from secondary sources, compiled from Noteworthy BIM Publications (NBPs) from around three case study countries (the UK, US and Australia). The generated information was used in developing a potential framework for BIM adoption. The UK, US and Australia were selected as sample case study countries due to their construction culture similarity in technologies and terminology, availability of national BIM adoption surveys as well as the availability of NBPs (Kassem et al. 2013), and their BIM participation at the world stage, i.e. based on BIM leadership (Edirisinghe and London 2015). The comparative analysis was introduced to scrutinise the following content in the three case study countries:

- Reasons behind BIM adoption
- Structure of the industry vis a vis digitalisation
- Origin and the method of adoption
- Resistance and Enforcement strategy
- Legislation, Standards and Guide
- Technology (infrastructure, manpower and access)
- Education, Training and Research
- Success, Challenges and Return on Investment (ROI).

Finally, appraise the potential benefits of adopting BIM concerning identified problems from the literature, which is also linked to successes recorded from case studies and the essential BIM benefits. Figure 3.5 presents a summary of the research procedure.

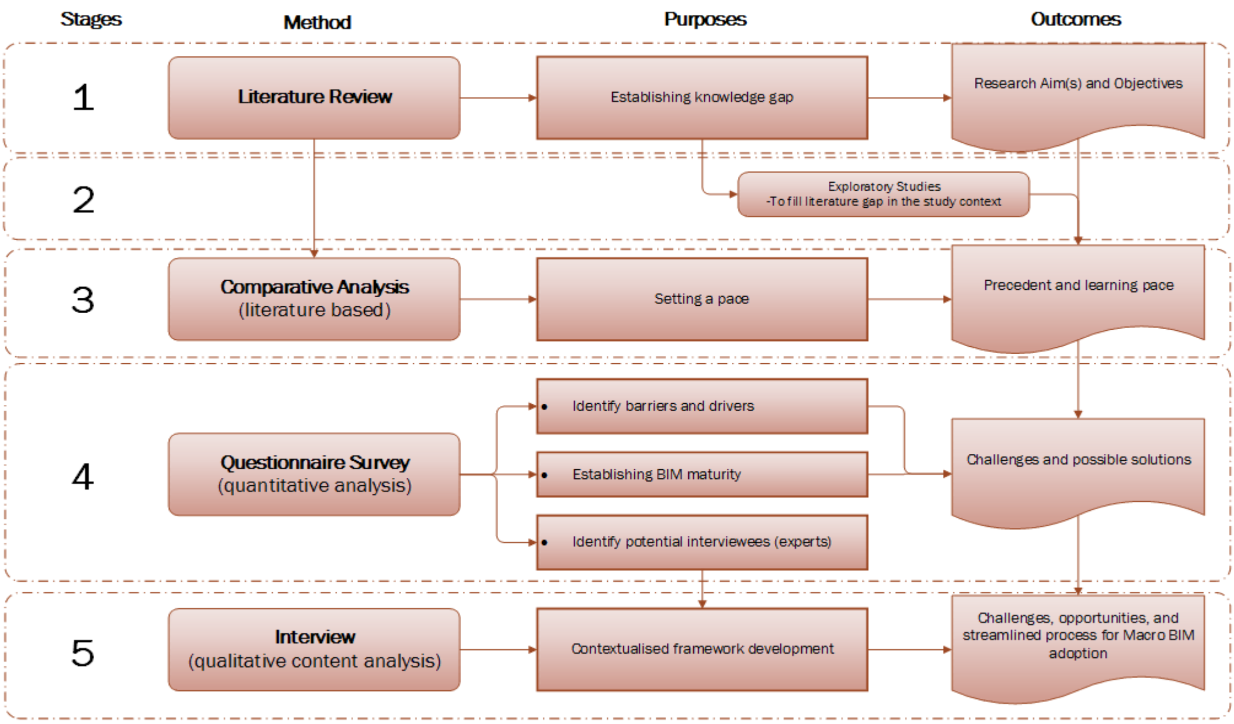


Figure 3.5: Research Procedure

In developing a framework, a basic conceptual model (conceptual description) is therefore adopted. In the theory building through conceptual methods, conceptual description model is 'primarily descriptive in its modelling of an event or phenomenon' (Meredith 1993). The conceptual model is expected to generate an extensive or simplified description of a well-structured diagram or chart (Meredith 1993). Thus, the framework is determined by both the quantitative (adoption policy from the second section) and qualitative content analysis (from the third section).

The overall research methodology is then consisting of a multi-method in which different methods were adapted to investigating the problems. A quantitative study is used to explore the industry's stage regarding BIM adoption; while on the other hand, a qualitative method is used to analyse the challenges and opportunities while paving a way to developing an effective strategy for the adoption. Succinctly, a combination of both quantitative and qualitative (mixed-method) methods are utilised to achieving the intended goal.

The following sections present the method of data collection and analysis.

3.2.1 Type of Data

Although secondary data (from the reviewed literature) are essential from the beginning of this research work, this is to set a scene, document the previous work and justify the gap. The primary data are crucial raw material to be processed and must be collected appropriately. There are two segments to the way primary data are collected in this research: questionnaire survey and semi-structured interview. A comprehensive questionnaire survey method (quantitative) is considered as a suitable method for an exploratory study and generalisation (Dawson 2009). In contrast, an interview is chosen due to its strength in validating the generated information; and the potentiality to focusing on fewer respondents as reported by Marshall et al. (2013) based on single case qualitative methodology. Moreover, exploratory studies are based on a non-probability sampling of respondents; while its analyses have been frequently used to create hypotheses for further study (Guest et al. 2011).

A graphical hierarchy structure is presented in Figure 3.6 to appreciate the data collection structure.

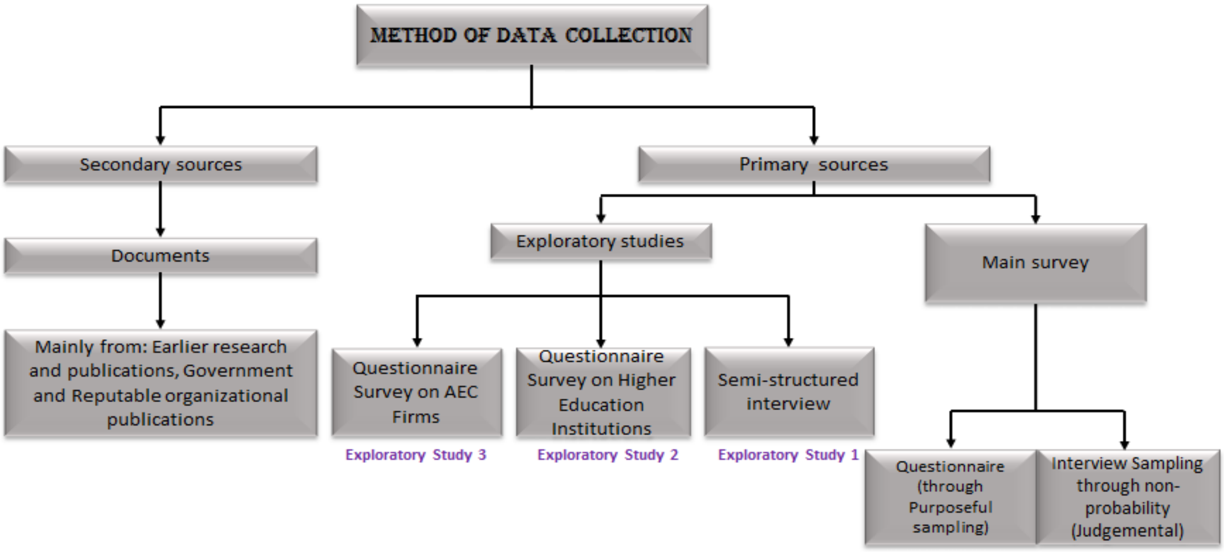


Figure 3.6: Method of data collection

The qualities considered while drafting the questionnaire are as follows:

- Relevance/ Profession of responsibility
- Educational qualification (relevance)
- Experience (age in such work)
- Staff rank, only middle and top/senior management are/will be considered (Smith Dana and Tardif 2009).

3.2.2 Questionnaire Survey

The Questionnaire survey was defined as the assessment of known population regarding their views, behaviours, beliefs, knowledge, and attitudes on a subject or object(s) (Maree and Pietersen 2007). The questionnaire was designed based on the previous studies in the area of macro BIM adoption, such as McAuley et al. (2018), Murguia (2019) etc. Moreover, the questionnaire survey was also designed in a way that it measures or assesses the following factors: awareness and usage of BIM, barriers and drivers for BIM adoption, and macro BIM adoption models. Also, the survey was crucial in identifying potential interviewees based on a specific research criterion which will be presented in chapter six (section 6.1, p.203).

With the introduction of a variety of instruments for measurements in research, researchers are left with numerous options of tools to use in conducting either quantitative or qualitative research (Zohrabi 2013). On the other hand, there is an inevitable need to set criteria for the evaluation of such instruments (Oluwatayo 2012). In principle, there are two most important criteria to evaluate research tools; these are validity and reliability.

3.2.2.1 Validity and Reliability

Face validity is a type of validity test on a questionnaire that helps a researcher assess the relevance and presentation of a measuring instrument, whether the items/questions in the tool are reasonable, relevant, clear and unambiguous (Oluwatayo 2012). Some scholars (i.e. Kaplan and Saccuzzo 2005; Whiston 2005) believe that face validity is subjective and offers no true validity as it does not measure what it is intended to be measured. On the contrary, Anastasi and Urbina (2007) maintained that face validity is a necessary feature of test that offers contextual validity. Face validity targets to improve the feasibility, readability, formatting and style consistency, as well as clarity of the language used in data collection tool (Taherdoost 2016). One of the ways to validate using face validity is through input by experts in the research subject (Anastasi and Urbina 2007; Oluwatayo 2012; Taherdoost 2016).

Before distributing the questionnaire, the questionnaire was validated using face validation and a pilot test. The face validation was achieved through two BIM academic experts (one internal and one external). The external is a BIM research expert, and one of the developers and authors of the Macro BIM adoption models; while the internal is from within the University of Study. The initial draft questionnaire was sent to them, where they made some suggestions ahead of the pilot test. The pilot test was achieved through a scouting or reconnaissance survey of a small number of respondents from BIM Africa group. Responses received within a fortnight demonstrate accurate measurement of the items intended to achieve the research objectives. The BIM Africa platform has also helped in identifying the right people as respondents to this research.

The reliability of data and results is one of the requirements for any research process. This dominantly involves dependability and replicability of information obtained from a piece of study (Nunan 1999). Thus, getting similar results in quantitative research is somewhat straightforward because of the numerical form of data involved. The Cronbach Alpha coefficient remained a frequently use internal consistency measure. It is considered as the suitable measure of reliability when making use of Likert or Weighing scales (Whitley 2002; Robinson 2009). With no outright rules for internal consistencies, however, it is mostly agreed to a minimum of 0.7 internal consistency coefficient (Whitley 2002; Robinson 2009).

The internal consistency (reliability) was carried out using a standard test Cronbach's Alpha (CA) as demonstrated in section 5.2.1.1.2, p.173.

The questionnaire was distributed online; the questionnaire survey questions are presented below, and a sample is attached as per Appendix – 9 (p.301).

Nigerian Building Information Modelling (BIM) Macro Adoption Study

Establishing Nigeria's BIM Maturity

* Required

1. **Email address ***

2. **What is your sex? *** *Mark only one oval.*
   - Male
   - Female

3. **What is your academic qualification? *** *Mark only one oval.*
   - OND or HND
   - B.Sc./B. Tech./B. Eng.
   - MSc
   - PhD

4. **What is your profession? *** *Mark only one oval.*
   - Architecture
   - Building Engineering
   - Civil/Structural Engineering
   - Electrical Engineering
   - Mechanical Engineering
   - Construction/Project Management
   - Quantity Surveying
   - Other:

5. **Which of the following best described your specialisation? *** *Mark only one oval.*
   - Contractor/Construction
   - Designer or Consultant
   - Client
   - Development Authority

6. **What is the size of your technical personnel? *** *Mark only one oval.*

- < 10 personnel (Micro)
- 10 - 50 personnel (Small)
- 50 - 200 personnel (Medium)
- > 200 personnel (Large)

7. **Who do you mostly work for? *** *Mark only one oval.*

- Government (public sector)
- Private (individuals or corporate bodies)
- Both (Public and Private)

8. **Where in Nigeria do you practice? *** *Mark only one oval.*

- North-Central
- North-East
- North-West
- South-East
- South-South
- South-West

9. **How long have you been in the practice? *** *Mark only one oval.*

- < 5 years
- 5 - 10 years
- 11 - 15 years
- > 15 years

Building Information Modelling (BIM) Awareness

BIM is the process of creating a digital model of a building or infrastructure facility. The fundamental idea behind BIM is to create and share the right information at the right time throughout the design, construction and operation of a building or facility, in order to improve efficiency and decision making (CIOB.)

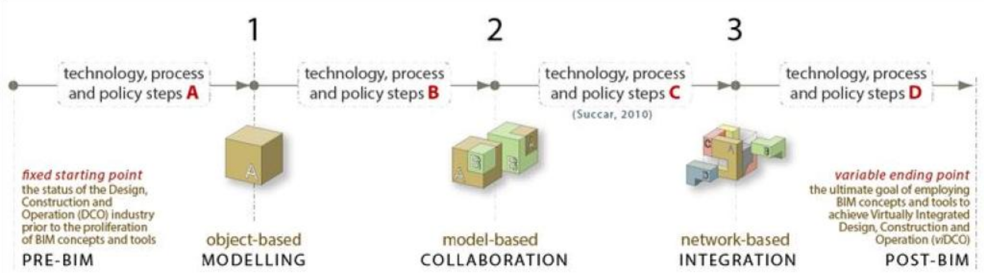
10. **Are you aware of Building Information Modelling (BIM) *** *Mark only one oval.*

- Yes
- No *After the last question in this section, stop filling out this form.*

11. **Have you ever used BIM in any of your project? *** *Mark only one oval.*

- Yes
- No *After the last question in this section, skip to question 12.*

12. **If yes, to what extent?**



Mark only one oval.

- Modelling only (BIM stage 1): We are using 3D (software) to generate geometric model (e.g. for details and visualisation)
- Collaboration (BIM stage 2): We are using and exchanging model with other stakeholders via the same tool (software format)
- Integration (BIM stage 3): We are using network based integration (network based solution for exchange)

BIM Maturity in Nigerian Construction Industry

13. **What do you consider as the major drivers to adopting BIM? (ranking from 1 - low to 5 - high) *** *Mark only one oval per row.*

	1	2	3	4	5
Availability of trained professionals to handle the tools BIM					
Software affordability					
Enabling environment within the industry					
Clients' interest in the use of BIM in their projects					
Awareness of the technology among industry stakeholders					
Cooperation and commitment of professional societies to its implementation					
Proof of cost savings by its adoption					
Cultural change among industry stakeholders					
Government support through legislation					
Collaborative Procurement methods					

14. **What do you consider as the major barriers to using BIM? (ranking from 1 - low to 5 - high) ***
Mark only one oval per row.

	1	2	3	4	5
Lack of expertise within the organisations					
Lack of expertise within the project team					
Lack of standardisation and protocols					
Lack of collaboration among stakeholders High					
Investment Cost					
Legal issues around ownership, IP & PI insurance					
Lack of client demand					
Lack of infrastructure					
Lack of government policy					
Industry's Cultural resistance					
Lack of additional project finance to support BIM					
Resistance at operational level					
Reluctance of team members to share information					
Return on Investment (ROI) issue					

15. **In your opinion, what is the industry's BIM capability based on the following BIM stages and fields (ranking from 0 - nothing achieved to 4 - highest achieved) ***

Cumulative Capability Increase →	TECHNOLOGY	PROCESS	POLICY
INTEGRATION	**3TE**: Integration Technologies Rate of adoption of *network-based* interchange solutions (e.g. model servers); rate of proliferation of real-time network-based integration across disparate systems	**3PR**: Integration Processes Rate of adoption of *integrated supply-chain* processes across the whole supply chain; rate of proliferation of interdisciplinary workflows across all project life cycle phases	**3PO**: Integration Policies Rate of adoption of *integrated supply-chain* standards, protocols and contractual agreements; rate of proliferation of interdisciplinary educational programmes
COLLABORATION	**2TE**: Collaboration Technologies Rate of *inter-organizational* adoption of model-sharing software and middleware tools (e.g. Navisworks, Vico and Ecodomus)	**2PR**: Collaboration Processes Rate of *inter-organizational* adoption of project BIM roles (e.g. Information Manager); rate of proliferation of multidisciplinary model-based workflows; rate of proliferation of new collaboration-centric business models	**2PO**: Collaboration Policies Rate of *inter-organizational* adoption of modelling standards and collaboration protocols; rate of proliferation of collaboration-centric contractual agreements and educational programmes
MODELLING	**1TE**: Modelling Technologies Rate of *intra-organizational* adoption of BIM software tools (e.g. Revit and Tekla) and their underlying hardware and network requirements	**1PR**: Modelling Processes Rate of *intra-organizational* BIM roles (e.g. model manager, and BIM trainer) and model-based workflows	**1PO**: Modelling Policies Rate of *intra-organizational* adoption of modelling standards (e.g. naming standards, shared parameters, level of details, and property sets) and file exchange protocols

Mark only one oval per row.

	0	1	2	3	4
Modelling Technologies					
Modelling processes					
Modelling policies					
Collaboration technologies					
Collaboration processes					
Collaboration policies					
Integration technologies					
Integration processes					
Integration policies					

16. **Can you measure the following BIM maturity components as to their respective availability in Nigeria (ranking from 0 - low maturity to 4 - high maturity) ***

Macro-maturity matrix at *granularity level 1*.

		a	b	c	d	e
		Low maturity	Medium–low maturity	Medium maturity	Medium–high maturity	High-maturity
I	Objectives, stages and milestones	There are no market-scale BIM objectives or well-defined BIM implementation stages or milestones	There are well-defined macro-BIM objectives, implementation milestones and capability stages	BIM objectives, stages and milestones are centrally managed and formally monitored	BIM objectives and stages are integrated into policies, processes and technologies and manifest themselves within all other macro-maturity components	BIM objectives and stages are continuously refined to reflect advancements in technology, facilitate process innovation, and benefit from international best practices
II	Champions and drivers	There are no identifiable market-wide champions or BIM implementation drivers	There are one or more volunteer champions and/or informal BIM drivers operating across the market	There is a unified task group or committee driving BIM implementation/diffusion across the market	Driver(s) coordinate all macro-adoption activities, minimise activity overlaps, and address diffusion gaps	Driver(s) role is diminished, replaced by optimised systems, standards and protocols
III	Regulatory framework	There is no formal BIM-era regulatory framework	There is a formal regulatory framework addressing basic BIM-era rights and responsibilities of a number of stakeholders	The formal regulatory framework covers all BIM-era rights and responsibilities of all stakeholders	The regulatory framework is integrated into all requirements, roles, processes and deliverables	The regulatory framework is continuously refined to reflect technological advancements and optimised collaborative workflows
IV	Noteworthy publications	There are no – or a small number of – noteworthy BIM publications (NBPs) across the market	There are many NBPs with overlapping knowledge content; some NBPs are redundant or collectively include knowledge gaps	NBPs are developed and/or coordinated by a single entity thus minimising overlaps and knowledge gaps	NBPs are authoritative, interconnected and integrated across project life cycle phases and the whole construction supply chain	NBPs are continuously optimised to reflect international best practices
V	Learning and education	BIM learning topics are neither identified nor included within legacy education/training programmes; learning providers lack the ability to deliver BIM-infused education	BIM learning topics are identified and introduced into education/training programmes; BIM learning providers are available across a number of disciplines and specialties	BIM learning topics are mapped to current and emergent roles; BIM learning providers deliver accredited programmes across disciplines and specialties	BIM learning topics are integrated across educational tiers (tertiary, and vocational) and address the learning requirements of all industry stakeholders	BIM learning topics are infused (not separately identifiable) into education, training and professional development programmes
VI	Measurements and benchmarks	There are no market-wide metrics applied in measuring BIM diffusion, organisational capability or project performance	Formal metrics are used to benchmark project outcomes and assess the abilities of individuals, organisations and teams across the market	Standardised metrics are used to centrally benchmark project outcomes; certify the abilities of individuals, organisations and teams; and accredit learning programmes, software systems and project delivery mechanisms	Standardised metrics and benchmarks are integrated into project requirements, workflows and deliverables; consistently used in defining and procuring services; and used to prequalify the abilities of individuals, organisations and teams	Standardised metrics are continuously revised to reflect evolving accreditation requirements and international best practices
VII	Standardised parts and deliverables	There no market-specific *object libraries* (e.g., doors and windows); service delivery *model uses* (e.g., clash detection) and *operational data* requirements (e.g., COBie)	*Object libraries* are available yet follow varied modelling and classification norms; service delivery *model uses* and *operational data* requirements are informally defined and partially used	Standardised *object libraries* are available and used; service delivery *model uses* and *operational data* requirements are formally defined and used across all project lifecycle phases	Standardised *object libraries*, service delivery *model uses*, and *operational data* requirements are integrated into, procurement mechanisms, project workflows and lifecycle facility operations	Standardised *object libraries*, service delivery *model uses* and *operational data* requirements are continuously optimised and realigned to improve usage, accessibility, interoperability and connectivity
VIII	Technology infrastructure	Non-existent, inadequate or unaffordable technology infrastructure (software, hardware and networks) as to prohibit widespread BIM adoption	The technology infrastructure is of adequate quality and affordability to enable BIM implementation within organisations and diffusion across varied market sectors	The technology infrastructure is of high quality and affordability enabling the efficient exchange, storage and management of complex, federated models among dispersed project teams	The technology infrastructure is uniformly accessible and interoperable allowing real-time network-based integration across disparate systems and data networks	The technology infrastructure is intuitive and ubiquitously accessible allowing seamless interchange between all users, virtual systems and physical objects across the whole lifecycle

Mark only one oval per row.

	0	1	2	3	4
Objective, stage and milestones					
Champions and Drivers					
Regulatory Framework					
Noteworthy Publications					
Leaning & Education					
Measurements & Benchmarks					
Standardised parts & Deliverables					
Technology Infrastructure					

17. **What is your assessment of the current BIM directional pressure dynamics in Nigeria (who is pushing BIM adoption) ***

DIFFUSION DYNAMIC	MACRO ACTOR, TRANSMITTER	PRESSURE MECHANISM	PRESSURE RECEPIENT, POTENTIAL ADOPTER	ISOMORPHIC PRESSURE TYPE
Top-Down	Government or regulatory body	Downwards	All stakeholders falling within the circle of influence of the authority exerting pressure	Coercive; normative
		Horizontal	Governments and authorities in other markets	mimetic
Middle-Out	Large organization or industry association	Downwards	Smaller organizations further down the supply chain; members of industry associations	Coercive; normative; mimetic
		Upwards	Governments and regulatory bodies within the market	Normative
		Horizontal	Other large organizations and industry bodies within or outside the market	Mimetic; normative
Bottom-Up	Small organization	Upwards	Larger organizations and industry bodies	Normative
		Horizontal	Other small organizations	Mimetic; normative

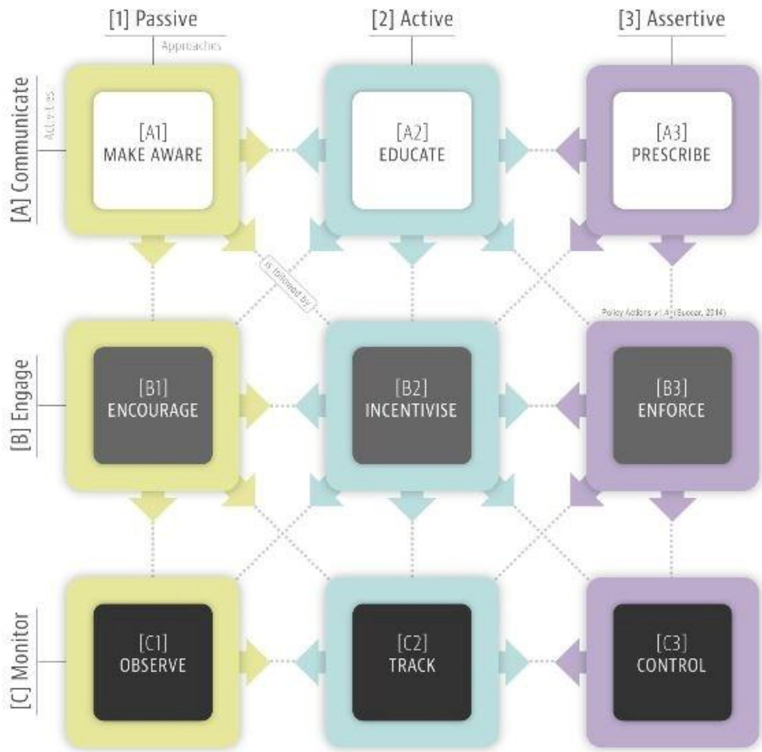
Mark only one oval.

- ◯ Top-down (e.g. government mandate and policies)
- ◯ Middle-out (e.g. driven by larger Design or Construction firms)
- ◯ Bottom-up (e.g. driven by smaller industry stakeholders from Designers and Contractors)

18. **Are there any regulations on BIM in Nigerian Construction Industry? *** *Mark only one oval.*

- ◯ Yes
- ◯ No

19. **What do you think is the most effective policy approach to enforce BIM in Nigeria ***



Mark only one oval per row.

	[1] Passive	[2] Active	[3] Assertive
[A] Communicate			
[B] Engage			
[C] Monitor			

20. **Rank the following players' contribution in facilitating diffusion of BIM within and across the industry in Nigeria (from 0 - no influence to 4 - high influence) ***

POLICY FIELD	PROCESS FIELD	TECHNOLOGY FIELD
1 Authorities Governmental players undertaking an active role in mandating or encouraging the adoption of BIM tools and workflows *e.g. the BIM Task Group in the UK and BCA in Singapore*	**3 Construction organizations** Designers, contractors, owners, operators and other organizational players involved in deploying BIM tools and workflows, training their staff and delivering BIM-enabled outcomes	**5 Software developers** The large software houses responsible for developing and maintaining BIM software tools, network solutions and middleware *e.g. Autodesk, Nemetschek and Trimble*
2 Educational institutions The universities and not-for-profit technical institutions developing and delivering learning programs and materials	**4 Individuals** The individual practitioner, researcher, lecturer and student involved in learning, or actively implementing BIM tools and workflows	**6 Value-adding resellers** The companies bridging and maintaining the relationship between software/network solution developers and end users

POLICY-PROCESS OVERLAP	PROCESS-TECHNOLOGY OVERLAP	POLICY-TECHNOLOGY OVERLAP
7 Industry associations Associations dedicated to representing the interests of their individual and organizational members *e.g. AMCA in Australia*	**8 Communities of practice** The informal grouping of individuals with a shared interest in improving their own BIM performance *e.g. Revit user groups*	**9 Technology advocates** The associations involved in developing and promoting technology-centric solutions for industry challenges *e.g. buildingSMART*

Mark only one oval per row.

	0	1	2	3	4
Policy makers					
Educational institutions					
Construction organisations					
Individual practitioners					
Technology developers					
Technology service providers					
Professional associations					
Communities of practice					
Technology advocates					

The questionnaire survey sample targeted professionals of the Nigerian construction industry, i.e. Architects, Engineers (Civil/Structural and MEP), Quantity Surveyors, Builders, Project Managers and Planners. The professionals may be working under or as a designer (consultant), contractor, or client/owner. The client may also be a private developer or public sector (Government Ministries or parastatals). The snowball sampling is used in reaching to broader respondents, mostly contacted via their corresponding email addresses supplied to their respective regulatory bodies.

3.2.2.2 Data Analysis of Questionnaire Survey

The data generated from the questionnaire survey is quantitative in nature. Thus, the data was analysed statistically, and with the aid of the adopted macro BIM adoption models. SPSS software was used in the analysis of the questionnaire survey, such as a reliability test was carried out on the collected data. Descriptive statistic was used for analysing the barriers and drivers to BIM adoption. The adopters and non-adopters' perceptions on the barriers and the drivers were also evaluated.

The first aspect of the questionnaire survey data was analysed statistically, using the Relative Importance Index (RII) and Rank Agreement Factor (RAF). The barriers and drivers toward BIM adoption in Nigeria, perception of adopters and non-adopters of BIM were evaluated. More detail of the analysis method is presented in section 5.2.1.

The reviewed literature revealed how valuable and relevant the macro BIM adoption models are (in section 2.7.1), and justification for its use in this study other than using a different means (section 2.7.1.7). Succar and Kassem (2015) developed five new conceptual constructs for assessing macro-BIM adoption, and later they were extensively developed in (Kassem and Succar 2017). The latter paper refined the developed conceptual tools, developed additional assessment metrics for successful assistance to policymakers and domain researchers to analyse, develop and improve BIM diffusion policies within a construction market. The second aspect of the questionnaire survey applied those well-defined and justified by Kassem and Succa (2017) models to test the following:

- Diffusion Area model

- Macro-Maturity Components model
- Macro-Diffusion Dynamics model
- Policy Actions model
- Macro-Diffusion Responsibilities model

These five models were used in establishing the Nigerian BIM Maturity, which aims to assist the policymakers in developing and assess the macro BIM diffusion policies, strategies and plans within the Nigerian construction industry. And, that can be achieved through the application of the five conceptual constructs above. Figure 2.7 presents the structures of these five macro BIM adoption models. The details of these models are then presented in section 2.7.1.

3.2.3 Semi-Structured Interview

The semi-structured interview was conducted exclusively as input to the potential frameworks generated from the results of comparative analysis and questionnaire survey analysis. The body of texts is the most apparent and appropriate data for content analysis; its sources include written documents, audio (verbal discussions) and visual representations (Krippendorff and Klaus 2018). The mass media industry has been the core users of content analyses. Though, this method has been expanding into other industries' applications and academics. And, the open-ended interview is mostly deployed for those purposes. The semi-structured interview was conducted to generate data from peoples' experiences in a process to discover reality (Nieuwenhuis 2007). This section of the research is qualitative, which is vital for socio-technical research (Shin 2014).

3.2.3.1 Sampling and Interview Questions

A well-conducted sampling enhances coherence, transparency, rigour, and sensitivity to the context of a study (Smith and Shinebourne 2012; Robinson 2014), and ultimately assesses the research validity.

Sampling refers to a process used to select individuals or groups to participate as a subject in the collection of research data (Saunders et al. 2012). There are two main sampling methods for a research purpose; these include the Probability and Non-probability sampling. The probability sampling is sometimes called representative sampling, and it involves random selection within a sample population. Each member of the population stands a chance of being selected

(Saunders et al. 2012). While non-probability sampling is a judgmental selection for which generalisation is out of the contest, and criteria are generally set to choose sample use for research.

Bryman and Bell (2015) divided both probability sampling and on-probability sampling into four different types. The probability sampling has the following: simple random sampling, systematic sampling, multi-stage cluster sampling and stratified random sampling; and, the non-probability sampling has the following divisions: snowball sampling, purposive sampling, convenience sampling, and quota sampling.

The potential interviewees of this main research were selected from within the study population, and the sampled population. There is a four-point approach to sampling in qualitative research (Robinson 2014). Robinson (2014) outlines them as:

- Point 1: Defining a sample universe, popularly known as "target population."
- Point 2: Decide and adopt a sample size (range of sample size)
- Point 3: Develop a sample strategy (e.g. purposive sampling and specifications)
- Point 4: Develop the sample (Recruitment of participants from the study population).

The four-point approach to sampling was attained through the following:

- The target population was reached based on specific attributes (i.e. location - Nigeria, industry - AEC, and knowledge - BIM awareness). Thus, both inclusion and exclusion set of criteria are used to generate some level of homogeneity (Luborsky and Rubinstein 1995).

- Sample size/range is commonly influenced by both theoretical and practical consideration (Luborsky and Rubinstein 1995) in this study. It is dominantly influenced by practicality and availability of the participants adopting a guideline of 3-16 participants (Smith and Shinebourne 2012).

- Sample strategy was based on quota purposive sampling (Mason 2017) with set criteria (i.e. BIM awareness and usage, Extend of BIM utilisation, Profession, Role in the industry, and Location of practice).

- Sample development, only potential interviewees (those who scaled through point 3) were invited for the interview in line with the following "*potential interviewees should be informed of the study's aims, of what participation entails, of its voluntary nature, of how anonymity is protected and any other information that will help them reach an informed, consensual decision to participate*" (Robinson 2014)

The above sampling criteria are necessary for reaching quality information rather than quantity while meeting up the ethical requirements of the research. For instance, Alhumayn (2018) adopted eleven participants (as interviewees) in his PhD research which is also a value within the upper part of 3-16 (11) participants as a guide in the Smith and Shinebourne (2012).

Figure 3.7 presents the locations and number of interviews conducted within the study country (Nigeria).

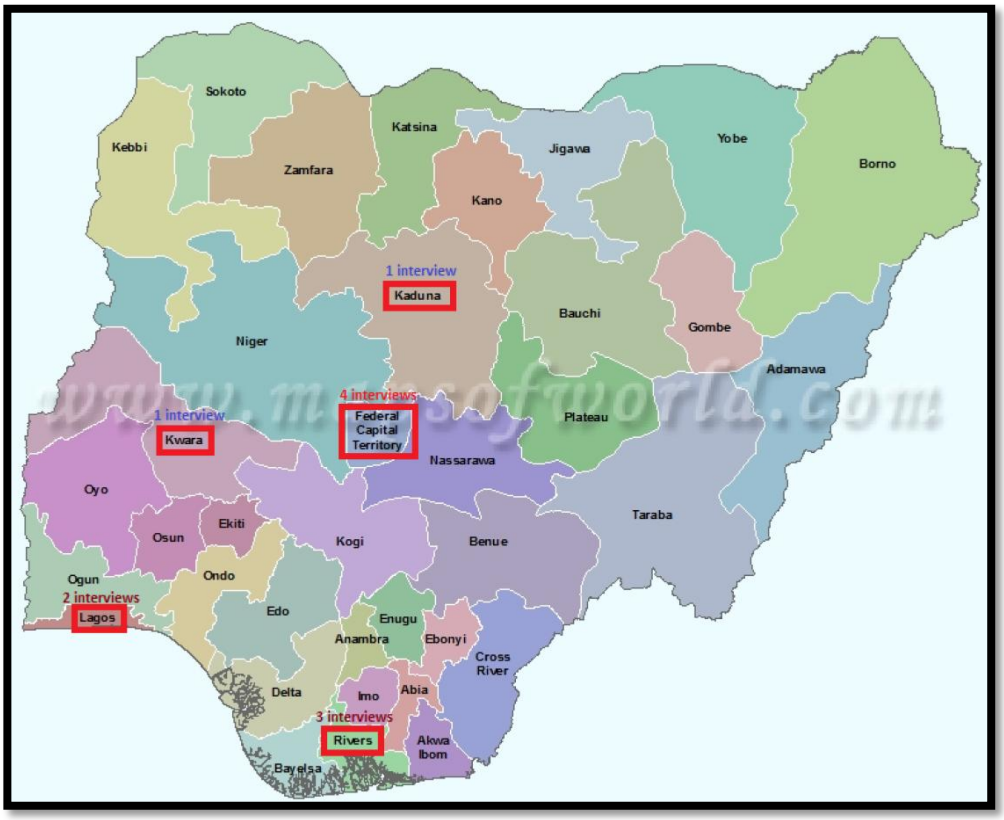


Figure 3.7: Locations and number of interviews in Nigeria

A total of nineteen (19) were evaluated as the potential interviewees, and consent letter was sent to them via email (see Appendix - 10). The letter was explicitly seeking their consent to be interviewed. The topic of interest was introduced in the letter as the interviewee has the right to know what the interview is all about. Out of the 19 sent emails, only eleven (11) replied and agreed to participate in the proposed interview. Thus, 11 interviews were conducted, and all have agreed to be audio recorded during the interviews.

The interview questions were generated under different themes and sub-themes. Some of the questions were for further explanatory (in-depth), while others were aimed to dig into their wealth of experiences on BIM adoption in the study market. Thus, these would provide the investigation with application-based knowledge of how BIM adoption could be adopted.

Forty-five numbers of questions were first taken to the interview (see Appendix - 11); but, the final questions and responses were reduced to thirty-six (36). This action is necessary to consolidate doubled responses/information. Some questions are strengthening and justifying others; thus, some responses reveal the same information, while some provide in-depth information to support the previous response(s).

After going through the responses over time, a total of eighteen (18) questions and responses were merged to form nine (9) questions and responses. The questions and answers merged are: 3 and 5; 4 and 28; 7 and 8; 19 and 20; 21 and 22; 27 and 34; 32 and 33; 35 and 37; and 43 merged with 44, refer to Appendix - 12. The merging of questions and answers is done to reduce the numbers at the same time, harmonise the responses to have streamlined outcomes and avoid fragment data/information. The questions are then categorised based on their intended aims. Total of thirty-three (33) questions was mapped with their aims, while the remaining three questions were used to draw the interviewees' demography. Table 3.2 presents the mapped question number with the aim of a question. This set of questions came into play from the barriers and drivers toward BIM adoption (p.175), the current status of the construction market (p.182) and lessons from the case study countries (p.93-94). This is in line with the philosophy underpinning the method of this investigation (refer to section 3.1.3.3, p.103).

Table 3.2: Question numbers mapped to aims

Q. No.	Question	Aim of the question
Q2	How and where did you know about Building Information Modelling (BIM)?	Means of Awareness
Q3	Based on your experience, can you describe what BIM is?	Understanding of BIM
Q4	What BIM tools or systems have you used or have seen being used by colleagues/clients, etc.?	BIM tools
Q7	What is your level of BIM utilisation as an individual and as an organisation?	BIM utilisation
Q8	What proportion of your projects benefited from the use of BIM and to what level?	BIM Implementation
Q9	How successful are these projects?	BIM Benefit/evaluation
Q10	What are the potential benefits of using BIM concept and what did you benefitted so far?	Potential benefits of BIM
Q11	What motivated you or your organisation to adopt the BIM on your projects?	Motivation/drivers of BIM
Q12	What do you think are the barriers against wide adoption of BIM in the Nigerian construction industry?	Barriers to the adoption of BIM
Q13	What challenges did you face before, during and after adopting BIM?	Challenges of BIM adoption
Q14	How did you manage these challenges?	Solution to adoption of BIM
Q15	What additional services have you been able to offer to clients because of using BIM?	Additional benefits of BIM
Q16	What is your experience with BIM as a new concept?	Experience
Q17	Is there any guide, protocol and standard to adopt BIM in Nigeria? Do you think a national guide (protocol/standard) is needed to adopt BIM? Or adopting other countries' guide will be appropriate?	Guide, protocol and standard in BIM
Q18	What form of contract do you generally use? Does the form of contract use adequate to deliver project where BIM is adopted?	Form of contract
Q19	What do you think if government plan to come up with policy on digitalisation in the AEC processes?	Policy regarding BIM
Q20	In the Nigerian government decides to mandate BIM as a standard way of working, how long (in years) do you think is realistically okay to prepare the industry for BIM implementation?	BIM Mandate
Q21	Any additional feedback on how this study can affect future direction of the Nigerian construction industry?	BIM study
Q22	If Nigeria would develop alliances with other international BIM promotional teams, who have developed guidance and support resources that could well be appropriate for Nigerian AEC. Would you support such strategy?	BIM alliance
Q23	Do you get BIM-trained personnel for employment or you get them specially trained?	BIM-trained personnel
Q24	Are the BIM tools available and affordable?	BIM tools available
Q25	Is the technology infrastructure adequate to support BIM concept?	Technology infrastructure (BIM

		related)
Q26	How would you think of government support on adopting BIM in terms of software, technology and infrastructure?	Government support on BIM
Q27	When building a model (at design stage) using BIM tools, do you have any challenge as to availability of objects or any building fabric within objects library as for Nigerian buildings?	Objects library
Q28	What was your level of participation (ROLE), please describe what method/ processes you used to specify roles/ responsibilities, requirements and deliverables?	Process roles/responsibilities (BIM related)
Q29	How ready your firm is to fully adopt BIM? And how ready do you think the industry and the government are to adopting BIM as well?	Readiness to adopt BIM
Q30	To manage BIM in Nigerian AEC, how do you think this process should be effectively managed?	Management – Process (BIM related)
Q31	Who do you think could play a better role in managing the BIM amongst the AEC stakeholders?	Management – Role (BIM related)
Q32	Who do you think could possibly take the responsibility of leading the BIM implementation?	Lead on BIM adoption
Q33	Where do you see yourself in the future in terms of BIM adoption/ implementation?	Ambition to BIM adoption
Q34	What is your time frame to fully adopt BIM in your process?	BIM adoption timeline
Q35	Who takes responsibility (cost) of using BIM on your projects? Who do you think should bear the cost of BIM process?	Cost of BIM
Q36	Do you have any comment that can help in setting out BIM adoption in Nigeria?	Solution to BIM adoption

The questions were developed in the form of documenting the benefits and challenges faced by local construction firms during adoption and implementation stages and beyond; at the same time identifying areas where improvements are required (Almuntaser et al. 2018; Alhumayn 2018). The two-pronged approach used as a method by Almuntaser et al. (2018) in developing a BIM adoption framework in the Saudi Arabian AEC industry sets a precedent in context-based BIM adoption framework. However, the Project Management Institute (PMI) framework might not necessarily be used considering the proliferation of the use of a template for developing a national BIM roadmap by many countries (ChangeAgents 2019).

The neutrality is achieved from the beginning of the data source (questionnaire response) where respondents came into play randomly, and the interviewees are from within them. The credibility, dependability, consistency and applicability were achieved through the set criteria of selection from the survey respondents. The set criteria were picked from the respondents' demography. The confirmability and trustworthiness are attained by reaching to the potential interviewees via email followed by phone calls.

3.2.3.2 Data Analysis

Since 1952, content analysis was known as an approach to the analysis of media text content to enable the generalisation of a result quantitatively (Berelson 1952). This approach (quantifying text) was quickly challenged and then developed further to a qualitative approach by the development of content analysis (Kracauer 1952). Bryman (2001) describes qualitative content analysis as a process of utilising textual data systematically in the development of new criteria. The concepts are driven and generated through the interpretation of respondents' statements (Wood 2001), and repetition of statements or words within the data generates significance to a criterion. Carney (1973) describes this method as a destination for most exploratory studies as in 'it gets the answers to the question to which it is applied'. Moreover, Roberts (1999) asserts that the ability of this approach to having coded data revisited at any time for confirmation makes it reliable for qualitative data analysis. Therefore, this method best fits the intended study.

The interviews were transcribed and coded with the aid of Nvivo 11 software. A qualitative content analysis was used to analyse the generated data based on pre-identified themes; the following steps were taken as described by Kumar (2011):

- Identify the main criteria
- Assign codes to the main criteria
- Classify responses under the main criteria
- Integrate the requirements and answers into the report text (Kumar 2019).

An in-depth study of the work involves a qualitative analysis. Qualitative content analysis is thus deployed for analysis of the data from the semi-structured interviews conducted. Matthew et al. (1994) prescribed the components involved in qualitative data analysed. An interactive model is generated (see Figure 3.8) to graphically present the components of data analysis as described by Matthew et al. (1994).

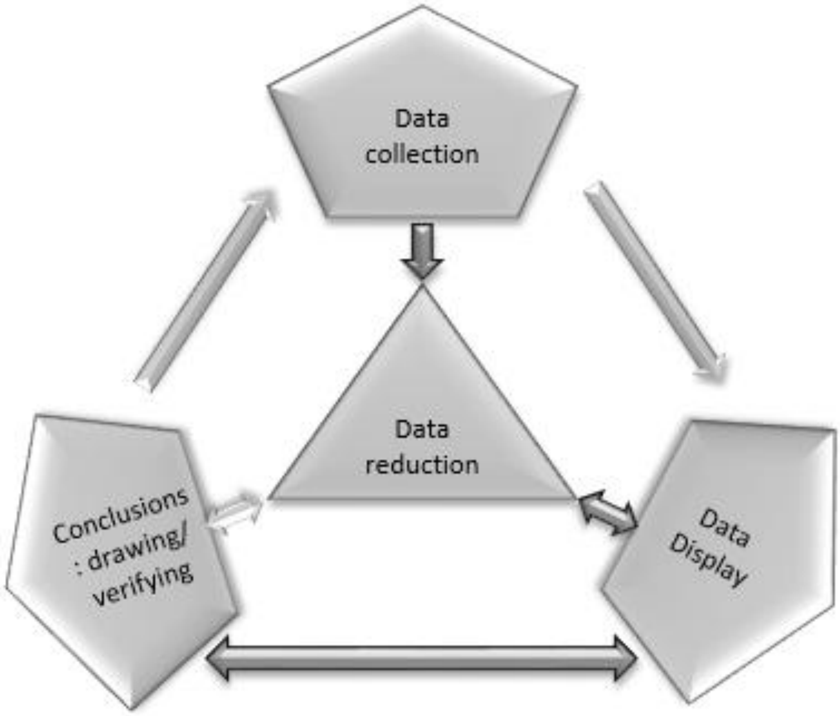


Figure 3.8: Components of data analysis; Interactive Model (Matthew et al., 1994)

Stemler (2000) explains content analysis as a technique of compressing body of texts (words) in an organised and replicable manner into a fewer categorised content through explicit coding rules. The content analysis allows easy examination of a large volume of data in a systematic method (US GAO 1996). The content analysis also provides an empirical basis for establishing patterns and trends in texts, documents, and even the impact of policy changes in society (Stemler 2000). This study design is in line with the six questions that should be answered using content analysis (Krippendorff 2018). These include the following: the data to be analysed, how the data is defined, the sample population, the context-based consideration, the analysis boundaries, and the target implications.

Given the above questions, interview data are analysed, which are defined from BIM adoption themes, drawn from the population of BIM adopters, and BIM field types are the relevant context. The boundaries of analysis are BIM adoption challenges, successes and drivers; while, effective strategy for BIM adoption in Nigeria is the target inference.

The most common perceptions on qualitative analysis of data, and content analysis in specific is word frequency count. It is mostly assumed that words with higher frequencies produce the sections of interest. It is evident in some cases, but not in all situations. For instance, there are some cases where the word is often found to carry different meanings at different locations in the same body of texts (under the same or different theme(s)) (Stemler 2000). And, some cases where different words meaning the same thing, under the same category but hardly count together. Besides, not every expression represents a category equally, meaning not every word in a group has equal weighting. Hence, these may be considered as a limitation, and thus, in performing word frequency count, researchers should bear in mind that some words may have multiple meanings, and some may have universal implications (Stemler 2000).

The content analysis technique is far beyond the word frequencies or word count, still, the richness of this technique is attributed to the confidence in the coding and the data categorisation. The category concerning the classification of data is a group of words or phrase with parallel meaning or connotations (Weber 1990). US GAO (1996, p. 20) states that the "categories must be mutually exclusive and exhaustive". The categories can be mutually exclusive as long as no element or unit falls between the two data points, and both the two elements are individually characterised by a data point only. While the exhaustiveness is having the data contain all recorded elements or unit without exception. The content analysis claims to the generality of finding(s), it, however, has some inherent limitations (Krippendorff 1989); these include:

- It requires many units of analysis to achieve a statistically significant finding, and that leads to quantitative commitment
- It favours the utilisation of contextual data that is stable and with unambiguous interpretations
- Its conclusions are not generalised beyond the given data if its categorisation is done base on the very material; and, if a general theory is applied, the findings tend to overlook much of the uniqueness and richness of the data in hand.

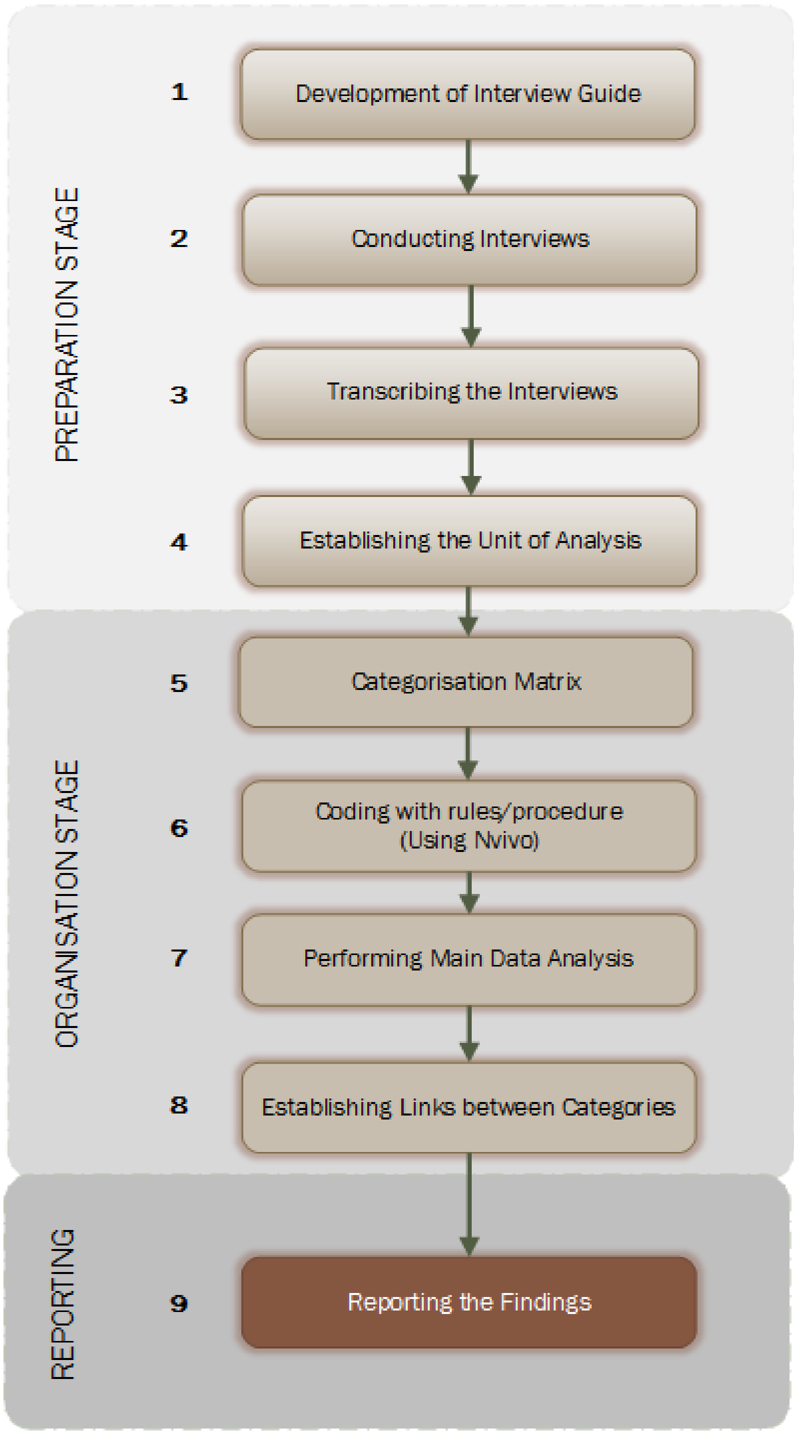


Figure 3.9: Process of the Qualitative Content Analysis (Adopted from Assaroundi el al., 2018)

The qualitative content analysis involves sequencing and process of data generation (preparation), organisation and reporting of result (Assarroudi et al. 2018); this is summarised and presented in Figure 3.9.

Reliability of tools in qualitative research remains a debatable area due to the kind of data involved. It is as a result of the focus on the perspective of human understanding and phenomena in the study (Cohen et al. 2013). The qualitative research struggles to demonstrate multiple interpretations of connotations assigned to conditions and actions (Brock-Utme 1996). Therefore, reliability in qualitative research is viewed as suitable information recorded as data by a researcher, and what is actually in the natural setting of the subject under investigation. Remarkably, some authors advocated that reliability in qualitative research should be exclusively considered with the following terms: neutrality, credibility, dependability, confirmability, consistency, trustworthiness, applicability, and transferability (Winter 2000; Stenbacka 2001; Golafshani 2003) rather than the impractical canons for quantitative research (LeCompete and Preissle 1993). Because typical quantitative research requires a degree of control and manipulation of phenomena, however, control and manipulation of occurrences in qualitative research may change the natural occurrence of events. Ultimately, a particular technique is adopted repeatedly to the same object that would yield the same result each time.

The main headings under BIM field types are the Process, Policy, and Technology; thus, considered as the themes. Although the vital aspects to determine the challenges and opportunities in the study market were not contextually established, thus 'understanding, awareness, readiness, motivators/drivers, and benefits' are highlighted as subjects. Furthermore, the three BIM field types were structured under both the barriers to adoption and solution to the adoption of the BIM in the Nigerian construction industry.

Consequently, the qualitative content analysis was carried out under a structured categorisation in the following themes and sub-themes format:

- Understanding of BIM in Nigeria
    - Means of Awareness
- BIM Awareness in Nigeria
- Readiness to Adopt BIM
    - Availability of BIM Tools
    - Level of BIM Usage (implementation)
    - Availability of BIM Trained Personnel
    - Availability of Technology Infrastructure
- Motivation and Drivers Toward BIM Adoption
    - Evaluation of Drivers Toward BIM Adoption

- BIM Adoption Benefits
  - Context Benefits of BIM Adoption
- BIM Adoption Barriers/Challenges
  - Process-based
  - Policy-based
  - Technology-based
- Solution to BIM adoption
  - Process-based
    - ✓ Management of BIM
    - ✓ Who to Lead BIM Implementation
  - Policy-based
    - ✓ BIM Policy – Mandate Timeline (for the industry)
    - ✓ BIM Adoption Timeline (for the firms in question)
  - Technology-based.

The structured categorisation was carried out to allow proper abstraction of information within the transcripts. That has been achieved using categorisation matrix as described by Elo and Kyngas (2008). For instance, one of the main categories is "solution to BIM adoption" with a generic categories "process, policy and technology" which are derived from previous studies or literature with more detailed sub-categories (Elo and Kyngas 2008).

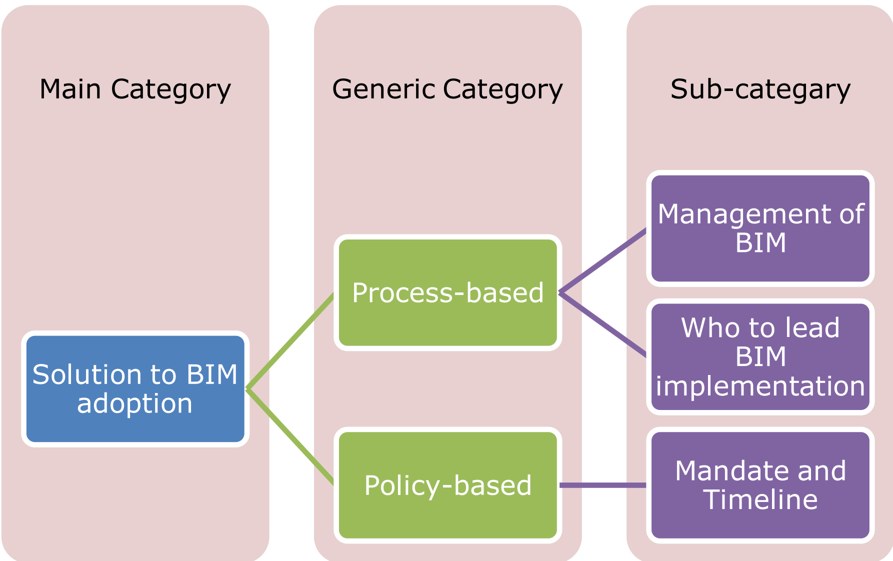


Figure 3.10: An example of the abstraction process for categorisation

Figure 3.10 demonstrates the abstraction process under a single category. The structured categorisation is deemed necessary to comply with the aim of this study

(Marshall and Rossman 1995; Kyngas and Vanhanen 1999; Robson 2002). Furthermore, coding of relevant and corresponding information follows using the categorisation matrix according to Kyngas and Vanhanen (1999), and this has effectively achieved with the aid of Nvivo application software. Table 3.3 presents a sample (from question number two) of how the categorisation matrix is used to abstract information.

Table 3.3: An example of categorisation matrix

	Dependence (event-based)	Means of awareness	Effectiveness	Concern(s)
How and where did you know about Building Information Modelling (BIM)?				

Information from every question is coded under different categories while equally responding to a specific query.

3.3 RESEARCH ETHICAL CONSIDERATION

The ethical consideration is one of the research segments that needed to be explored before or during research planning. There are potential ethical issues with studies involving mostly human, animal, plant, and environment (Silverman 2013). The ethical concerns were considered before undertaking the collection of data and the analysis. These can be noticed from the methodology adopted to any potential harm to the research participants. The process was conducted following the legal and ethical requirements of the Robert Gordon University (RGU). Consent of a research participant, the confidentiality of information, and trust are considered as the main areas of ethical concerns regarding qualitative research (Ryen 2016).

To maintain the integrity of the research and security of data the RGU's ethical conduct was considered and duly followed; especially in the guidance covering the treatment of participants (i.e. informed consent, and confidentiality & anonymity). RGU's Research Ethics Policy is included in Appendix - 14.

The major area that requires ethical consideration in this study was the use of an interview as a tool for data collection. A semi-structured interview was used, and that involves tape recording of the interview sessions. The interviewees were informed of the purpose of the interview, and their anonymity and confidentiality were assured in the introductory and consent letter (see Appendix - 10). In the opening statement of interview sessions, the ethical issues were raised in seeking their permission before the commencement of the interview. All the interviewees agreed to that. Every interviewee's consent was pursued before the audio recording of the interview. More so, their personal details have remained anonymous, as presented in *Table 9.1*.

The raw data generated from the research participants will no longer be of interest once the research is completed, and a minimum data retention period is reached. The information generated is in the risk of falling into the third party's hand, which is disposed to ethical compromise. To mitigate the bridge of data access the raw data from the questionnaire survey output and the interview scripts shall be destroyed at the end of the research and the data retention period stipulated by the RGU's ethical guide. Thus, research data destruction requires authorisation by the University. Once formal permission is received from the University to destroy the research data, it is crucial to destroy the data in a way that ensures the information cannot be recreated (University of Western Australia 2020).

3.4 CHAPTER SUMMARY

This research activity consists of two main sections; the first section is quantitative in nature as it deals with "How much are BIM being utilised?" It involves the application of five macro BIM maturity conceptual models, establishing BIM maturity within the study context. And the second section is qualitative as the sequence and procedure of qualitative content analysis is adopted. And lastly, ethical issues and guide under the University's research ethics policy are presented.

The overall methodology of this research consists of a pacifying process in which different methods were adopted to investigate the problems. A purely quantitative study is used to explore the industry's stage in the BIM adoption; while on the other hand, a qualitative method is used to analyse the challenges and opportunities while paving a way to developing an effective strategy for the BIM adoption in the study country (Nigeria). Succinctly, a mixed-method is used in achieving the research objectives.

CHAPTER FOUR: EXPLORATORY STUDIES

4.1 CHAPTER OVERVIEW

In chapter three, the methodology and philosophy underpinning this research were presented and explained.

This chapter presents the analyses and results of exploratory studies undertaken to fill the literature gap observed in the early stage of this research; there was limited literature identified in the relevant context (see section 2.9). The study was undertaken through a one-to-one interview and a questionnaire survey. Qualitative and quantitative data were generated from the interview and questionnaire survey, respectively.

The interview data is analysed using qualitative content analysis, and the state of BIM adoption in Nigeria was determined. As a complement to one of the findings in the qualitative (interview) study, another enquiry was made (through questionnaire survey) as to determine the readiness of Nigerian Universities to train students on BIM tools and the level of BIM training they currently offered.

The questionnaire survey data was analysed using descriptive statistics, and the concept of diffusion of innovation was deployed to determine the status of BIM awareness and adoption concerning other countries (USA, UK and South Africa) to appreciate the level of BIM diffusion in the construction market.

The exploratory studies revealed the levels of BIM awareness and adoption in the Nigerian construction industry, the level of BIM tools' training and training capabilities in the Nigerian Universities. The state and status of BIM awareness and adoption were established both qualitatively and quantitatively. The exploratory studies set to acquire information for a better understanding of the industry; thus, providing a base on which the research can genuinely built-on.

4.2 INTRODUCTION TO THE EXPLORATORY STUDIES

At the beginning of this research (in 2017), a longitudinal review of the literature was undertaken within the context of Nigeria vis-à-vis the BIM trend, status and its barriers. The review revealed BIM related information from different states (locations) on separate professions and specialities. The previous investigations within the Nigerian AEC industry were dominantly on consultants (designers), within specific areas, and achieved through a questionnaire survey. These studies are summarised and presented as Appendix – 1. These studies revealed limitations on direct (face-to-face) interactions with the professionals from the design and construction domains as well as the clients. One could not authoritatively conclude a unified status of the Nigerian BIM development and adoption trend. Consequently, exploratory studies were suggested to fully understand the Nigerian construction market on which the primary investigation can build on.

The exploratory studies are three in number and are described as follows:

Exploratory study 1 - State Of BIM Adoption in Nigeria (Qualitative Approach)

Exploratory study 2 - Higher Education Institutions Readiness to BIM Training

Exploratory study 3 - Diffusion of Innovations: Status of BIM Uptake in Nigeria.

The exploratory studies were designed to fill the observed gaps in the literature as such sample size is not significant to represent the main investigative study. The exploratory studies' design included the development of interview questions based on the pending challenges discovered in the previous investigations (exploratory study 1); followed by a questionnaire survey to observe the diffusion level considering two developed countries and one developing country as precedents (exploratory study 3). While the exploratory study 2 came into play as a result of two yarning issues. The man-power challenges reported by most of the previous studies, and the finding from the qualitative research (exploratory study 1); that the industry is battling in getting a BIM-trained professional graduate from the Nigerian Higher Institutions (HEIs).

The exploratory studies questions were drafted basically from the predominant assertion of the low-level BIM awareness and knowledge, lack of trained professionals to handle the BIM tools, and further to the legislative provisions on the deployment of BIM in the industry. With regards to the BIM training in the HEIs, the questions were generated toward assessing their training capabilities and current level of training. Ultimate, qualitative and quantitative exploratory studies compliment the respondents' reliability and diversity in the current situation.

4.3 STATE OF BIM ADOPTION IN NIGERIA (QUALITATIVE APPROACH)

The level of BIM adoption is relatively high in most developed countries, but there remains a long way to go in developing countries regarding BIM adoption, especially Nigeria. Despite several years of discussions and research in the area of BIM and its adoption, the Nigerian construction industry received no attention in terms of academic discussion until 2013. In 2013, the first conference paper (Readiness of Nigerian building design firms to adopt building information modelling (BIM) technologies) by Abubakar et al. (2013) came into the academic mainstream. It was the first attempt to study BIM in Nigeria, although mainly it was very limited in context (focused on designers only). Moreover, the study was focused primarily on assessing the readiness of the first line adopters of BIM in the industry. A Structured questionnaire survey (generating quantitative data) and semi-formal interviews were used for data collection, and quantitative analysis is dominantly utilised as a method of their investigation. The research was due to lack of clarity on whether the industry was ready or not to adopt the BIM technology, which is a sign of a starting point or "readiness ramp" (Succar 2014). The BIM starting point in Nigeria wasn't yet evaluated on its awareness or usage but searching for a significant match towards the adoption.

There is a lack of direct input (interview) by critical stakeholders of the industry, which can be noticed in the eleven available published works. The literature within the study context concentrated on trying to assess BIM (within a limited profession or location) - there was no attempt to identify the present stage of development of the key BIM fields (Technology, Process and Policy).

Moreover, no NBPs were identified within this study context is available. This exploratory study aimed to examines the extent of BIM adoption in Nigeria. Awareness and adoption levels of BIM are examined; challenges and the possibility of its broader adoption in Nigeria are discussed.

This component of exploratory studies aimed to determine the state of BIM awareness, adoption and challenges from the key players' (designers, constructors and the client) perspective. The objectives are to: evaluate BIM awareness and knowledge; identify adoption challenges.

4.3.1 Exploratory Study Design

A qualitative approach to content analysis is considered as a suitable approach to this exploratory study (Carney 1973). This is deemed to be ideal as the study is exploratory based. Generally, exploratory studies are based on a nonprobability sampling of respondents. While its analyses have been frequently used to create hypotheses for further research (Guest et al. 2011); and, it is focused on fewer respondents as reported by Marshall et al. (2013) which is on the bases of single case qualitative methodology.

The interview questions are semi-structured; the 'open-ended' questions allow additional information from the interviewees. It is critical to explore what is missing notably from other studies that mostly deployed questionnaire survey. It is then beneficial to the entire study in positioning the Nigerian construction market into its right state/position and help in preparing the right questions in the investigative study.

4.3.2 Data Collection

This section focuses on the data generated from the exploratory study participants and their demography. Semi-structured interviews with consultant, contractor and the clients/authority who are all stakeholders in the industry were carried out. The method adopted allowed the interviewees to interact freely, express their views and comment on general aspects of the vital area, hence providing the opportunity to the interviewer generate direct, relevant and additional information (Trumbull 2005).

The study sample involved 4 participants who are the critical parties in the built asset procurement process and, by association, BIM adoption. This sample was selected by considering their importance in the industry's decision making as well as the priority of purpose. The sample consists of three parties (consultant, contractor and client) each having one representation plus an additional one from a client who happened to be representing a development control body (public sector). Ryen (2016) assertion of "research subjects have the right to know that they are being researched, the right to be informed about the nature of the research and the right to withdraw at any time" was accomplished. Requests for the interviews were sent via email with highlights on the research subject and objectives; they (interviewees) subsequently responded with a schedule for the interview. In consideration of the research ethics and privacy policy, the consent (with the condition of anonymity) of the interviewees was sought to audio-record the sessions which were granted, and the interviews lasted between eight to twenty-two minutes. The transcribed interviews are presented as an Appendix - 5.

4.3.2.1 Respondents' Profile

Interviewee 1 – Contractor Project Manager (CPM): This is a construction professional with over ten years' experience as a project manager in Nigeria. He works with a highly reputable construction company with a head office in Abuja. The construction firm is highly specialized and interested in building construction works; moreover, they also carry out road construction works. At the time of the interview, the project manager is managing a project worth about $30 million. This company is representing the top category of contractors in the country (Nigeria).

Interviewee 2 – Client Engineer (CLE): Is a civil engineer working at managerial level with a government authority. The government authority is serving as client representative as well as development control body to the Federal Capital (Abuja) of Nigeria. The authority is also a pilot organization for implementing new government policies regarding innovations in the construction industry.

Interviewee 3 – Client Architect (CLA): An Architect working at decision-making level with the same organization as Interviewee 2. Moreover, this respondent happened to be amongst team members piloting e-procurement back in the 2000s. Also participated during a move by the Nigerian government to actualize e-governance initiatives in the same period.

Interviewee 4 – Consultant Architect (COA): A reputable and experienced Architect that worked previously with a highly established AEC firm in Lagos for several years and is currently Managing Director of a medium scale architectural firm.

The table below Table 4.1 presents the summary of the participants' company profiles:

Table 4.1: Participants' company profiles (Author generated)

Interviewees	Organization size	Organizational Annual fee volume	Organization Role	Project type	Organization location
Interviewee 1 (CPM)	>20 staff (large)	>$10M (large)	Contractor	Mainly building works, then road construction	Abuja, Bauchi Gombe, Jigawa Kaduna, Kano and Lagos
Interviewee 2 (CLE)	>20 staff (large)	>$10M (large)	Client	Building and Infrastructure	Abuja
Interviewee 3 (CLA)	>20 staff (large)	>$10M (large)	Client/development control	Building and development control	Abuja
Interviewee 4 (COA)	10-20 staff (medium)	>$500K-10M (small-medium)	Consultant	Building works	Kaduna

The interview questions were specifically made flexible enough to explore participants' experiences and trends of innovation in their respective organisations. While allowing themes to emerge, the questions were based on previous studies (literature) and the main research objectives.

4.3.2.2 Method of Analysis

Using the identified steps (Figure 4.1) by Creswell (2009), the fetched data from the conducted interviews (Appendix – 5 p.285) were analysed thoroughly and rationally through qualitative content analysis thereby achieving a precise interpretation of interviewees' knowledge and abilities (Spiggle 1994).

Following the successful interviews, the transcribed interviews are considered to be raw and primary data. The data are then coded, based on the pre-identified criteria from reviewed literature (McAuley et al. 2017).

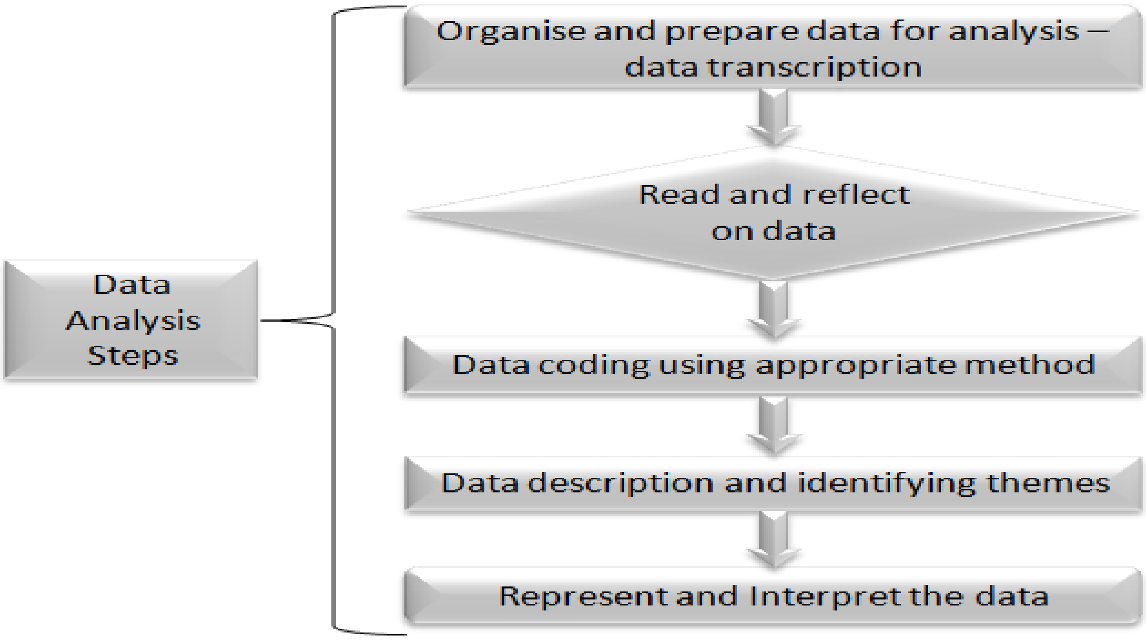


Figure 4.1: Data Analysis Process (adopted from Creswell, 2009)

Based on data analysis, three criteria were recognised. These will be presented in section 4.3.3.

4.3.3 Analysis and Discussion

The study findings are presented in three main criteria. The three criteria are; Level of Awareness in the critical areas of BIM, the evaluated capabilities of the stakeholders, and BIM adoption and challenges in the industry. These criteria are identified based on the study purpose and of course, reflected from the questions asked at the interview. Although the transcription language has not been tidied, quotations were used to justify this study assertion.

4.3.3.1 BIM Awareness and Knowledge

There is little knowledge of BIM, even at the awareness level. The practitioners' point of view is that they have limited knowledge in terms of awareness of BIM. For example, Interviewees CLE and CLA disclosed that:

> "My knowledge on Building Information Modelling is pretty below limited, is an area that I will say I heard of it virtually today through the research student and it appears quite exciting to me…" (CLE)

> "…my knowledge is restricted to a general sense, and we don't have that here…" (CLA)

Their response is surprising given their backgrounds, as previously stated.

On the other hand, some of the stakeholders debunked portrayed a lack of clear understanding of the term 'building information modelling'.

> "Am not aware of anything Building Information Modelling." CPM

> "To be honest, this is the first time I am hearing about building information modelling." (COA)

Moreover, after going deep into the conversation, they had used some of the lower level BIM tools (2D and 3D CAD systems). Hence, there is an indication of limited and low-level BIM tools utilisation: a little trace of 'file-based collaboration' with 3D CAD for object visualisation and appreciation.

> "…the one we are using is coming from consultants even, the consultants we are working with are using that 2dimensional AutoCAD," (CPM)

> "…I have used AutoCAD, yes, Civil CAD, yes, but know it to have harmonise it into BIM I will say no, but as isolated software for design, yes…" (CLE)

> "…I do a design in AutoCAD," (COA)

There is an indication that the firms use some couples of BIM tools within their organisations only, not in collaboration with other firms as this is referred to as 'lonely BIM'. This is happening mostly from the highly developed (multi-disciplinary) consulting firms, they revealed they have been practising collaborative design at their organisational level only.

> "…the firm has its own in-house engineers: Mechanical, Structural and everything; we come together within the office…; and do all the design within the same software that we have. Do that in-house not with any other consulting firms…" (COA)

The above reaction indicates limited usage at their level and adopting the working process within a confined environment. As such, the extent of awareness and the usage at that level remained low and limited.

4.3.3.2 Stakeholders Capabilities

It was perceived that the consultants are relatively using some BIM tools (i.e. AutoCAD and Revit), while not knowing them as BIM tools, and also not utilising them to their full potentials (i.e. collaborating and integrating via the tools rather than the opposite).

> "I know software like Revit does that to some extend and then like 3D Home views" (COA)

It was observed that the contractors are reliant on the kind of tool consultants (designers) used at the design stage. They mostly adopt what the consultants are using because of their interdependence. Thus, they do not mind using whatever the consultant uses and provides them with; while it was observed that the designers are the first line of adopters (Abubakar et al. 2013).

"…the one we are using is coming from consultants even; …2D AutoCAD." (CPM)

Government is a major client for the construction sector in Nigeria and, moreover, a client for big/major projects in the country. One of the interviewees revealed that the Federal Capital Development Authority (FCDA) is the pilot organisation for the adoption of innovation in construction (i.e. e-tendering) as well as e-governance.

> "… FCDA is the pilot agency in the entire country ...because we are more likely to succeed, then other Agencies were to key in and learn from us…" (CLA)

The members of the authority (FCDA) have been using some BIM tools for infrastructure (i.e. AutoCAD and Civil CAD) development, especially for design. However, the usage level is not such as to integrate their system, but rather for design and design checks only.

> "…yes, AutoCAD yes, Civil CAD yes, but know it to have harmonise it into a BIM I will say no, but as an isolated software for design, yes I have used it severally for infrastructural design works…" (CLE)

There is a strong indication that the knowledge of BIM tools and the concept is more prominent with the consultants (designers) than clients and contractors.

Such is also revealed by some early studies like (Abubakar et al. 2013), and this vindicated the assertion in the BIM+ and construction manager's survey of 2017 in the UK, that local authorities did not understand BIM "…and that more than 70% of clients, in general, did not understand the benefits of BIM" (Richard 2017).

4.3.3.3 BIM adoption challenges

None of the interviewees ever participated in a project where BIM is deployed. This can be seen as an evident lack of understanding and participation (BIM adoption) by professionals in collaborative working. However, a 'lonely BIM' at modelling and collaboration stage can be noticed with the highly established consultancy firms.

> "…the firm has its own in-house engineers: Mechanical engineers, Structural engineers and everything; …and do all the design within the same software that we have. Do that in-house not with any other consulting firm…" (COA)

Most of the countries where BIM adoption is dynamic have some level of government participation or even policy and guidelines for BIM adoption. In the case of Nigeria, there is no explicit legislative provision on the use of software and other innovative aids in the construction industry, as explained by the Interviewees. Lack of contextual guideline can be a setback to BIM implementation; such can be noticed in countries like UAE (Valappil and Saleeb 2016). Regulatory bodies and development control agencies are typically enforcing building codes (mostly British Standards (BS) and Code of Practice (CP) etc.).

> "For a policy regarding use of software, explicitly stated no!" (CLE)

> "I will not tell you out rightly that am aware of any kind of legislative backup…" (CLA)

> "Legislatively, there is none!" (COA)

An Interviewee (CLA) from the Federal Capital Development Authority (FCDA) discloses that there was a plan for adoption of digital procurement funded by the World Bank and the United Nations Development Programme (UNDP). He further revealed that the Federal Capital Territory (FCT) minister then (2003-2007) was fully committed and involved in actualising that, but after he left, all the process subsequently stopped. Moreover, no planned implementation of that policy was in place, and every aspect of the programme virtually failed. Also, it was noticed that there is no policy to enforcing the use of new design or construction tools (i.e. BIM).

> "…No legislative support and no any policy enforcement in relation to use of software. Since there is no policy, then the enforcement cannot come in." (CLE)

> "…am not aware there is any legislation, …e-procurement for now is just an option." (CLA)

> "Legislatively, there is none! That is why am even looking at the institute (Institute of Architects) basically entirely…, …Since there is no legislation in that regards, then no legislative backup to enforcing this process" (COA)

It was observed that sufficient funding is one of the challenges of digitalisation in the industry. However, while there are a few interventions from some government agencies, these still do not work, as the intended digitalisation in the pilot Authority (FCDA) has also stopped.

> "...I do know that federal ministry of science and technology is doing something in that regard, and then we have some Agencies that has been assisting, like NITDA..." (CLA)

The effort of digitalisation (e-procurement) at the pilot agency has failed. As proclaimed by the interviewee CLA. The earlier proposed e-procurement suffered many setbacks, amongst which was the resistance by contractors to register online; this has been the case for over a decade.

> "Now when we wanted to launch a pilot for e-procurement, for example, one of the requirements entail having contractors to be registered in our electronic data base and that is where we were stocked because most of them were not compliant…" (CLA)

For the authority, they have a keen interest and appear ready to adopt BIM, although their understanding of it is quite limited. Funding has been considered a big issue, coupled with a lack of experts in the field of BIM adoption and implementation. On the other hand, there is a need for an articulated proposal to the government regarding BIM potential benefits to the country's construction sector. Those who know it very well are expected to play a vital role in informing the government. At the same time, a firm pledge is required by the heads of government agencies and parastatals to begin the adoption and implementation of BIM.

> "I think the government is more than ready and willing to do that… …there is no knowledge, no expertise along that area at all; I think BIM is when a proposal is articulated well and presented to the department of engineering (FCDA) I am sure we would work toward that line to make things much easier for us, we appreciate this." (CLE)

> "Am a government person but unfortunately I have to speak to you from personal point of view, we need a champion, everything we achieved here it was because of Nasiru El-Rufai, he was personally interested, he was personally involved." (CLA)

Unreliability of electricity is one of those factors associated with speedy ICT adoption everywhere, including the construction industry. However, Nigeria has suffered from a significant shortage of power for decades (Adhekpukoli 2018).

> "…there is a major problem of power; if you ask me, I think power was one of the major reasons that has stolen the development… …we had issues even with the people we are supposed to be serving and the ever issue of power that will always remain the big problem if we are going to embark on any endeavour…" (CLA)

For a clear record here, based on the Interviewees responses, it has been established that power is one of the significant challenges posed against technology adoption and BIM adoption in particular.

4.3.3.4 Thematic Finding

Contractors are associated with the lack of BIM tools utilisation with the type of training received by graduates of higher institutions (university). New, innovative ways of working are not taught in schools, which is why the old ways remained. Also, the trend of the adoption should start from training in Universities to designers and subsequently, the contractors.

> "The best way to adopting this system is marketing, and the marketing must start from school. Because whatever training I get from school will be what to be using until I get training with this BIM; …the marketing will start from schools" (CPM)

There are also issues with the professional societies and regulatory bodies; the innovations should have been driven by them, with an example of this seen in the USA (Hamma-adama and Kouider 2019). But, many professionals are yet to be digitally literate.

> "…by the way one need to understand that not everybody within the profession is also digitally compliant." (COA)

The professional organizations should have been the focal points for professional developments; centres where innovations are introduced, marketed and even trained. Consultants perceived the same idea of BIM adoption as in the USA where US Institute of Architects initially leads its adoption before the governments' intervention as also identified in section 2.8.1.

> "It's quite a good initiative; …presented and accepted by the professions within the industry before…the process of being legislated upon by the government…" (COA)

Succinctly, the lack of BIM trained personnel which is associated with the training received in the higher institutions, and also the lack of involvement of professional societies coupled with low awareness contributed to the lack of BIM adoption. No legislative provision for BIM adoption leads to no regulation to its usage. Moreover, there is no trace of BIM demand by clients (public or private), as it has been seen in places like Sweden (Davies et al., 2015).

4.3.4 Results and Conclusions

The purpose of this exploratory study was to determine the state of the key BIM fields (Technology, Process and Policy) from the key construction industry players (designers, constructors and the client) in the Nigerian AEC. The exploratory study reveals that there is a misperception of the term "BIM" or "Building Information Modelling". However, many are aware of the tools without recognising them as BIM-related technology, and without knowing BIM as a process. Thus, the industry professionals are not very clear about BIM as a process, nor do they have a clear understanding of its working process. There is a low level of BIM awareness across the entire body of stakeholders, especially clients and contractors, coupled with a significant deficit of experts in the required technology. Lack of accessibility to the technology and power (electricity) issues combine with a lack of streamlined BIM adoption process and professional societies’ involvement; no policy and guideline or regulation to adopting BIM process. There is a trace of adoption within designers at the organisational level only.

Thus, to facilitate adoption, the following recommendations are made based on the interviewees’ narratives:

Presenting a comprehensive proposal (by the professional societies) to the government, proposed a government-driven policy; development of an all-in-one blueprint for effective adoption; improve awareness and training by developing a useful adoption framework.

4.3.5 State of BIM Adoption Summary

The analysed interviews revealed that the key players are generally not familiar with the term “Building Information Modelling” or “BIM”. However, they are mostly aware of some of the BIM tools (i.e. AutoCAD, Revit, etc.). Only a few used some BIM tools were identified at the organizational level (lonely BIM), as was some evidence of model-based collaboration (BIM stage 1) or BIM Level 1. Furthermore, no legislative provision on BIM adoption nor regulation of its usage was noted. Moreover, the government is open to embracing an innovative way of working to promote and advanced sufficiently regarding viability. A lack of BIM experts is a significant barrier to BIM adoption at all levels. The study recommends a comprehensive proposal by professional societies to the government; propose a government-driven policy, and development of an all-in-one blueprint for BIM adoption, if the industry is genuinely minded to compete with its global counterparts.

4.4 HIGHER EDUCATION INSTITUTIONS READINESS TO BIM TRAINING

The exploratory in section 4.3 revealed concerns on the BIM technology skill gap in the industry, with one of them pointing to the training institutions (universities) as the causes of the BIM knowledge gap. The institutions are argued not to be producing the required confident and competent graduates on BIM tools (Hamma-adama et al. 2018b). Suggests that, the industry staff should be trained in the new process; otherwise, it becomes difficult to adopt BIM.

Thus, the above assertion necessitates an enquiry to assess the extent/level of students' training in this context. Therefore, a questionnaire survey was designed to investigate this challenge and was presented based on the research areas outlined below:

- BIM tools' training requirements in terms of training personnel, computer lab, computer hardware & software
- The proficiency level of training
- Proficiency level at graduation.

These research areas are selected to assess the technology capability field type in the BIM fields (Succar 2009) in terms of training.

4.4.1 Introduction

Computer-Aided Design (CAD) began to be developed in the 1960s. Since then, technologies have continued to evolve, with the main change being from Computer Assisted Drawing to Computer-Aided Design. CAD technologies development is driven by the industries' applications (notably, manufacturing) (Dill & Kasik, 2012), but research remains the basis. Major manufacturing companies strongly backed the development of CAD systems at their early stage (Ye et al. 2004).

Regardless of how CAD technology and the industry evolve, students in Universities want to acquire technologies that can best aid their career. Rossignac (2004) identified many benefits to education-driven research in CAD, amongst which is helping students to understand its core aspects quickly, and to be able to put what they learn to good use immediately. It is a source of instant gratification and motivation for a student to practise and learn more in this way. Although it could be challenging to provide necessary needs to include Building Information Modelling (BIM) training in university education, it is argued to be the right step to prepare the future employees (construction professionals) for the industry

(McGraw-Hill 2008).

Barison and Santos (2010) reported on a 2007 BIMForum survey of eight USA academic institutions regarding their level of BIM training, and it was found that more than 80% of them taught BIM in their courses. Even the minority (<20%) had introduced BIM in their teaching curricula since 2002. This has, of course, has helped the USA to be at the forefront of BIM adoption and also with its widespread use even before the government legislated it use (Casey 2008; Hill 2014). However, developing nations are lagging in BIM awareness, adoption and the number of BIM experts (Eadie et al. 2013, Froise and Shakantu 2014); could this be due to a shortage of knowledge? Consequently, lack of BIM software skills poses a significant challenge to graduating students.

It can be understood that the CAD knowledge and skills needed by students vary from profession to profession, person to person, job to job, and perhaps the CAD-related roles they may perform in their subsequent careers (Ye et al. 2004). However, all students should receive training on the rudiments of CAD and the methodology of design. It is the university's responsibility to offer a wide range of specialist knowledge to students, while it is the responsibility of students to enhance their expertise in specific areas (Dankwort et al. 2004).

This aspect of the study is a complementary to the first exploratory study (section 4.3) aimed to determine the capacity of Nigerian universities to provide BIM tools training for BIM adoption in AEC through assessment of institutions' infrastructure (hardware and software) capacity; skilled/workforce capacity; the level of BIM tools' training and proficiency; as well as the outcome of the trained graduates of the built environment and engineering disciplines.

4.4.2 Method

The purpose of the survey was to determine the level of BIM tools training received by students (from engineering and built environment schools) in Nigerian higher institutions of learning. The research is quantitative, and its approach is analytical. Primary data was obtained from instructors, tutors/ lecturers in the Nigerian universities through a questionnaire survey. Considering the different courses involved in this investigation, a cluster sampling technique is adopted. A cluster sampling is a type of probability sampling that involves selecting a population sample where a target population is mutually homogeneous yet heterogeneous internally. The population is grouped (like hierarchy) into the number of heterogeneity (known as a cluster), and simple random sampling is applied to each group (Ross 1978). The respondents were chosen randomly (using cluster random sampling) (Gravetter and Forzano 2011) from higher institutions of learning in the country where civil, mechanical and electrical engineering as well as built environment courses are taught. A structured questionnaire is used as a tool for the collection of data based on the research questions.

Email addresses used in the questionnaire distribution were compiled from the clustered institutions' websites. The questionnaires were randomly distributed through across 46 universities that offer engineering courses (civil, electrical and mechanical), including 33 universities where built environment courses are taught. The questionnaire targeting tutors in those departments was typed and distributed by email along with an online survey version prepared in 'Google-form'. A link was incorporated in the email to allow for the survey to be completed online or completed word document and return that by email (as an attachment).

The groups (in a cluster) were formed and compiled based on course and university. The study design targets to achieving at least a representation from each targeted cluster; the target group and response rate are calculated as follows:

There were 46 institutions offering engineering (civil, electrical and mechanical) courses that are three engineering departments were considered;

33 schools offer built environment-related courses

- ⇨ 46*(3)+ 33 = 171 (departments) as population size – potential respondents.
- ⇨ 39/171 = 23% response, beyond 12% at liberal condition (Nulty 2008).

The respondents were asked to assess the availability and capacity of their hardware and software in terms of availability, capacity and quantity. The proficiency level of training delivered to students and proficiency training outcome of the courses were also asked to be assessed by the scale of basic, novice, intermediate, advance and expert.

The questionnaire constitutes of predominantly multiple-choice close-ended questions. The respondents were mainly from the following areas of the country: North-west, North-central and South-west in sliding order of quantity, then with very few from North-east and South-east. The low response from North-East relates to a fewer number of Universities (3 Universities) offering construction-related courses; and, for the South-East, it's just a low response rate. The uneven geographical spread was mainly due to the unequal distribution of universities offering those courses.

A total of 54 emails were sent; this number is lower than the potential respondents due to limited availability of email addresses of the potential respondents. Out of the 54 sent emails, a total of 39 responses were received, which represents 72.2% response rate; very adequate for online response rate (47%) as benchmarked by Ballantyne (2005) and 55% for paper-based. The survey responses will be analysed and discussed in the following section.

4.4.3 Respondents' Profile and Data Collection

The survey revealed that 82.1% of the respondents were lecturers; while 17.9% were technicians and technologists; over 70% of the lecturers had qualifications ranging from M.Sc. to Ph.D., and fewer than 30% were first-degree holders only. A summary of the demographic profile of the respondents is presented in Table 4.2.

Table 4.2: Demographic Profile of the Respondents (N=39)

		n	*%*
Respondent affiliation	Architecture	10	25.60
	Building	2	5.10
	Engineering	25	64.10
	Land Surveying	1	2.60
	Quantity Surveyor	1	2.60
Cadre	Lecturer	32	82.10
	Technologist	7	17.90
Academic qualification	BSc/B. Tech.	9	23.10
	M.Sc.	24	61.50
	Ph. D	6	15.40

As presented in Table 4.2, the distribution of respondents is as follows: Architectural technology recorded a higher response rate (25.6%) at individual career level; this can be seen to be associated with their keen interest in the subject area. Engineering departments constituted over 60% of the responses; this is not surprising given the number of disciplines involved in the engineering profession (civil, electrical and mechanical); and the remaining contributed 10.2%. However, when individual courses (splitting engineering into three branches) are considered, the architectural course can be regarded as the highest respondents.

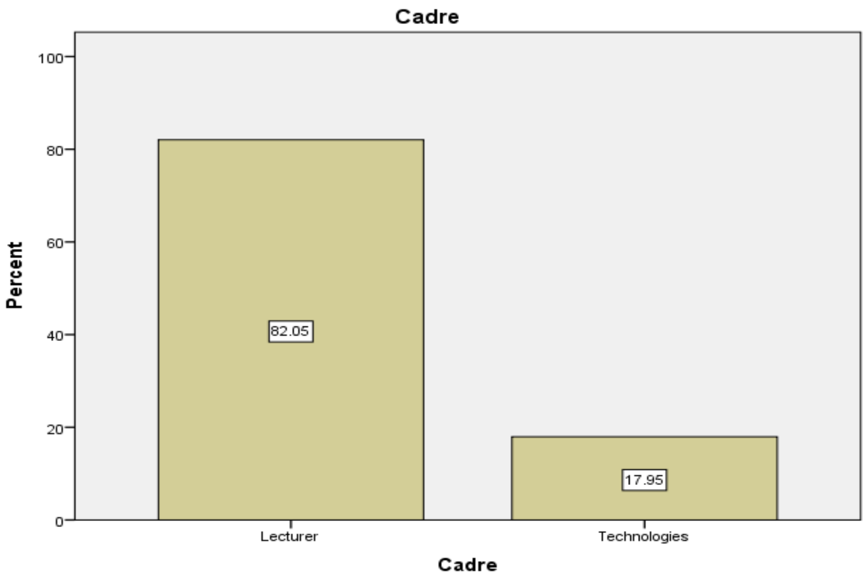


Figure 4.2: The respondents' cadre from Nigerian universities

More than 50% of the respondents were experienced tutors, ranging from 5 years to over 15 years in academia. Figure 4.2 and Figure 4.3 present respondents' cadre and academic qualifications, respectively

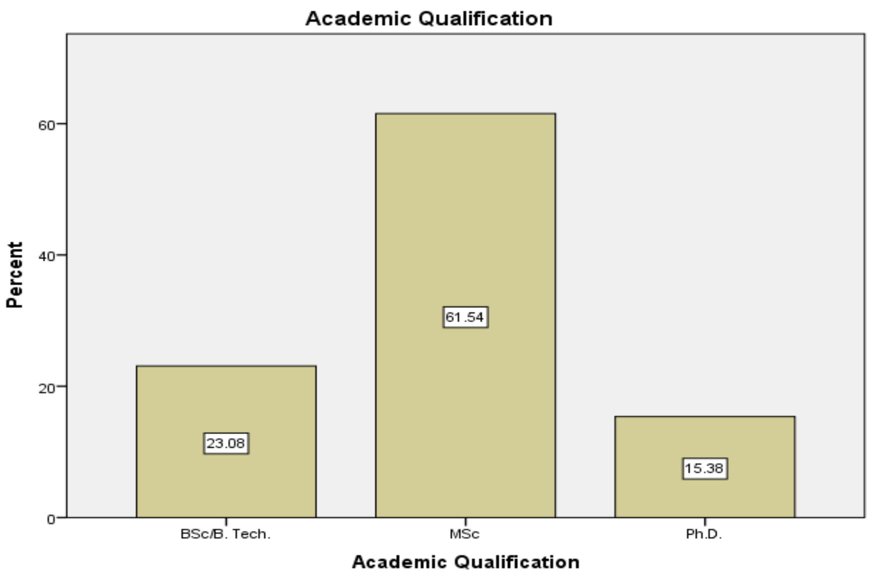


Figure 4.3: The respondents' academic qualifications

In terms of training capacity, it was discovered that 77% of the institutions had relatively adequate computer laboratories, as represented in Figure 4.4. About

44% of the schools have more than 30 PCs in their respective laboratories (Figure 4.5), but only 20% happened to have modelling software in their PCs (Figure 4.6), while only 13.3% of the students were enrolled for such (modelling) software training.

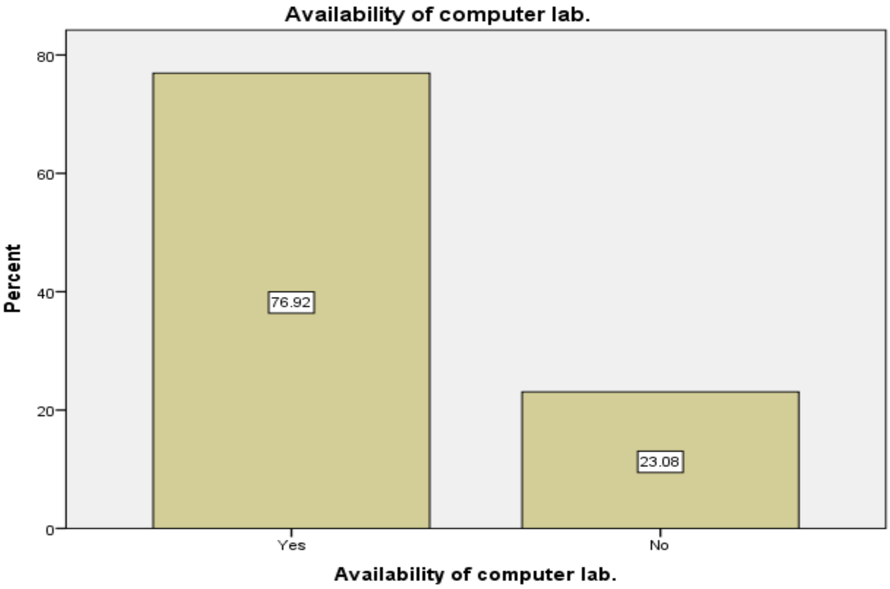


Figure 4.4: Availability of computer laboratory in the subject departments

With over 40% of the departments having more than 30 computers for training, a reasonable number of schools can, therefore, be considered to be hardware sufficient or have considerable amounts of computers for training. However, this can only be fully and confidently concluded if the number of students is established (PCs to students' ratio). A statistical distribution can be seen in Figure 4.5.

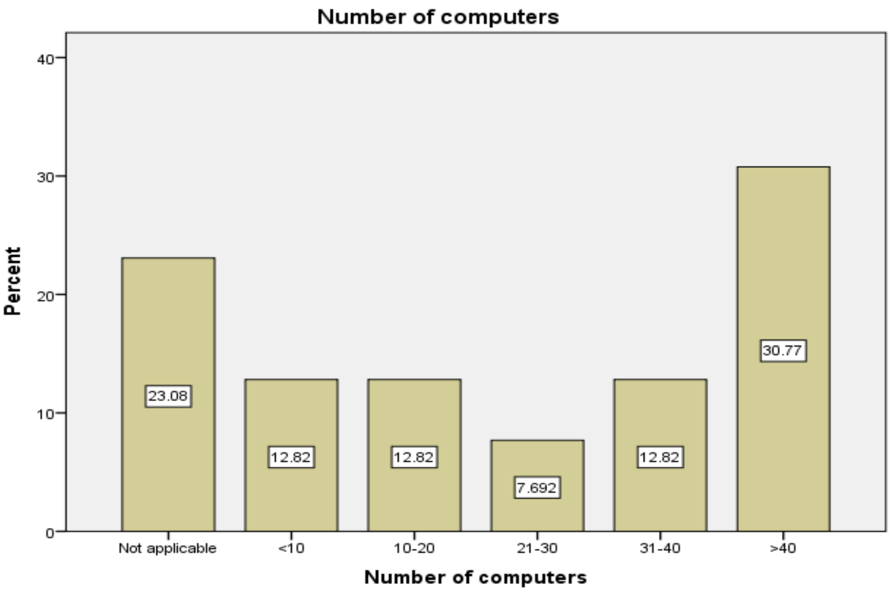


Figure 4.5: The quantitative capacity of the computer laboratories

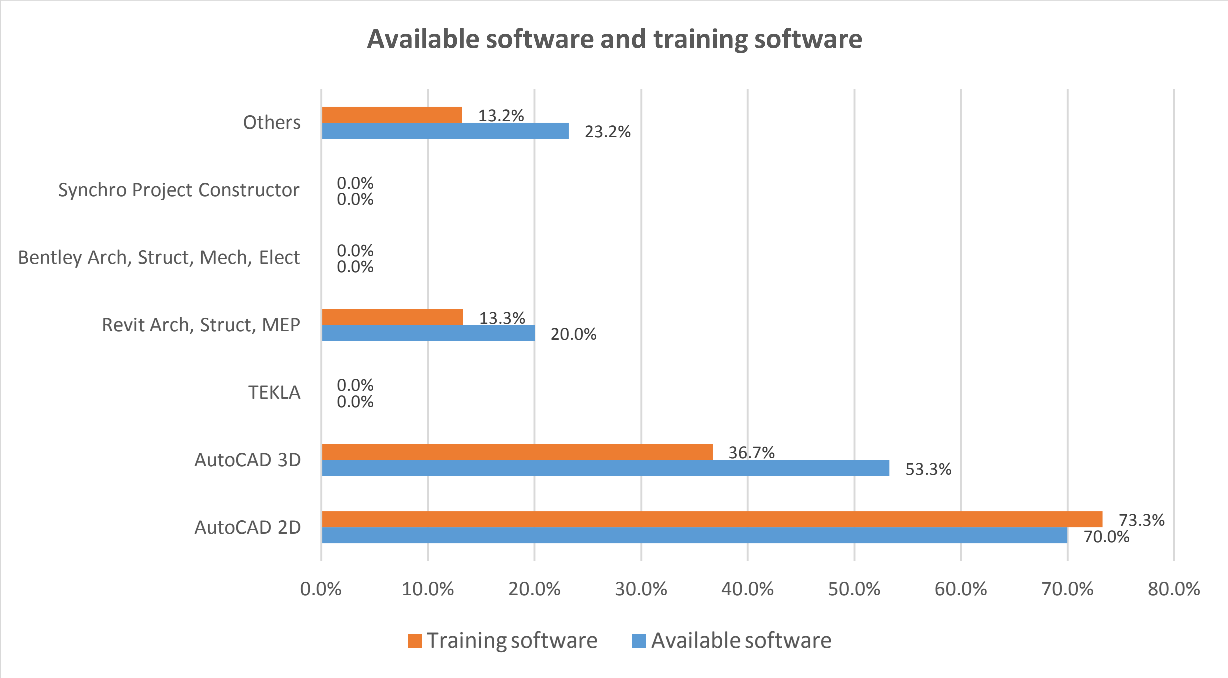


Figure 4.6: Availability of BIM Tools

4.4.4 Analysis and Discussion

4.4.4.1 Proficiency of application software training

From Figure 4.7 below, it can be observed that the intermediate, fundamental awareness, as well as novice, topped the proficiency level of training offered to students. However, higher percentages of deficit can be noticed at fundamental and intermediate levels (the yield is lower than the efforts). Hence, students receiving intermediate and fundamental awareness level of training are experiencing output challenges in which the outputs are less than the inputs (43.3% to 33.3% and 36.7% to 30% respectively). However, the novice, advance and expert experienced higher outputs in relation to the inputs (16.7% to 23.3%, 3.3% to 6.7% and 0% to 3.3% respectively). This indicates the possibility of some trained students advancing their proficiency level; this positivity is seen to be associated with the type of software available (advanced software) and the student-computer ratio.

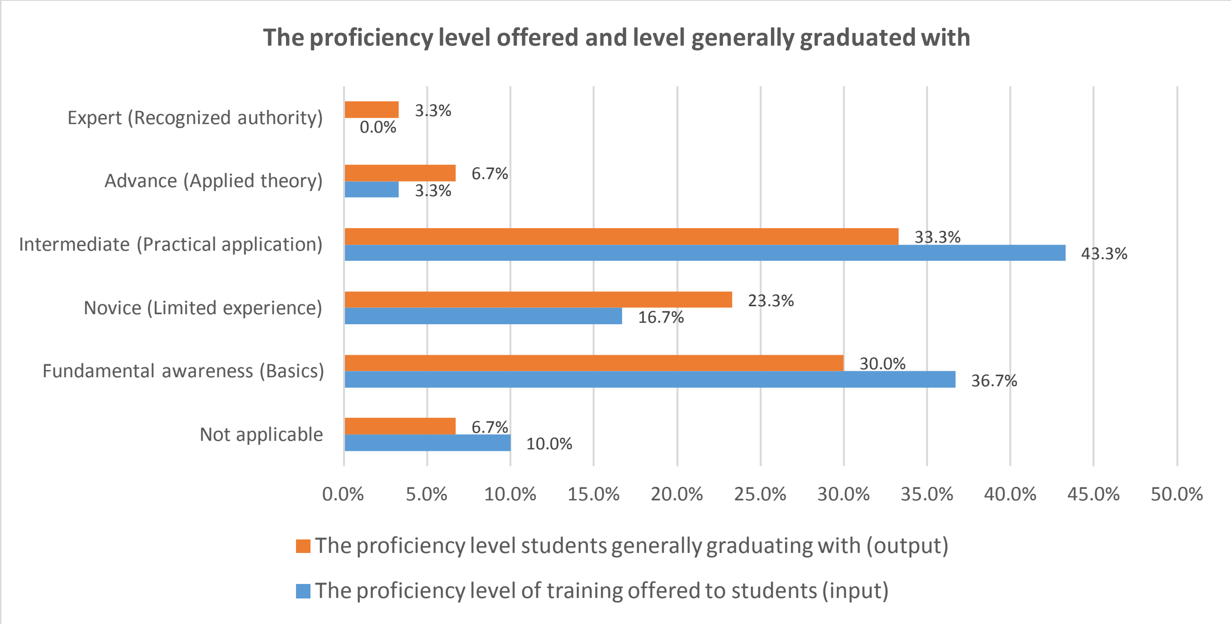


Figure 4.7: Proficiency level offered and what is generally graduated with

It can also be seen that 2D CAD is a basic tool of all the institutions that offered application software packages training to students, with 73.3% receiving training on 2D CAD basics up to application level. For 3D CAD training, everyone trained on 3D CAD was equally trained on 2D CAD as well. This means that those trained on 3D CAD are the subset of those trained on 2D CAD. To ascertain those trained on 2D CAD only, the following are evaluated:

73.3% for 2D CAD in general

36.7% for 3D CAD

73.3% - 36.7% = 36.6% for 2D CAD only

36.7% (3D CAD) + 36.6% (2D CAD only) = 73.3% for both 2D and 3D CAD training.

In summary, 73.3% of students were graduating with 2D CAD knowledge, thus acquiring limited and basic understanding. Moreover, over half of the schools (53.3%) had 3D CAD software which was usually incorporated with 2D CAD, but only 36.7% are training students on 3D CAD (up to practical application). On the other hand, less than a quarter of the institutions were observed to have collaboration software (i.e. Revit Arch, Struct, MEP). And only about half of the quarter is enrolling students for such software (i.e. Revit Arch, Struct, MEP) training, perhaps due to a shortage of trainers or experts. Figure 4-8 below presents the variations in software availability and training.

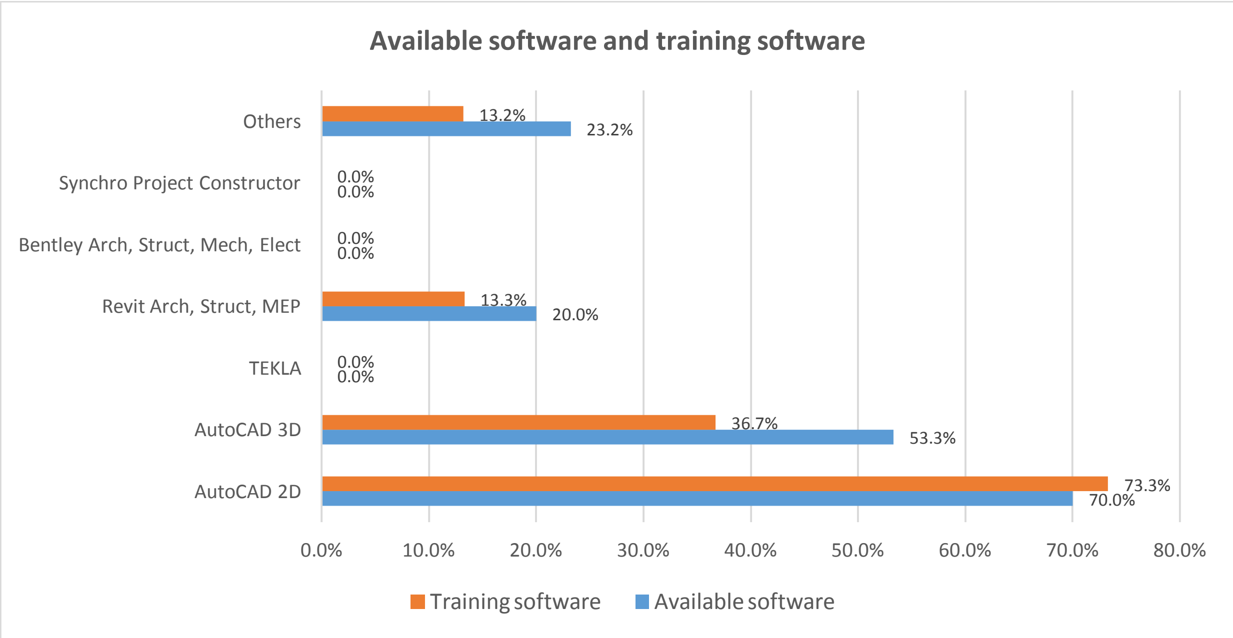


Figure 4.8: The available software packages and the training software

A T-test gives basic but exact strategies for comparing relationship coefficients between a dependent variable and a set of independent or constant factor(s) (Meng et al. 1992). This is often a nonparametric test strategy for the investigation of matched-pair information, based on contrasts, or for a single test. The invalid theory is that the contrasts, or person perceptions within the single-sample case, have a conveyance centred around zero (Woolson 2007). The supreme values are positioned. The test measurement is the entirety of the positions for either the positive or the negative values. The *t-test* carried out to check for a correlation between the provision of software for the training, and the proficiency of training acquired at graduation rejected the null hypothesis (Ho). Table 4.3 refers to this.

Table 4.3: Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Highest software for training - Proficiency at graduation	.487	1.189	.190	.102	.873	2.558	38	.015

The t=2.558 means t falls within the rejection region for the null hypothesis; hence there is a correlation in the population as H_o is rejected. Moreover, the correlation is significant at the 0.01 level (2-tailed). Their relationship has less than 5% (1.5%) possibility to had happened by chance; therefore, the correlation is statistically significant.

To fully present the impact of the availability of software on the proficiency training received by the students, a multiple plots (Figure 4.9) is generated to explicitly shows its rippling effect over the total responses in time.

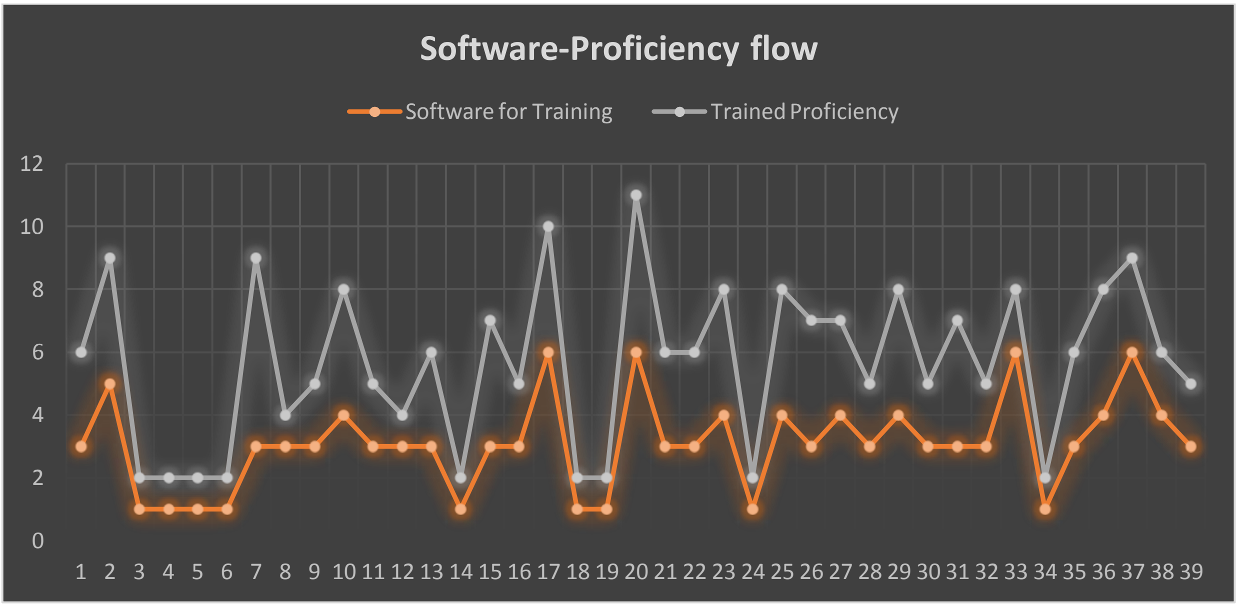


Figure 4.9: The software-proficiency flow chart (proficiency rating against respondents)

4.4.4.2 Correlations amongst variables

While examining the role of infrastructure on training, correlation analysis was carried out between variables (hardware and software) on the one hand, and proficiency level of training received by students on the other side. It was found that there is a significant correlation (refer to Table 4.4) between both the availability and quantity of computers with the level of training offered to and proficiency level acquired by graduates. The correlation between hardware (available computers) and the training received by students is positive with 0.659 significance at 0.01 level. Moreover, the availability of software is most critical to the level of training; the correlation is positively strong with a significance of 0.804 at 0.01 level (refer to Table 4.4). In this context, the proficiency level at graduation significantly (0.903) depends on the proficiency level of training, and thus of the trainers.

Table 4.4: Correlations

		Dept.	Academic Qualification	Availability of computer lab.	Number of computers	Highest available software	Highest software for training	Training proficiency	Proficiency at graduation
Department	Pearson Correlation	1	-.147	.209	-.253	-.380*	-.385*	-.189	-.055
	Sig. (2-tailed)		.373	.201	.120	.017	.015	.248	.741
	N	39	39	39	39	39	39	39	39
Academic Qualification	Pearson Correlation	-.147	1	-.129	.209	.208	.293	.284	.118
	Sig. (2-tailed)	.373		.433	.201	.204	.071	.080	.475
	N	39	39	39	39	39	39	39	39
Availability of computer lab.	Pearson Correlation	.209	-.129	1	-.733**	-.796**	-.781**	-.671**	-.653**
	Sig. (2-tailed)	.201	.433		.000	.000	.000	.000	.000
	N	39	39	39	39	39	39	39	39
Highest available software	Pearson Correlation	-.380*	.208	-.796**	.779**	1	.877**	.673**	.556**
	Sig. (2-tailed)	.017	.204	.000	.000		.000	.000	.000
	N	39	39	39	39	39	39	39	39
Highest software for training	Pearson Correlation	-.385*	.293	-.781**	.742**	.877**	1	.804**	.649**
	Sig. (2-tailed)	.015	.071	.000	.000	.000		.000	.000
	N	39	39	39	39	39	39	39	39
Training proficiency	Pearson Correlation	-.189	.284	-.671**	.659**	.673**	.804**	1	.903**
	Sig. (2-tailed)	.248	.080	.000	.000	.000	.000		.000
	N	39	39	39	39	39	39	39	39
Proficiency at graduation	Pearson Correlation	-.055	.118	-.653**	.556**	.556**	.649**	.903**	1
	Sig. (2-tailed)	.741	.475	.000	.000	.000	.000	.000	
	N	39	39	39	39	39	39	39	39

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

Table 4.5: Correlations

	Academic Qualification	*Trained Proficiency*
Academic Qualification	1	
Trained Proficiency	0.118	1

On the other hand, the academic qualification of trainers does not have significance in training proficiency, whether at training or graduation (Table 4.5). Although the educational qualification does not significantly affect the training outcome, "train the trainers" is still a strategy to maintain knowledge transfer and keep the trainers up-to-date on the latest technology.

4.4.5 Result and Conclusion

This study aimed to determine the capability of Nigerian Universities in providing BIM tools training through the assessment of Nigerian universities' infrastructure (hardware and software) capacity; skilled personnel; the level of BIM tools' training and proficiency; as well as the outcome of the trained students at graduation.

Architecture has a keen interest in this subject. Architectural schools also acquire more than 50% of the modelling software. Hence, architectural schools are at the forefront of CAD (BIM Level 1) training. Considering that most institutions have relatively sufficient hardware, the institutions can, therefore, be considered physically (on a hardware basis) ready to offer BIM tools training at BIM Level 1! However, technically they are not prepared because of the low availability of modelling software and intensive training.

The construction industry in Nigeria lacks experts and trained personnel in collaboration tools (Hamma-adama et al. 2018), and most graduates are generally trained on 'file-based collaboration' – 2D and 3D CAD. A clear obstacle can be noted at the institutional level regarding training on collaborative working for the industry's applicability and needs. The proficiency level received at graduation mainly ranges from basic to practical application, and the higher the software sophistication, the higher the proficiency level of training received by students. With only 13.3% modelling software training across the institutions (mostly architectural schools), the trained graduates on modelling software will insufficient to the construction industry's need. Therefore, there are limited trained personnel to be employed for wider BIM adoption.

In brief, this study reveals that the type and proficiency level of training offered to students in the subject suffers high probability of manpower shortage for BIM adoption even at BIM Level 1 as well as collaborative working, i.e. BIM Level 2. Therefore, the adoption rate is likely to be low due to the continuous shortage of trained graduates on BIM tools. To achieve sufficient training on BIM tools, availability of software in these institutions is critical.

To achieve significant levels of BIM tools training a strategic plan for training at the institutional level is recommended. This will involve the introduction of new modules in the institutions' curricula; procurement of at least modelling and collaborative software (BIM Level 1 and 2); training the trainers, and involvement of professional societies for continuous professional development.

4.5 DIFFUSION OF INNOVATIONS: STATUS OF BIM UPTAKE IN NIGERIA

This exploratory study is an opportunity to contribute to setting the agenda of research and industrial practice in this vital area: BIM in Nigeria. BIM potentiality as a system is not limited to the effective management of primary data, but also offers active and detailed monitoring, and facility performance analysis that can support innovative and more cost-effective management of sophisticated facilities (Mitchell and Schevers 2006). It can be realised that many countries are increasingly using BIM for innovative approaches to construction relationships, which is likely to give them a competitive advantage in an increasingly globalised economy (Froise and Shakantu 2014).

Primary data of this exploratory study was gathered using a questionnaire as a tool of enquiry. The study targets Nigerian contractors and consultants (architects, engineers and quantity surveyors); the approach to the research is quantitative. The data is analysed by percentages, and the results are compared with results of surveys conducted in two developed countries and a developing country that studied BIM adoption rates. The latter was examined in terms of line of enquiry known as the 'diffusion of innovations' to define the Nigerian status on BIM adoption. The findings set a pace to continues evaluation of BIM adoption rate in Nigeria and used as a benchmark to further development of BIM awareness and adoption.

4.5.1 Method

A questionnaire survey was adopted for data collection; descriptive statistics used together with the diffusion of innovation model in establishing BIM diffuses in the Nigerian AEC. The purpose of the survey was to determine the level to which the construction stakeholders are currently using CAD/BIM technologies and integrated construction processes in Nigeria. These results were then compared to the status and uptake of these technologies in some of case study countries (US, UK and South Africa) identified in the literature.

4.5.1.1 Precedents

To achieve comparable results, the questions were aimed at gathering similar information to that available from other countries. The NBS survey has done extensive research on BIM report in the UK, the McGraw-Hill Construction survey report (2012) and the surveys by Froise & Shakantu (2014) in South Africa. Figure 4.10 describes the adoption rate of three different regions, as presented in the Froise & Shakantu (2014) study:

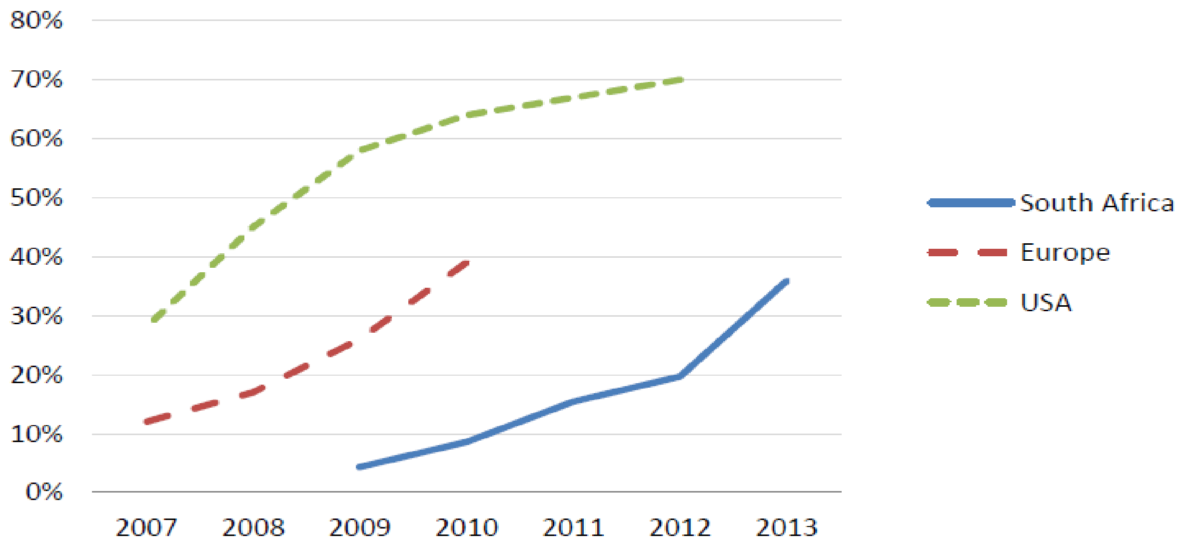


Figure 4.10: BIM adoption (Froise and Shakantu 2014)

Two modern precedent studies are relevant to this study to match the Nigerian situation with those countries. Firstly, surveys piloted by the NBS in the UK from 2011 to 2017 that sequentially analysed the BIM usage and perceptions of professionals are utilised. Secondly, Froise & Shakantu's study that compares the some developed regions (the USA and Europe) with South African construction markets is also adopted. The Froise & Shakantu's survey looks at BIM awareness and adoption levels, and take-up among architects and contractors; this study was conducted in 2014.

The United Kingdom (UK), the United States of America (USA) and South Africa are selected as sample countries to test BIM awareness and adoption. This selection reflects two main principles or measures (Kassem et al. 2013): (a) the resemblance between the two developed nations (UK and US) in their construction markets in terms of applicable technologies and terminology; and also, the two developing countries (South Africa and Nigeria), (b) the availability of reasonably comprehensive BIM adoption surveys (NBS survey from 2011 to 2017 in the U.K. and the McGraw-Hill Construction, 2013 for the USA).

4.5.1.2 Data Collection

In the collection of data, the questionnaire was designed in a closed-ended form with few areas where open-ended questions were asked. The open question provided an opportunity for additional or different information to be provided.

This section presents the result of a survey that examined different aspects of BIM usage in Nigeria. The questionnaire was sent to contractors and consultants (designers) mostly engaged in building construction category in Nigeria. These firms are mostly based in three zones of the country (North-central, North-west and South-west) with a minimal number from South-east and North-east due to difficulty in gaining contact information of these zones.

The questionnaire was set-up in two different formats, in a word document and 'google-form'; the word document was then attached and send via email together with the google form link for online participants. The targeted population is the Nigerian construction industry, and the sample size of this study is dominantly on the basis of BIM awareness (as dependent variable). Most studies from Nigeria regarding BIM used an average of 100 as sample size (see Appendix – 1, page 276). A total of 133 emails were sent, out of which a total of 80 responses were received (some by email and some via the online version); this represents approximately 60% response rate, hence adequate according to the 55% for paper-based response rate and 47% for online response rate (Ballantyne 2005). The responses received from contractors were five which represents 6.3% of the responses, architects returned 30 (37.5%), quantity surveyors returned 6 (7.5%), engineers returned 36 (45%), and Clients returned 3 (3.8%).

4.5.2 Analysis and Discussion

Initial observation was the substantial difference in the response rates by the construction professionals involved. The same method of notification and delivery of the questionnaire was used, but significant differences are evident. The difference may potentially be credited by the awareness levels of the five different groups, where architects were substantially more aware than other professionals considering architects as a single entity; however, engineers recorded higher numbers. That is, of course, associated with the number of disciplines involved in the engineering (civil, electrical and mechanical) profession. Table 4.6 presents the profile of the respondents.

Table 4.6: Demographic profile of respondents (N = 80) Variables Category

		n	%
Respondent affiliation	Architect	30	37.50
	Client	3	3.75
	Contractor	5	6.25
	Engineering	36	45.00
	Quantity Surveyor	6	7.50
Company size	Less than 10 technical staff	24	30.00
	10 - 15 technical staff	17	21.25
	More than 15 technical staff	39	48.75
Practicing experience	Less than 5 years	20	25.00
	5-10 years	30	37.50
	11-15 years	18	22.50
	More than 15 years	12	15.00

4.5.2.1 BIM Awareness

It can be noticed that there is a significant dissimilarity amongst architects and engineers, and the remaining three (notably, the contractors) when it comes to BIM awareness. 34.8% of those aware are architects, and 51.5% of those aware are civil, electrical and mechanical engineers, while only 6.1% is the contribution of the contractors in terms of BIM awareness. Figure 4.11 presents the level of BIM awareness in Nigeria.

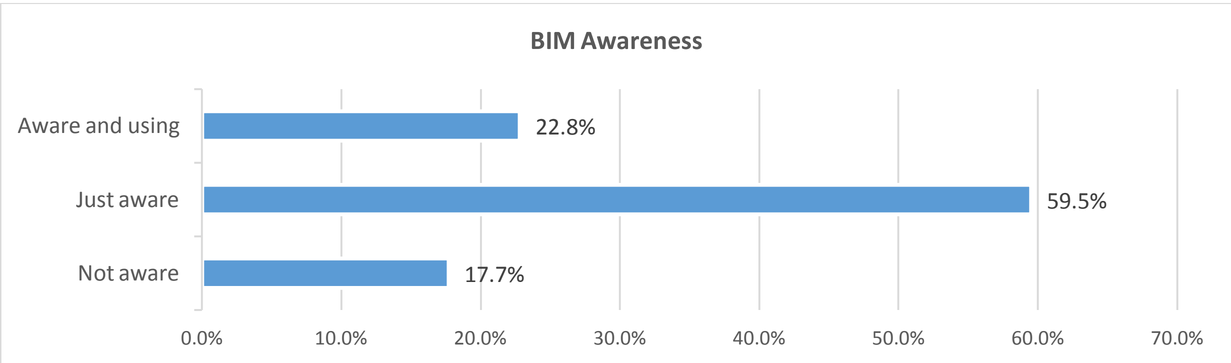


Figure 4.11: BIM Awareness in Nigeria

Considering the above percentages in Figure 4.11, the "just aware", that's their level of awareness relatively okay as the entire early majority (59.5%) are familiar with BIM. However, only a few (22.8%) adopted BIM, and this includes the innovators and the early adopters.

4.5.2.2 Use of BIM

Most architects (61.9%) are aware of BIM, but only 26.9% uses some form of BIM tools. Other than the clients, all the professions are at least aware of BIM to at least 50%, but the adoption has a lot of disparities; the awareness to adoption are 57.5% to 27.5%; 60% to 20%; 66% to 0% for engineers, contractors and quantity surveyors respectively. Figure 4.12 below presents the awareness and adoption percentages.

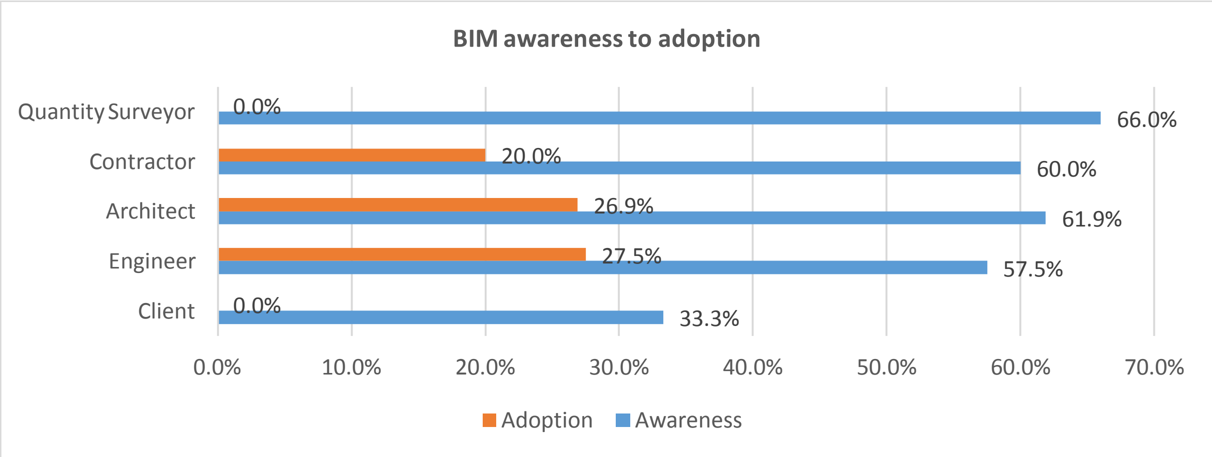


Figure 4.12: BIM Awareness and Adoption

The results are compared with surveys conducted in other countries. The most recent is the National BIM survey, conducted for 2017 (Richard 2017) which reveals 97% BIM awareness (nearly universal) and 62% adoption. Thus, the gap is too wide to be compared; therefore, the nearer survey findings corresponding to that of the USA is the 2012 NBS report where BIM awareness recorded 79%, and adoption recorded 31%.

Considering 2012 survey in the UK; 2012 survey by McGraw-Hill for the USA, McGraw-Hill (2012) found that BIM adoption recorded up to 71% adoption in the USA which demonstrates how fast BIM is being adopted especially considering 49% adoption in the year 2009.

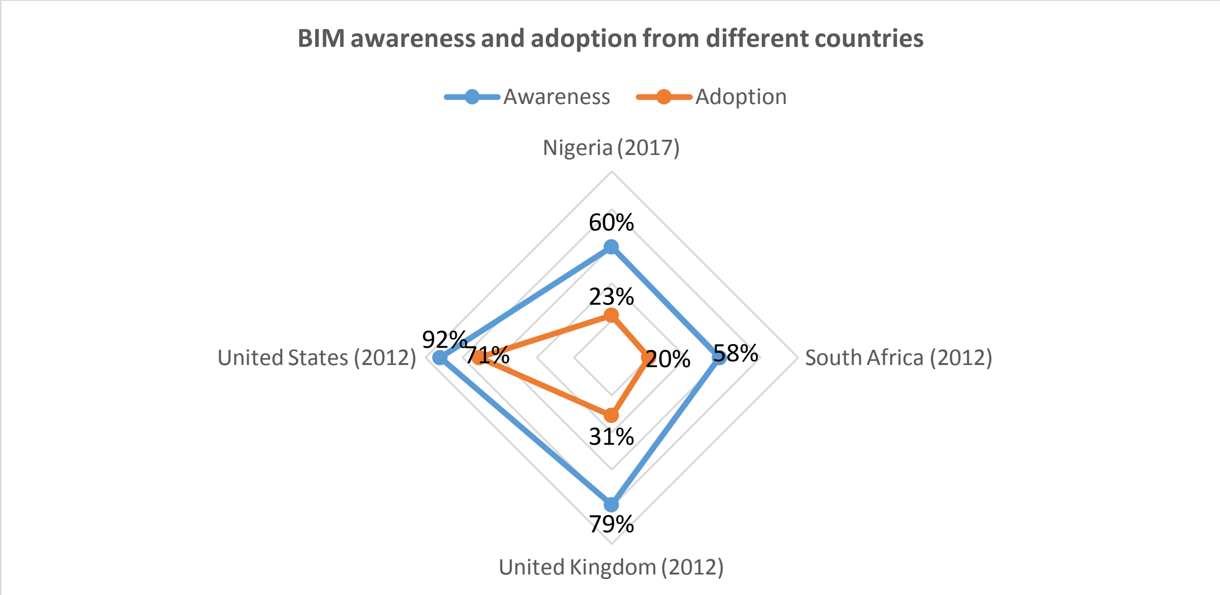


Figure 4.13: BIM Awareness and Adoption Variations by countries

The least country is South Africa; 58% were aware of the BIM, and 20% adopted it (Froise and Shakantu 2014). Going by these results, Figure 4.14 presents and compares the NBS survey result (2012), McGraw-Hill survey (2012), Froise and Shakantu survey (2014) and the current study survey (2017).

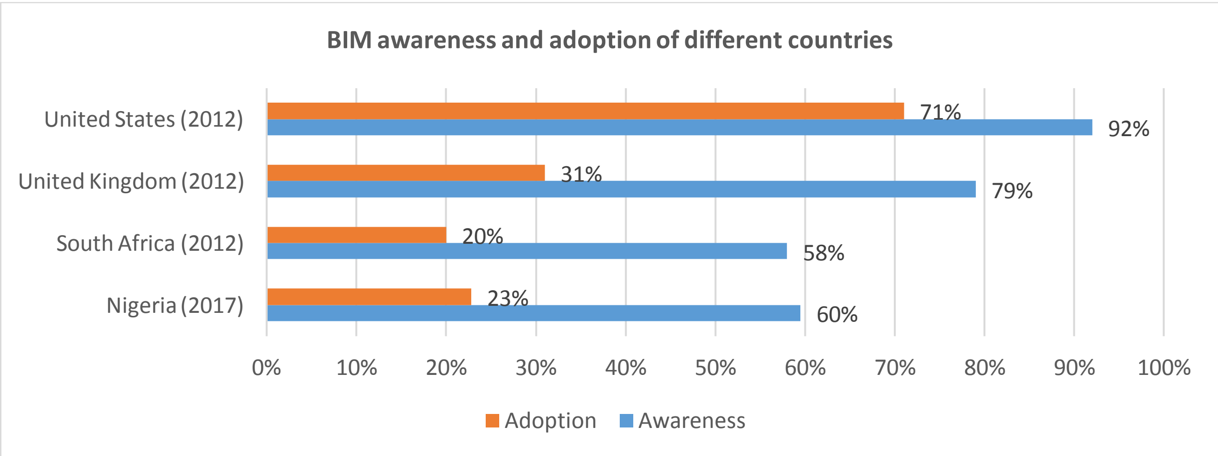


Figure 4.14: BIM Awareness and Adoption from Different Countries

The adoption of innovation generates self-pressure towards the rate at which the innovation diffuses (Rogers 2003). The adoption rate is expected to progress (faster) since it is still below 50%. However, it will keep on slowing down before the adoption reaches 50% (where the adoption curve flattens). At the same time, the awareness level becomes extensive through the adopting group.

As of 2017, Nigeria is five years behind the USA plus 50% of adoption (71%

adoption for USA in 2012 against 22.8% adoption for Nigeria in 2017). While UK BIM adoption in 2012 was 31% which is 8.2% more adoption compared to Nigeria in 2017 (31% for the UK in 2012 against 22.8% for Nigeria in 2017); hence Nigeria is more than five years behind the UK. For a developing country closer to Nigeria (South Africa), Nigeria was approximately five years behind South Africa in terms of BIM adoption, i.e. 20% adoption for South Africa in 2012 against 22.8% adoption for Nigeria in 2017.

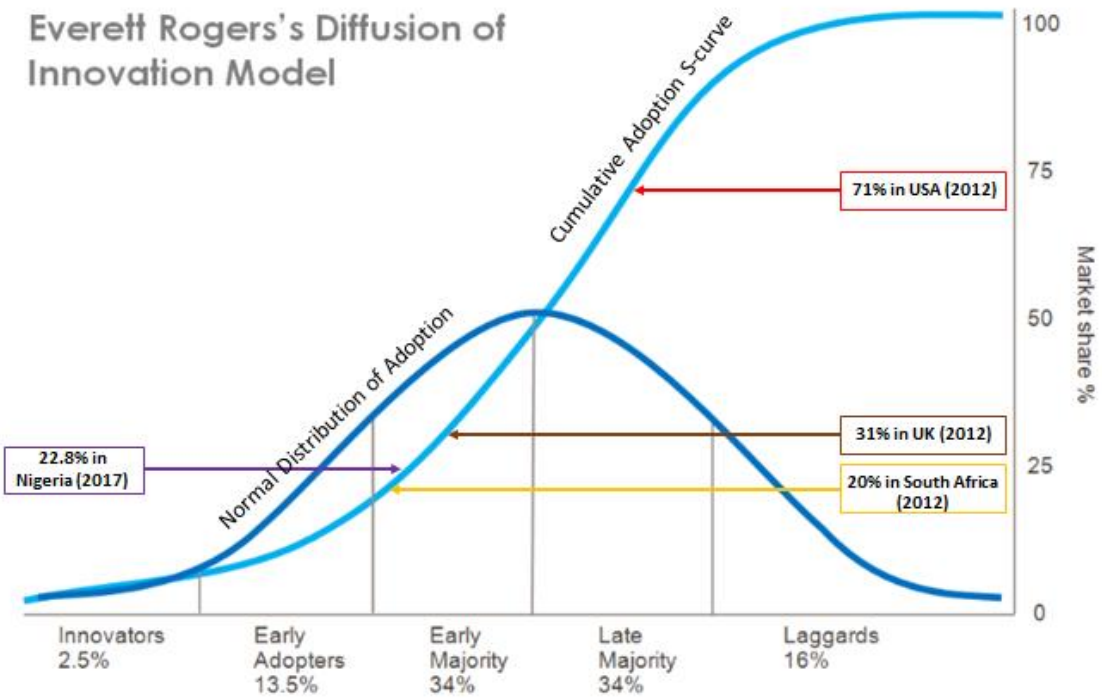


Figure 4.15: Diffusion of Innovation: BIM Adoption Summary (Author's inscription)

The level of BIM adoptions presented in Figure 4.15 is based on a common year of data available within the countries under consideration. There is no BIM adoption data in 2012 for Nigeria; as such, the survey carried out in 2017 (as an exploratory study) is used. The percentages of adoptions are inscribed along the cumulative curve of the diffusion of innovation model. This stands to describe the population of adopters of each country and their relative status. Their current states may not express the current situations; however, that brings to light their adoption trends and their relative adoption flow.

4.5.3 Conclusion

This exploratory study reveals that BIM adoption in Nigerian AEC industry is lagging behind the three countries (USA, UK and South Africa) by at least five years. Moreover, the adoption to awareness pattern of the Nigerian construction industry is more like that of the UK and South Africa; approximately like the UK's pattern of 31:79 in 2012, and Nigerian pattern (23:60) in 2017 (approximate adoption to awareness ration of 2:5).

Finally, the early majority of the adopters has just started to adopt BIM technology. The industry is expected to follow the UK's trend based on the awareness to adoption ratio. Still, the adoption process needs to be streamlined to achieve the adoption rate of 6% (average) as achieved by the UK construction industry yearly. This development came up after the streamlined process developed in mandating the BIM on public projects. And also, the UK's major clients are progressively insisting on a BIM platform for their new facilities. The UK government is driving the process by creating a conducive atmosphere to the BIM utilization and requiring that, new public buildings are produced in a collaborative environment using BIM.

4.6 CHAPTER SUMMARY

This chapter aimed to explore the state of BIM awareness and usage in the Nigerian construction industry. The study also examined the level of preparedness of the education sector in offering training on BIM tools. The study adopted both qualitative and quantitative means to explore the Nigerian construction industry's state on BIM in general.

The exploratory study one (section 4.3) reveals a trace of adoption within designers at an organisational level only. However, there is a misconception about the term "BIM" or "Building Information Modelling". Although many are aware of the BIM tools, they are not aware or knowing their potentials. Moreover, there is a low level of BIM awareness by clients and contractors; significant deficit of experts on the BIM technology; lack of accessibility of the technology, and power (electricity) issues - Infrastructure; lack of a streamlined process of adoption; lack of professional societies' involvement; and lack of policy and guideline. To facilitate BIM adoption, the following are recommended based on the study findings. Champion from the government side with a government-driven strategy is needed; an all-in-one blueprint for BIM adoption; improve awareness and training (in higher education institutions) and involve the professional institutes or bodies.

The exploratory study two (section 4.4) that has been precipitated by the exploratory study one (section 4.3); the study discovers a substantial training gap in higher education institutions. Furthermore, it was discovered that there is considerable hardware (computers and laboratories) for BIM tools training. However, the software and the trainers (skilled tutors) are not available or insufficient to produce significant BIM trained graduates for the industry's need to satisfy/support BIM adoption.

The exploratory study three (section 4.5) of this chapter explored the BIM adoption uptake in Nigeria in comparison to three other countries (USA, UK and South Africa). The study revealed that BIM adoption in Nigerian is lagging behind the three countries (USA, UK and South Africa) by at least five years. Moreover, the adoption to awareness pattern of the Nigerian construction industry is more like that of the UK and South Africa. The adoption to awareness ratio is approximately like the UK's pattern of 31:79 in 2012, and Nigerian pattern (23:60) in 2017 (approximate adoption to awareness ration of 2:5). The Nigerian AEC industry is expected to follow the UK's trend based on the awareness to adoption ratio. Still, the adoption process needs to be streamlined to achieve the adoption rate of 6% (average) as achieved by the UK construction industry yearly. Table 4.7 presents summary of the exploratory findings.

Table 4.7: Summary of the Exploratory Studies' findings (Compiled by Author)

Exploratory Studies	Study Approach	Outcome
1. State of BIM Adoption In Nigeria	Qualitative with data collected using a semi-structured interview	☐ There is a trace of BIM adoption at organisation level among AEC designers. ☐ A misconception about the term "BIM" or "Building Information Modelling". ☐ Although many are aware of the BIM tools, they are not aware or knowing their potentials. Moreover, there is a low level of BIM awareness by clients and contractors. ☐ The following are challenges to BIM adoption: experts' deficit on the BIM technology; lack of accessibility of the technology, and power (electricity) issues; lack of a streamlined process of

			adoption; lack of professional societies' involvement; and lack of policy and guideline. ☐ To facilitate BIM adoption, the following are recommended: Champion from the government side with a government-driven strategy is needed; improve awareness and training (in higher education institutions) and involve the professional institutes or bodies.
2.	**Higher Education Institutions' Readiness to BIM Training**	Quantitative, and data collected through a questionnaire survey	☐ The study discovers a substantial training gap in higher education institutions. ☐ The software and the trainers (skilled tutors) are not available or insufficient to produce significant BIM trained graduates for the industry's need to satisfy/support BIM adoption.
3.	**Diffusion Of Innovations: Status of BIM Uptake in Nigeria**	Quantitative, and data collected through a questionnaire survey	☐ The BIM adoption in Nigerian is lagging behind three countries (USA, UK and South Africa) considered by at least five years. The adoption to awareness pattern of the Nigerian construction industry is more like that of the UK and South Africa (approximate adoption to awareness ration of 2:5). ☐ The adoption process requires a structured effort to achieve the adoption rate of 6% (at average) as achieved by the UK construction industry yearly.

Finally, the exploratory study fits into the entire study through filling the literature gap recognised at the beginning of the study (section 2.1) and also brings to light the need to develop a framework or roadmap to achieve a wide BIM adoption in Nigerian AEC. The wide BIM adoption in the Nigerian AEC is potential to solving some of the industry's challenges and improving the industry's efficacy.

CHAPTER FIVE: ANALYSES OF QUESTIONNAIRE DATA

5.1 CHAPTER OVERVIEW

This chapter presents the analyses and results of data fetched from the questionnaire survey. The chapter deals with objective four (Establishing the Nigerian construction industry BIM Maturity) of this thesis. The quantitative data generated from the questionnaire survey were analysed using the Statistical Package for Social Sciences (SPSS). Significant barriers and drivers to BIM adoption were established based on the BIM adopters and non-adopters' perspectives. The Nigerian Macro BIM adoption maturity is established using five macro BIM adoption models. The models revealed low diffusion level of 11% and low maturity components (especially in the regulatory framework and Noteworthy BIM Publications (NBPs)). They equally suggested a 'bottom-up' dynamic due to lack of regulations. The Policy Actions Model is partly distributed with 'active' policy approach dominant (especially at communication). As for responsibility to facilitate BIM diffusion in Nigeria, educational institutions are ranked highest, followed by individual practitioners; while communities of practice (professional societies) come the lowest to facilitate BIM diffusion in the market. This chapter also demonstrated briefly how the findings are used further to develop a roadmap for an effective BIM adoption in Nigeria.

5.2 BARRIERS AND DRIVERS TOWARD BIM ADOPTION IN NIGERIA

BIM as a new paradigm shift in the construction industry, this innovation is gaining high recognition both in academic discourse (research) and industry (application). However, its wide (universal) adoption is facing challenges but yet persistent within the industry and across the world. These challenges are more the same rather than different; although their significance and uniqueness vary with country. On the other hand, the drivers that facilitate its adoption have similar trends with the barriers.

This section of the study is aimed to fill the gap of differentiating by order of importance, the common barriers as well as drivers toward BIM adoption from adopters and non-adopters' perspectives within the Nigerian construction market.

This will allow an informed decision in the development of a strategy to effective BIM adoption within the Nigerian construction market.

5.2.1 Method

The review of literature in section 2.7.2 (as a secondary source) was the first step; serving as precedent and baseline to the study. Primary data is generated through a questionnaire using the compiled barriers and drivers of BIM adoption from Table 2.2 and Table 2.3, respectively. To determine the target population, interested parties were quite insignificant (in number) as the country of study has relatively low BIM awareness (Hamma-adama et al. 2018c). A mixture of purposeful sampling and snowball method was adopted in sampling and data collection procedure. The purposeful sampling (Coyne 1997) was chosen to allow the researcher to select only the participants who possess the qualities necessary to provide meaningful input and reliable assessment of the study context and snowball (Noy 2008) was utilised in generating substantial (in both quality and quantity) responses.

A quantitative research approach is adopted for this questionnaire survey. A quantitative research method is adopted to achieve a wide coverage of the questionnaire, a considerable response rate, a bias-free response, and a free from privacy issues (Naoum 2012). A structured questionnaire survey was used for the primary data collection. The questionnaire targets data to contextually determine the significant barriers and drivers to adopt BIM in Nigeria. As it is set for a purpose, only those aware of BIM are of interest to this research. Thus, the data used is only from those aware of BIM in the study context.

Reliability test, descriptive statistics and Relative Importance Index (RII) were subsequently deployed in the data analysis. The reliability test was carried out to ascertain an internal consistency of the scale of items used in the questionnaire as well as the reliability of the questionnaire for further analysis. Descriptive statistics and RII are used in the investigation to determine the essential elements and their interdependencies.

As for the respondents' profile, categorical data is generated while the main (enquiry) questions involved the use of a five-point weighing scale, rating with five as the highest rank and one the lowest.

Based on the five-point Weighing scale, a standard method of ranking was used, which is the RII.

RII is defined by the relationship as (Eadie et al. 2013):

$$\text{Relative Importance Index (RII)} = \frac{\Sigma W}{A \times N} \quad (0 \leq \text{index} \leq 1)$$

where:

W= weighting given to each element by the respondents.

i.e. between 1 and 5, where 1 is the least significant impact and 5 is the most significant impact;

A= highest weight; and

N= total number of respondents.

Remaining are evaluated by simple descriptive statistics (in percentages); the barriers and drivers ranked by the respondents are examined in terms of their interaction with BIM. Some have already adopted the BIM, while some are still at the awareness stage. To determine their level of agreement and disagreement as to their items' ratings, a comparison was carried out using the Rank Agreement Factor (RAF).

RAF is defined by the following relationships:

$$RAF = \frac{1}{N}\left[\sum_{i=1}^{N} \left|R_{i,1} - R_{i,2}\right|\right]$$

And, maximum RAF (RAFmax) is then evaluated with:

$$RAF_{\max} = \frac{1}{N}\left[\sum_{i=1}^{N} \left|R_{i,1} - R_{j,2}\right|\right]$$

Where;

$R_{i,1}$ is the rank of item i in group 1,

$R_{i,2}$, is the rank of item i in group 2,

N is the total number of items, which is the same for each group,

$R_{j,2}$ is the rank of item j in group 2, and;

$j = N - i + 1$.

Percentage Disagreement (PD) between the two groups is the ratio of RAF to RAFmax, as expressed below:

$$PD = \frac{RAF}{RAFmax} \times 100$$

While the Percentage Agreement (PA) between the two ranked groups is the balance of percentage from the PD, which is:

PA = 100 – PD

A higher RAF value indicates a weaker agreement between the two groups. Thus, the RAF value of zero means a complete agreement between two subject groups. Spider diagrams (Figure 5.1 and Figure 5.2) are plotted to illustrate the ranking variations by the two set groups graphically.

5.2.1.1 Data Collection

The respondents' demographic information, reliability test result, statistical analyses on the barriers and the drivers as well as relative important index are evaluated and presented in the sub-headings below.

5.2.1.1.1 Demographic profile of respondents

Table 5.1 presents the details of the respondents involved in the survey. The details include their location of practice in Nigeria, year of experience in the industry, size of their organisations, profession, specialisation and their highest qualifications.

Table 5.1: Analysis of socio-economic variables. (Source: field survey, 2018.)

Variable	Characteristics	Freq.	Percentage (%)	Total
Location of practice	North-Central	26	38.2	
	North-East	11	16.2	
	North-West	16	23.5	
	South-East	2	2.9	
	South-South	4	5.9	
	South-West	9	13.2	68
Years of practice	< 5 years	14	20.6	
	5 - 10 years	27	39.7	
	11 - 15 years	15	22.1	
	> 15 years	12	17.6	68
Number of employees	< 10 personnel (Micro)	29	42.6	
	10 - 50 personnel (Small)	29	42.6	
	50 - 200 personnel (Medium)	7	10.3	
	> 200 personnel (Large)	3	4.4	68
Profession	Architecture	16	23.5	
	Building Engineering	1	1.5	
	Civil/Structural Engineering	30	44.1	
	Electrical Engineering	8	11.8	
	Mechanical Engineering	4	5.9	
	Construction Management	1	1.5	
	Quantity Surveying	7	10.3	
	Other:	1	1.5	68
Specialization	Contractor/Construction	19	27.9	
	Designer or Consultant	41	60.3	
	Client	4	5.9	
	Development Authority	4	5.9	68
Highest qualification	OND or HND	2	2.9	
	B.Sc./B.Tech./B Eng.	34	50.0	
	MSc/M.Eng.	25	36.8	
	PhD	7	10.3	68

There are considerably higher respondents from four out the six zones, this happened due to a higher number of researchers' network, and a considerable number of firms and construction works within North-Central and South-West specifically. The predominant respondents are having 5 to 15 years of experience in the industry and mostly (about 80%) came from micro (<10 personnel) and small (10 – 50 personnel) firms. In the case of their professions, specialities and educational qualifications, over 60% of them came from Architectural and Civil/Structural engineering backgrounds and working as designers/consultants and contractors. In addition, more than 80% are first degree (B.Sc./B.Tech./B.Eng) and second-degree (MSc/M.Eng.) holders.

5.2.1.1.2 Reliability Test

The reliability test is carried out to ascertain an internal consistency of the scale of items used in the questionnaire as well as the reliability of the questionnaire for further analysis. Thus, Cronbach's Alpha is adopted for the reliability analysis, and the results are compared with George and Mallery (2003) acceptability of, any coefficient of Cronbach's alpha greater than 0.6, as such, all the items are within acceptable limit with Cronbach's Alpha coefficient of 0.95 (see Table 5.2 and Table 5.3). All values >0.7 are considered acceptable (Whitley 2002; Robinson 2009; Pallant 2013), thus with values >0.9 indicated a high level of internal consistency of items measurements and meant they are closely related.

Table 5.2: Reliability Test

Item-Total Statistics				
	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
Availability of trained professionals to handle the tools	75.75	396.94	.68	.95
BIM Software affordability	76.09	396.80	.65	.95
Enabling environment within the industry	76.18	399.70	.69	.95
Clients interest in the use of BIM in their projects	76.15	391.14	.68	.95
Awareness of the technology among industry stakeholders	76.09	404.95	.59	.95
Cooperation and commitment of professional societies to its implementation	76.16	397.78	.68	.95
Proof of cost savings by its adoption	75.94	406.62	.55	.95
Cultural change among industry stakeholders	76.54	402.52	.65	.95
Government support through legislation	76.51	389.18	.75	.95
Collaborative Procurement methods	76.46	394.25	.72	.95
Lack of expertise within the organizations	75.79	406.29	.52	.95
Lack of expertise within the project team	75.97	402.78	.58	.95
Lack of standardization and protocols	76.04	397.71	.69	.95
Lack of collaboration among stakeholders	76.26	398.23	.70	.95
High Investment Cost	76.35	393.81	.71	.95
Legal issues around ownership, IP & PI insurance	76.69	397.38	.68	.95
Lack of client demand	76.21	398.20	.59	.95
Lack of infrastructure	76.40	394.21	.67	.95
Lack of government policy	76.24	391.41	.71	.95
Industry's Cultural resistance	76.31	401.95	.64	.95
Lack of additional project finance to support BIM	76.24	394.84	.72	.95
Resistance at operational level	76.62	405.82	.57	.95
Reluctance of team members to share information	76.26	398.74	.75	.95
Return on Investment (ROI) issue	76.60	401.86	.64	.95

Table 5.3: Reliability Alpha Value

Reliability Statistics	
Cronbach's Alpha	N of Items
.95	24

Each item in the list (Table 5.2) demonstrates a strong and close relationship with other items as such proved a reliable internal consistency of items and measurements.

5.2.2 Results and Discussion

5.2.2.1 Barriers to BIM adoption in Nigeria

Subjecting the fourteen generated barriers to BIM adoption in Nigeria into RII (see Table 5.4) using a Five-point Weighing scale (1-5), it is realised that the 1st to 9th ranked barriers are the most significant with RII ≥ 0.70 (mean ≥3.5) in a five-point scale (Badu et al. 2012).

The result, in general, indicated lack of expertise within the organisations, lack of expertise within the project team, lack of standardisation and protocols, and lack of client demand as the most influential barriers (1st to 4th) respectively. Then ranked the following: lack of government policy, lack of additional project finance to support BIM, lack of collaboration among stakeholders, and the reluctance of team members to share information as 5^{th}.

Table 5.4: RII and ranking of barriers against BIM adoption in Nigeria

Number of Rank R & Weighted value W impact	Weight 5	Weight 4	Weight 3	Weight 2	Weight 1	Total	Σ W	RII	Rank
Lack of expertise within the organisations	110	92	39	10	5	68	256	0.75	1
Lack of expertise within the project team	90	92	42	14	6	68	244	0.72	2
Lack of standardisation and protocols	85	76	63	8	7	68	239	0.70	3
Lack of client demand	95	60	42	22	9	68	228	0.67	4
Lack of government policy	85	80	27	24	10	68	226	0.66	5
Lack of additional project finance to support BIM	75	64	63	16	8	68	226	0.66	5
Lack of collaboration among stakeholders	55	88	51	24	6	68	224	0.66	5
Reluctance of team members to share information	40	100	57	22	5	68	224	0.66	5
Industry's Cultural resistance	50	80	60	26	5	68	221	0.65	9
High Investment Cost	80	44	60	26	8	68	218	0.64	10
Lack of infrastructure	60	84	42	16	13	68	215	0.63	11
Return on Investment (ROI) issue	40	48	75	30	8	68	201	0.59	12
Resistance at operational level	30	56	81	24	9	68	200	0.59	12
Legal issues around ownership, IP & PI insurance	50	36	63	36	10	68	195	0.57	14

These barriers were analysed further to balance the perceptions by the BIM adopters and non-adopters. Table 5.5 presents the two group rankings. From a first glance on radar plot (Figure 5.1), adopters ranking was quite simultaneous, indicating a higher level of reality and consistency. At the same time, non-adopters are a sort of zig-zag manner (ranking whether very high or very low). This suggests that, while adopting BIM perception to barriers change as realities are becoming dominant. The barriers ranked 1st, 2nd, 3rd and 4th by non-adopters, were ranked 2nd, 6th, 9th and 1st by adopters with quite lower average index, as such what is perceived most influential barriers before adoption tend to change after adoption perhaps such challenges were dealt with in the adoption process.

Table 5.5: Variation of barriers ranking among adopters and non-adopters

BARRIERS	Adopters		Non-adopters	
	RII	Rank	RII	Rank
Lack of standardisation and protocols	0.74	1	0.66	4
Lack of expertise within the organisations	0.72	2	0.79	1
Industry's Cultural resistance	0.69	3	0.60	11
Lack of additional project finance to support BIM	0.69	3	0.64	9
Lack of client demand	0.68	5	0.66	4
Lack of expertise within the project team	0.67	6	0.77	2
Lack of government policy	0.67	6	0.66	4
Lack of collaboration among stakeholders	0.66	8	0.66	4
Resistance at operational level	0.65	9	0.52	14
Reluctance of team members to share information	0.65	9	0.67	3
High Investment Cost	0.64	11	0.64	8
Lack of infrastructure	0.63	12	0.63	10
Return on Investment (ROI) issue	0.59	13	0.59	12
Legal issues around ownership, IP & PI insurance	0.57	14	0.58	13
Average RII	**0.66**		**0.65**	

At the individual (each) item's level, most barriers are having nearly the same Relative Importance Index (RII); only a few can be seen with up 0.1 differences. These items include the industry's cultural resistance (0.69-0.60=0.09), lack of expertise within the project team (0.67-0.77=0.10), and resistance at the operational level (0.65-0.52=0.13). The industry's cultural resistance can be experienced or noticed more by the adopters, especially when trying to work with a non-adopter firm; thus, may be seen as more important and higher thank a non-adopter. In contrast, the lack of expertise within the project team would be seen more important by the non-adopters than by one who already started the BIM journey (adopter). Lastly, the resistance at the operational level appears more of value to one who started the BIM deployment journey (adopter) and less of importance to one who does not even try using it (non-adopters).

On the other hand, they quite agree on more than half of these barriers as to their significance or indexes. For instance, High Investment Cost, Lack of infrastructure, and Return on Investment (ROI) issues scored the same magnitude, although they were in different ranks. This situation leads to the determination of Percentage Disagreement (PD) and Percentage Agreement (PA) to allow us to drive exclusive findings.

Table 5.6 presents the evaluation of the PD and PA. The result reveals 49.48% PD and 50.52% PA, meaning both groups have approximately 50:50 agreement to disagreement, in other words, they agreed on half (50%) of the ratings and disagreed on the other half (50%). Conclusively, this indicates that the adopters are still at the infancy stage as their PA is still high (50%). Higher PA does not go with the findings from (Eadie et al. 2014) that "…BIM adopters change their views on the most significant barriers to BIM after implementation by ranking them differently than those yet to adopt BIM" (Eadie et al. 2014) [p. 92]. Moreover, the RII average of 0.66 for adopters and 0.65 for non-adopters indicated a small difference to their perception of BIM adoption barriers. Thus, this indicates that Nigeria is in the early stage of BIM adoption.

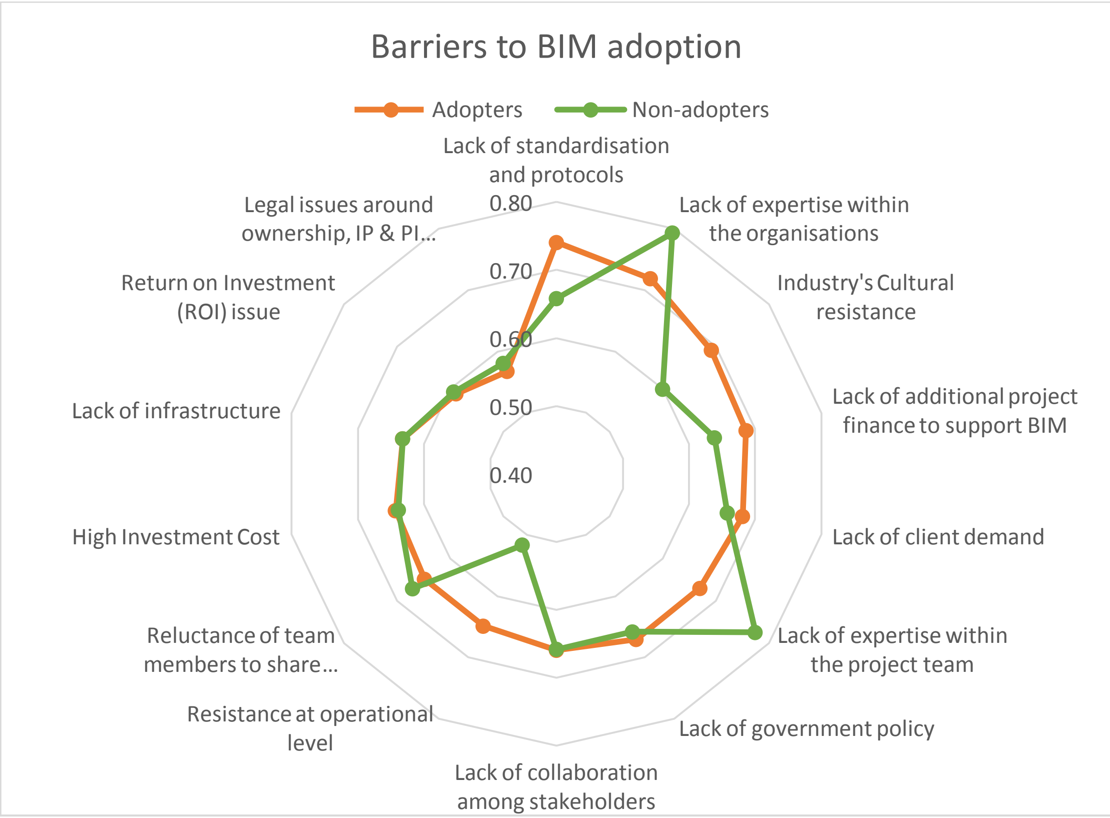


Figure 5.1: Variation of barriers ranking among adopters and non-adopters (Source: field survey, 2018.)

Succinctly, nine of the fourteen barriers are significantly important to both adopters and non-adopters; however, the remaining five appeared less important to both groups. These five barriers are resistance at the operational level, high investment cost, lack of infrastructure, return on investment (ROI) issue as well as legal issues around ownership, IP & PI insurance.

Table 5.6: RAF, PD and PA values for BIM Barriers

BARRIERS	BIM Users	BIM Non-users					
	Rank (Ri1)	Rank (Ri2)	Ri1-Ri2	Absolute of Ri1-Ri2	Rj2 = Ri2 corresponds to (N-Ri1+1) from Ri1	Ri1-Rj2	Absolute of Ri1-Rj2
Lack of standardisation and protocols	1	4	-3	3	13	-12	12
Lack of expertise within the organisations	2	1	1	1	12	-10	10
Industry's Cultural resistance	3	11	-8	8	10	-7	7
Lack of additional project finance to support BIM	3	9	-6	6	10	-7	7
Lack of client demand	5	4	1	1	3	2	2
Lack of expertise within the project team	6	2	4	4	14	-8	8
Lack of government policy	6	4	2	2	14	-8	8
Lack of collaboration among stakeholders	8	4	4	4	4	4	4
Resistance at operational level	9	14	-5	5	2	7	7
Reluctance of team members to share information	9	3	6	6	2	7	7
High Investment Cost	11	8	3	3	9	2	2
Lack of infrastructure	12	10	2	2	11	1	1
Return on Investment (ROI) issue	13	12	1	1	1	12	12
Legal issues around ownership, IP & PI insurance	14	13	1	2	4	10	10
			Absolute Sum	48		Absolute Sum	97
			RAF	3.43		RAF MAX	6.93
			PD	49.48%		PA	50.52%

5.2.2.2 Drivers to BIM adoption in Nigeria

Subjecting the ten generated drivers (section 2.7.2) to BIM adoption in Nigeria into RII (see Table 5.7) using the Five-point Weighing scale (1-5), it was realised that the 1st to 7th ranked drivers are the most significant with RII ≥ 0.70 (mean ≥3.5) in a five-point Weighing scale (Badu et al. 2012). The most influential drivers revealed are the availability of trained professionals to handle the tools, proof of cost savings by its adoption, BIM Software affordability and awareness of the technology among industry stakeholders (in descending order). Moreover, ranked the following as 5th clients' interest in the use of BIM in their projects, cooperation and commitment of professional societies to its implementation, and enabling environment within the industry.

Table 5.7: RII and ranking of drivers against BIM adoption in Nigeria

Number of Rank R & Weighted value W impact	Weight 5	Weight 4	Weight 3	Weight 2	Weight 1	Total	∑ W	RII	Rank
Availability of trained professionals to handle the tools	130	84	24	16	5	68	259	0.76	1
Proof of cost savings by its adoption	85	88	57	12	4	68	246	0.72	2
BIM Software affordability	90	84	36	18	8	68	236	0.69	3
Awareness of the technology among industry stakeholders	70	84	57	22	3	68	236	0.69	3
Clients interest in the use of BIM in their projects	115	48	45	12	12	68	232	0.68	5
Cooperation and commitment of professional societies to its implementation	80	72	48	26	5	68	231	0.68	5
Enabling environment within the industry	60	92	48	26	4	68	230	0.68	5
Collaborative Procurement methods	45	84	54	16	12	68	211	0.62	8
Government support through legislation	65	64	42	22	14	68	207	0.61	9
Cultural change among industry stakeholders	20	92	54	32	7	68	205	0.60	10

These drivers were analysed further to balance the perceptions by both adopters and non-adopters. Table 5.8 presents the two group rankings. From a first glance on radar plot (Figure 5.2), adopters ranking was simultaneous, indicating a higher level of reality and consistency while non-adopters are a sort of zig-zag at some points (ranking very high and very low). This suggests that while adopting BIM, perception to driving the adoption changes. The drivers ranked 1st, 2nd, 3rd and 4th by non-adopters, are ranked 1st, 8th, 5th and 2nd by adopters with a very small difference of average RII, as such what are perceived most influential drivers before adoption tend to change after adoption.

On the other hand, RII average of 0.68 and 0.67 for adopters and non-adopters scoring revealed that the adopters are still at an early stage, so they perceived the same drivers' influence with the non-adopters.

Table 5.8: Variation of drivers ranking among adopters and non-adopters

DRIVERS	**Adopters**		**Non-adopters**	
	RII	**Rank**	**RII**	**Rank**
Availability of trained professionals to handle the tools	0.76	1	0.77	1
Proof of cost savings by its adoption	0.74	2	0.70	4
Clients interest in the use of BIM in their projects	0.70	3	0.66	6
Enabling environment within the industry	0.69	4	0.66	6
Awareness of the technology among industry stakeholders	0.68	5	0.71	3
Cooperation and commitment of professional societies to its implementation	0.68	5	0.68	5
Cultural change among industry stakeholders	0.66	7	0.54	10
BIM Software affordability	0.65	8	0.74	2
Collaborative Procurement methods	0.65	8	0.59	8
Government support through legislation	0.61	10	0.61	8
Average RII	**0.68**		**0.67**	

Notwithstanding, the adopters and non-adopters nearly have the same average RII, the adopters disagree a bit more than they agree with the non-adopters in terms of individual drivers' influence to the adoption of BIM (see Table 5.8). The availability of trained professionals to handle the tools, cooperation and commitment of professional societies to BIM implementation and Government support through legislation are drivers scoring the same and rated the same to moving the adoption further by both adopters and non-adopter; which perhaps suggesting persistent drivers needed to invest on.

Table 5.9 presents the evaluation of the PD and PA. The result reveals more justification for early BIM adoption stage in the country. PD is found to be 58.82% and PA as 41.18%, means both groups have approximately or nearly 40:60

agreement to disagreement ratio, in other words, they agreed on 4 out of 10 (40%) of the drivers' scoring and disagreed on the remaining 6 out of the 10 (60%) drivers' scoring.

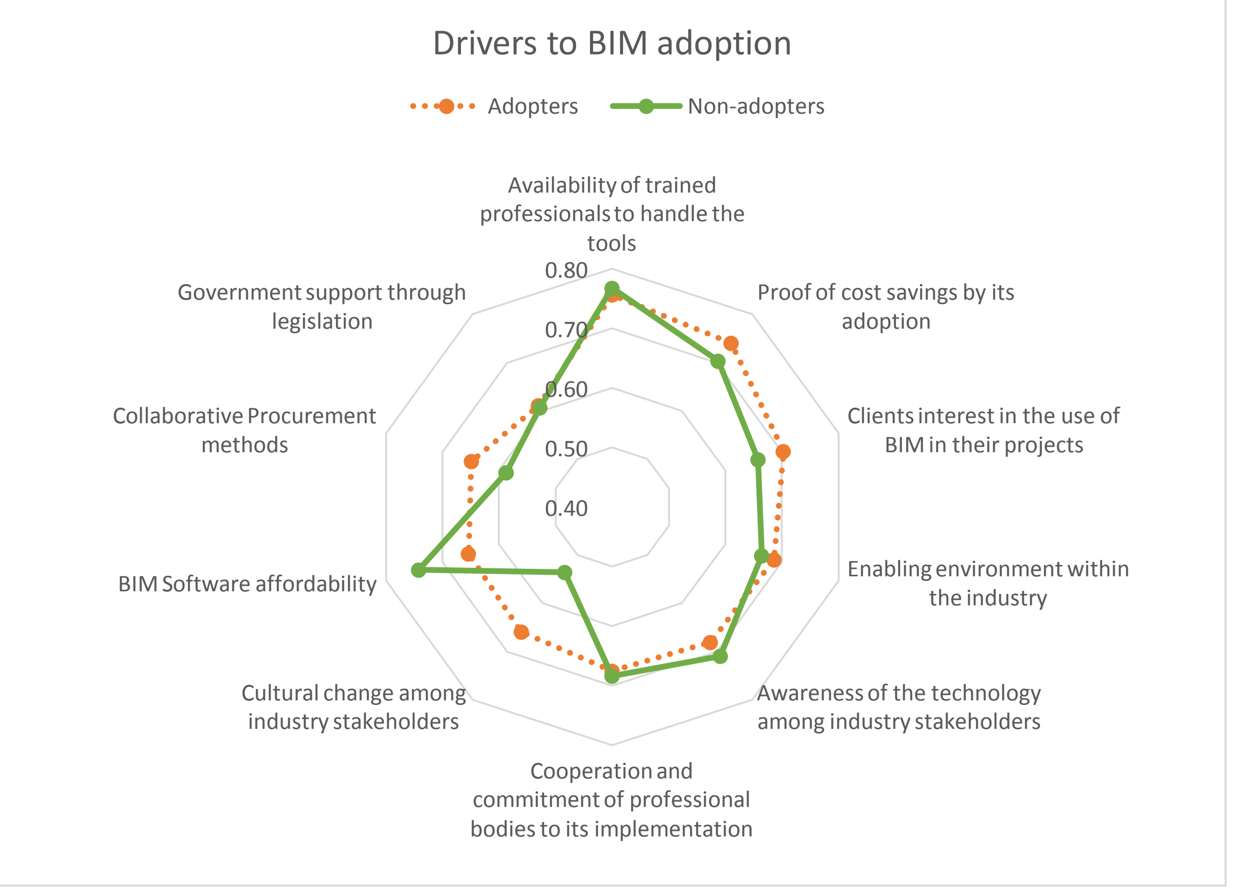


Figure 5.2: Variation of drivers ranking among adopters and non-adopters (Source: field survey, 2018.)

Succinctly, all the drivers are of high importance to both adopters and non-adopters with the exception of three who appeared less compared to the rest. These three drivers are cultural change among industry stakeholders, collaborative procurement methods and government support through legislation.

Table 5.9: RAF, PD and PA values for BIM Drivers

DRIVERS	**BIM Users** Rank (R1)	**BIM Non-users** Rank (R2)	R*i*1-R*i*2	Absolute of R*i*1-R*i*2	R*j*2 = R*i*2 corresponds to (N-R*i*1+1) from R*i*1	R*i*1-R*j*2	Absolute of R*i*1-R*j*2
Availability of trained professionals to handle the tools	1	1	0	0	8	-7	7
Proof of cost savings by its adoption	2	4	-2	2	8	-6	6
Clients interest in the use of BIM in their projects	3	6	-3	3	2	1	1
Enabling environment within the industry	4	6	-2	2	10	-6	6
Awareness of the technology among industry stakeholders	5	3	2	2	5	0	0
Cooperation and commitment of professional societies to its implementation	5	5	0	0	5	0	0
Cultural change among industry stakeholders	7	10	-3	3	6	1	1
BIM Software affordability	8	2	6	6	6	2	2
Collaborative Procurement methods	8	8	0	0	6	2	2
Government support through legislation	10	8	2	2	1	9	9
			Absolute Sum	20		Absolute Sum	34
			RAF	2.00		RAF MAX	3.40
			PD	58.82%		PA	41.18%

5.2.3 Findings/Conclusions

The urgent need for BIM adoption in the construction industry is providing huge opportunities in research and development. However, research in barriers and drivers to BIM adoption did not yield or fetched universal adoption; thus, that leaves a question of inadequacy or misrepresentations. There are several findings on barriers and drivers to adopt BIM from the literature, many of which having a different influence over the other. Nigeria is among developing countries where BIM is becoming vibrant; however, BIM adoption in Nigeria remains in its infancy. This piece of study aims at filling the gap of differentiating by order of importance, the common barriers vis-a-vis drivers toward BIM adoption in the Nigerian construction industry. Fourteen barriers and ten drivers identified from the literature, five Weighing scale was used for measurement of respondents' perceptions and RII was used to rank perceptions. The findings discovered that 1st to 9th ranked barriers are very important (highly influential) against the adoption and 1st to 7th drivers are significant (highly influential) to facilitate BIM adoption in Nigeria.

Further evaluation was carried out in comparing the perception of those adopted BIM and those that have not. Ranking and scoring of barriers and drivers amongst adopters and non-adopters have nearly 50:50 PD to PA, which suggests early adoption stage or low maturity level. Typical and most significant barriers and drivers were established from the two set groups. The common and most significant barriers to adopters and non-adopters are:

- Lack of standardisation and protocols
- Lack of expertise within the organisations
- Industry's Cultural resistance
- Lack of additional project finance to support BIM
- Lack of client demand
- Lack of expertise within the project team
- Lack of government policy
- Lack of collaboration among stakeholders
- Reluctance of team members to share information

And, the common and most significant drivers to adopters and non-adopters are:

- Availability of trained professionals to handle the tools
- Proof of cost savings by its adoption
- Clients interest in the use of BIM in their projects
- Enabling environment within the industry
- Awareness of the technology among industry stakeholders
- Cooperation and commitment of professional societies to its implementation
- BIM Software affordability.

This study contributes to knowledge in providing an in-depth understanding of barriers and drivers from adopters and non-adopters perspectives, their strengths of influences (from the two groups) and their combined impact to the adoption of BIM in the Nigerian construction industry.

5.3 MACRO BIM ADOPTION (ESTABLISHING NIGERIA'S BIM MATURITY)

The Nigerian macro-BIM adoption study aims to assist the policy makers in developing and or assessing the macro BIM diffusion policies, strategies and plans within the Nigerian construction market. Sequel to the completion of the assessment, the study aimed to achieve deliverables at Initiation Phase of Policy Development and specifically the development of a seed BIM policy framework and engagement with stakeholders. Finally, the assessment and planning of diffusion roles are generated by mapping the macro player groups and the macro maturity components.

This section of the analysis is carried out mainly to assist the researcher in the development of a working strategy for an effective BIM adoption. Therefore, assessment of current market-specific on BIM diffusion policies becomes necessary, and the developed macro-BIM maturity models by (Succar and Kassem 2015) is thus adopted. The adopted framework consists of five conceptual models, as illustrated in Succar and Kassem (2015).

The precedence set by these models in their application of establishing BIM adoption at macro level ensured that the adopted framework is appropriate to achieve the researchers' objectives.

5.3.1 Nigerian Macro Maturity Model

A structured questionnaire was used as a tool for data collection (Yilmaz et al. 2017) hosted online using google forms. Besides, the snowball method was adopted in targeting the survey respondents due to low level of BIM awareness and maturity in the country (Hamma-adama et al. 2018). A few numbers of BIM adopters volunteered to participate in the survey, and subsequently, more participants were recorded through them (initial respondents) – snowball. The thirty-Seven (37) valid responses are part of the sixty-nine (69) responses recorded in the same survey of section 5.2. The 37 participants are respondents who adopted BIM, which ais referred to as 'adopters' in the previous section (5.2). The demography of the respondents is presented in Table 5.10, and the data was analysed quantitatively. This study is 'market' specific; and the target was establishing the level of BIM 'diffusion and adoption' in Nigeria.

Table 5.10: Profile of respondents (field survey, 2018.)

Variable	Characteristics	Freq.	Percentage (%)	Total
Location of practice	North-Central	18	48.6	
	North-East	2	5.4	
	North-West	8	21.6	
	South-East	2	5.4	
	South-South	3	8.1	
	South-West	4	10.8	37
Years practice	< 5 years	12	32.4	
	5 - 10 years	13	35.1	
	11 - 15 years	5	13.5	
	> 15 years	7	18.9	37
Number of employees	< 10 personnel (Micro)	21	56.8	
	10 - 50 personnel (Small)	12	32.4	
	50 - 200 personnel (Medium)	3	8.1	
	> 200 personnel (Large)	1	2.7	37
Profession	Architecture	14	37.8	
	Building Engineering	1	2.7	
	Civil/Structural Engineering	14	37.8	
	Construction Management	0	0.0	
	Electrical Engineering	0	0.0	
	Mechanical Engineering	1	2.7	
	Quantity Surveying	6	16.2	
	Other	1	2.7	37
Specialization	Contractor/Construction	8	21.6	
	Designer or Consultant	27	73.0	
	Client	1	2.7	
	Development Authority	1	2.7	37
Level of BIM utilization	Modelling only - BIM stage 1	20	54.1	
	Limited to Collaboration - BIM stage 2	12	32.4	
	Up to Integration - BIM stage 3	5	13.5	37

There are two dominant BIM maturity classifications or capability stages; these are the Succar (2009) descriptive BIM capability stages 1, 2 and 3 and the Bew-Richards' BIM maturity levels 0, 1, 2 and 3. The Succar's three-stage capabilities evaluate maturity from the first point of adoption (POA) just after the readiness ramp as BIM stage 1 (modelling only), to BIM stage 2 (limited to collaboration) and BIM stage 3 (up to integration). On the other hand, Bew-Richards' UK BIM maturity is prescribed based on levels, BIM level 0, BIM level 1, BIM level 2 and BIM level 3. Level 0 is an unmanaged CAD, predominantly two-dimensional CAD system (2D) with paper or electronic paper as a dominant information exchange mechanism (BIM Industry Working Group 2011b). Moreover, the level 0 appears to be of the same description of POA or pre-BIM in Succar and Kassem (2016), while the BIM level 1, 2 and 3 may be seen to be matching with the Succar-Kassem's capability stages 1, 2 and 3 respectively. Going by a wide consideration of BIM capability stages in most of BIM studies, Succar-Kassem's maturity stages are specifically adopted for this section of work as it were in the Macro-BIM adoption conceptual models (Succar and Kassem 2015).

5.3.1.1 Model A: Diffusion Areas model

Diffusion area model explains how BIM field types (process, policy and technology) relate with the BIM capability stages (integration, collaboration and modelling) to produce nine diffusion areas. That is where BIM diffusion occurs; such regions can be analysed and planned. Question 15 in the questionnaire survey refers to Appendix – 9 (9.9p.301) deals with the assessment of the Diffusion Areas. The findings here demonstrated an irregular distribution of rates as evaluated in Table 5.11 and presented in Figure 5.3. Nigeria and Ireland are reasonably mature in applying technology for modelling purpose with a little move at utilising technology for collaboration as well as processes at the modelling stage. There is a shallow level of inter-organisational collaboration and no model workflow at both fields not to talk of integration. On the other hand, there has been no policy or mandate by the government (Hamma-adama et al. 2018).

Table 5.11: Evaluation of the Diffusion Areas

Respondents	Modelling Technologies	Modelling processes	Modelling policies	Collaboration technologies	Collaboration processes	Collaboration policies	Integration technologies	Integration processes	Integration policies
Res. 1	3.0	1.0	2.0	2.0	2.0	2.0	1.0	2.0	1.0
Res. 2	3.0	2.0	1.0	0.0	0.0	0.0	1.0	1.0	0.0
Res. 3	4.0	2.0	1.0	2.0	2.0	1.0	1.0	1.0	1.0
Res. 4	3.0	2.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0
Res. 5	2.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Res. 6	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.0
Res. 7	2.0	1.0	1.0	1.0	0.0	0.0	1.0	1.0	1.0
Res. 8	3.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	0.0
Res. 9	4.0	2.0	1.0	2.0	2.0	1.0	2.0	2.0	1.0
Res. 10	2.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Res. 11	2.0	1.0	0.0	1.0	1.0	0.0	0.0	0.0	0.0
Res. 12	2.0	1.0	0.0	1.0	1.0	0.0	0.0	0.0	0.0
Res. 13	3.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	1.0
Res. 14	2.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0
Res. 15	4.0	2.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0
Res. 16	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Res. 17	3.0	1.0	1.0	2.0	1.0	1.0	2.0	1.0	1.0
Res. 18	2.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Res. 19	1.0	2.0	2.0	2.0	1.0	2.0	1.0	1.0	1.0
Res. 20	4.0	2.0	2.0	2.0	2.0	2.0	1.0	1.0	0.0
Res. 21	4.0	2.0	2.0	2.0	2.0	1.0	2.0	2.0	1.0
Res. 22	2.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.0
Res. 23	4.0	2.0	1.0	2.0	1.0	1.0	1.0	1.0	0.0
Res. 24	3.0	2.0	2.0	1.0	1.0	1.0	2.0	2.0	1.0
Res. 25	2.0	1.0	1.0	1.0	1.0	1.0	0.0	0.0	0.0
Res. 26	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Res. 27	2.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Res. 28	3.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	1.0
Res. 29	1.0	1.0	0.0	1.0	1.0	0.0	1.0	1.0	0.0
Res. 30	3.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	1.0
Res. 31	0.0	0.0	0.0	1.0	1.0	0.0	1.0	0.0	0.0
Res. 32	2.0	1.0	2.0	2.0	1.0	2.0	2.0	2.0	1.0
Res. 33	2.0	1.0	0.0	1.0	1.0	0.0	0.0	0.0	0.0
Res. 34	1.0	1.0	0.0	1.0	1.0	0.0	0.0	0.0	0.0
Res. 35	2.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Res. 36	3.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	1.0
Res. 37	3.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Mean	2.4	1.3	1.0	1.2	1.0	0.8	0.9	0.9	0.5
Remark	**Medium-High**	**Medium**	**Medium - Low**	**Medium**	**Medium - Low**	**Medium - Low**	**Medium**	**Medium - Low**	**Low /Low - Medium**
Diffusion Capabilities (%)	**59%**	**32%**	**25%**	**30%**	**26%**	**21%**	**24%**	**23%**	**11%**

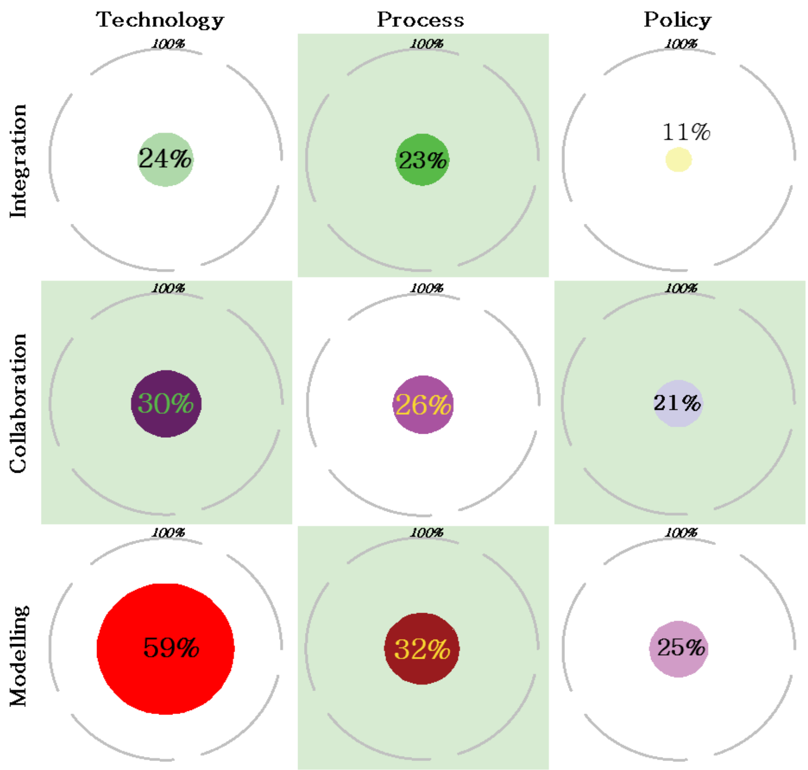


Figure 5.3: Diffusion Areas model for Nigeria

The survey results showed that Nigeria is mature for modelling technologies and processes, but it is weak in regard to collaboration processes and policies. The presented result in Figure 5.3 demonstrates deficiencies in the area of operations and procedures at least from the collaboration stage. It is therefore established that by 2018, the diffusion levels of staged capability milestones in the Nigerian construction market are as follows:

25% diffusion rate of modelling capabilities,

21% diffusion rate of collaboration capabilities and

11% diffusion rate of integration capabilities.

5.3.1.2 Model B: Macro-Maturity Components model

There are eight complementary components within the Macro Maturity Components model used in measuring and establishing the maturity of BIM at a country level. The developed and refined components by (Kassem and Succar 2017) are as follows: Champions and drivers; Measurements and benchmarks; Noteworthy publications; Objectives, stages and milestones; Learning and education;

Standardised parts and deliverables; Regulatory frameworks and Technology infrastructure.

Figure 5.4 illustrates BIM macro-maturity components in Nigeria, which is Nigeria's current maturity within each component. These components were assessed with BIMMI, which has different maturity levels (from the outer to the inner circle) as follows: ad-hoc – low maturity; defined – medium-low maturity; managed – medium maturity; integrated – medium-high maturity; and optimised – high maturity.

The components converge as they mature from a to e corresponding to ad-hoc to optimised or low maturity to high maturity. These components and their maturity index set a very clear description of all the eight components within a market. The closer these components are (converging), the mature they are. Assessments are made holistically based on granular matrix as to compare relative maturity of one component over the other as prescribed in table 11 of Succar and Kassem (2015). Successively, each component is evaluated using component-specific metrics as described in table 3–10 p.70-72 of Succar and Kassem (2015).

Question 16 in the questionnaire survey refers to Appendix – 9 (p.301) deals with the assessment of the Macro-maturity components. Table 5.12 presents the data and the evaluation of each component based on the component-specific metrics.

Table 5.12:Evaluation of the Macro-Maturity Components

Respondents	Objective, stage and milestones	Champions and Drivers	Regulatory Framework	Noteworthy Publications	Leaning & Education	Measurements & Benchmarks	Standardised parts & Deliverables	Technology Infrastructure
Respondent 1	3.0	2.0	0.0	1.0	4.0	3.0	2.0	3.0
Respondent 2	2.0	1.0	1.0	0.0	1.0	1.0	3.0	2.0
Respondent 3	1.0	3.0	0.0	0.0	0.0	1.0	0.0	0.0
Respondent 4	0.0	1.0	0.0	0.0	1.0	0.0	1.0	1.0
Respondent 5	1.0	2.0	0.0	0.0	3.0	1.0	1.0	3.0
Respondent 6	1.0	2.0	0.0	1.0	0.0	1.0	2.0	1.0
Respondent 7	2.0	1.0	1.0	0.0	1.0	1.0	0.0	1.0
Respondent 8	1.0	2.0	2.0	2.0	4.0	4.0	4.0	4.0
Respondent 9	2.0	0.0	0.0	0.0	2.0	1.0	2.0	1.0
Respondent 10	2.0	1.0	0.0	0.0	1.0	1.0	1.0	2.0
Respondent 11	1.0	3.0	0.0	0.0	1.0	1.0	1.0	1.0
Respondent 12	1.0	2.0	0.0	0.0	1.0	1.0	1.0	2.0
Respondent 13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Respondent 14	0.0	1.0	0.0	0.0	0.0	0.0	0.0	1.0
Respondent 15	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Respondent 16	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0
Respondent 17	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0
Respondent 18	2.0	2.0	0.0	1.0	1.0	1.0	1.0	1.0
Respondent 19	4.0	3.0	1.0	0.0	3.0	3.0	3.0	3.0
Respondent 20	4.0	4.0	2.0	2.0	4.0	4.0	1.0	1.0
Respondent 21	4.0	3.0	2.0	1.0	2.0	2.0	2.0	2.0
Respondent 22	3.0	2.0	0.0	0.0	2.0	0.0	0.0	0.0
Respondent 23	1.0	2.0	0.0	2.0	0.0	1.0	2.0	1.0
Respondent 24	2.0	2.0	1.0	1.0	2.0	2.0	2.0	2.0
Respondent 25	2.0	1.0	0.0	0.0	2.0	1.0	1.0	1.0
Respondent 26	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0
Respondent 27	2.0	3.0	2.0	2.0	3.0	3.0	2.0	3.0
Respondent 28	1.0	1.0	0.0	0.0	1.0	1.0	1.0	1.0
Respondent 29	2.0	1.0	0.0	0.0	1.0	1.0	0.0	1.0
Respondent 30	1.0	2.0	1.0	0.0	2.0	2.0	3.0	3.0
Respondent 31	2.0	1.0	0.0	0.0	1.0	1.0	0.0	1.0
Respondent 32	0.0	0.0	0.0	0.0	1.0	1.0	1.0	0.0
Respondent 33	1.0	2.0	0.0	0.0	1.0	0.0	0.0	0.0
Respondent 34	1.0	1.0	0.0	0.0	1.0	1.0	1.0	1.0
Respondent 35	2.0	1.0	1.0	0.0	1.0	2.0	2.0	1.0
Respondent 36	4.0	3.0	2.0	2.0	2.0	2.0	4.0	4.0
Respondent 37	0.0	1.0	0.0	0.0	1.0	1.0	1.0	1.0
Mean	1.5	1.6	0.4	0.4	1.4	1.2	1.2	1.3
Remark	**Medium - Low / Medium**	**Medium - Low / Medium**	**Low**	**Low**	**Medium - Low**	**Medium - Low**	**Medium - Low**	**Medium - Low**
Percentage	**38%**	**41%**	**11%**	**10%**	**34%**	**30%**	**30%**	**33%**

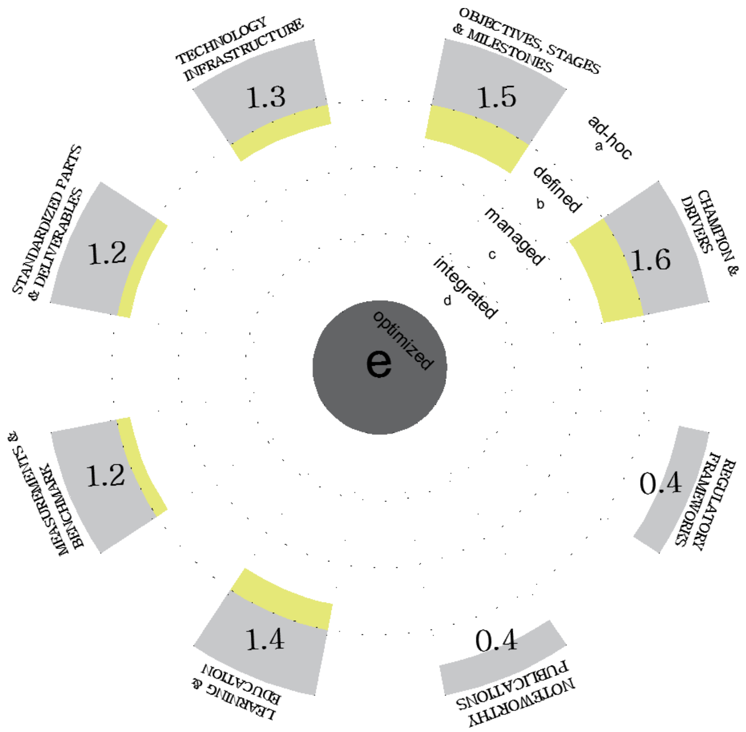


Figure 5.4: Macro-Maturity Components model for Nigeria

The Nigerian construction market appears with a dominant 'medium-low' maturity. Champions & drivers are leading with 1.6 (between medium-low and medium maturity) on a Five-point weighing scale of 0, 1, 2, 3, and 4 corresponding to maturity levels of a, b, c, d and e as described above. These indicate that the components tangle between 'defined' and 'managed' levels (b and c), as such, all the components needed a push. The evaluation suggests an early adopter with individuals as champions promoting the BIM adoption.

Moreover, ranking regulatory framework lowest is an indication that the government lacks policy consideration in this regard; and pending when a statutory requirement is considered, most of these components may not advance.

5.3.1.3 Model C: Macro-Diffusion Dynamics model

The macro-diffusion dynamic model was adopted from pp.72 fig.7 of (Succar and Kassem 2015), primarily to assess the adoption trend within a market and compare with the directional pressures to how diffusion unfolds within a specific market. This model comprises three diffusion dynamics, namely: Bottom-Up; Middle-Out and Top-Down (Succar and Kassem 2015). Moreover, this model sets four directional pressure mechanisms which are laid over the three diffusion dynamics; these include Downwards, Horizontal Downwards, Upwards Horizontal and Upwards Horizontal pressures. A question (question 17: Appendix – 9, p.301) was asked to the BIM adopters in Nigeria to determine the current diffusion dynamic of the market. The responses are presented in Table 5.13.

Table 5.13: Response to the Macro Diffusion Dynamics

Respondents	Top-down	Middle-out	Bottom-up
Respondent 1			Bottom-up
Respondent 2		Middle-out	
Respondent 3		Middle-out	
Respondent 4			Bottom-up
Respondent 5		Middle-out	
Respondent 6		Middle-out	
Respondent 7		Middle-out	
Respondent 8		Middle-out	
Respondent 9		Middle-out	
Respondent 10	Top-down		
Respondent 11		Middle-out	
Respondent 12			Bottom-up
Respondent 13			Bottom-up
Respondent 14			Bottom-up
Respondent 15			Bottom-up
Respondent 16			Bottom-up
Respondent 17			Bottom-up
Respondent 18		Middle-out	
Respondent 19			Bottom-up
Respondent 20			Bottom-up
Respondent 21		Middle-out	
Respondent 22			Bottom-up
Respondent 23			Bottom-up
Respondent 24		Middle-out	
Respondent 25			Bottom-up
Respondent 26			Bottom-up
Respondent 27			Bottom-up
Respondent 28		Middle-out	
Respondent 29		Middle-out	
Respondent 30			Bottom-up
Respondent 31	Top-down		
Respondent 32		Middle-out	
Respondent 33			Bottom-up
Respondent 34			Bottom-up
Respondent 35	Top-down		
Respondent 36			Bottom-up
Respondent 37			Bottom-up
Frequency	**3**	**14**	**20**
Response (%)	**8%**	**38%**	**54%**

The study reveals Nigeria's diffusion dynamic as predominantly bottom-up, by 'majority' response (Figure 5.5); this has been evaluated from the research participants' responses calculated in Table 5.13. The result indicated smaller organisations are those pushing the adoption in the industry but not the bigger firms or the government (Succar and Kassem 2015). However, the bigger organisations seem to be picking up, as a result, suggests their suit.

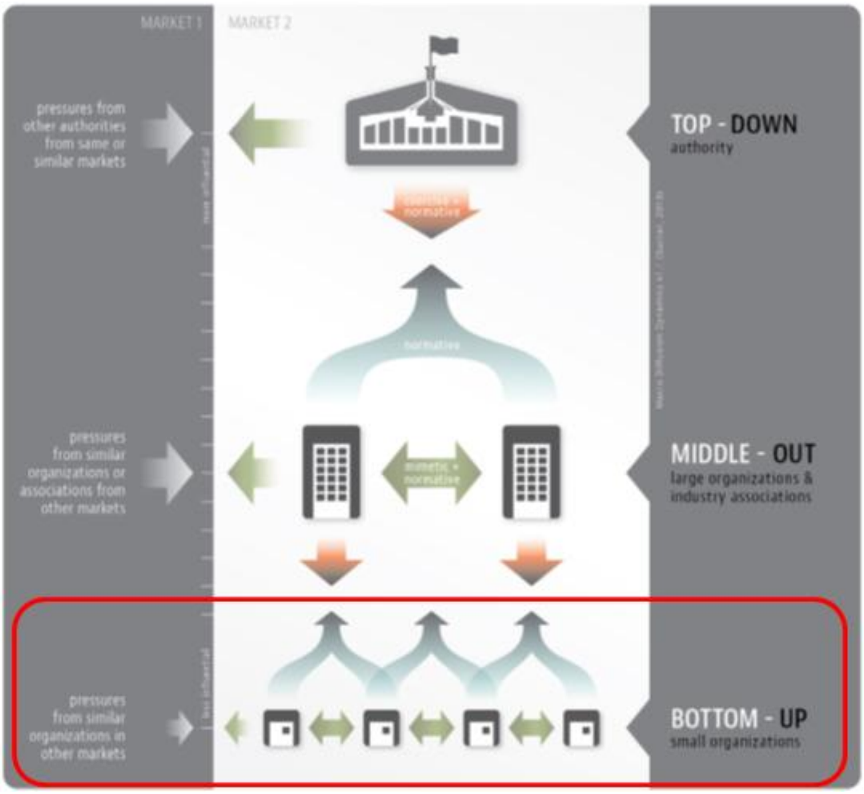


Figure 5.5: Diffusion Dynamics Model (Succar and Kassem 2015)

The bottom-up diffusion dynamic assured the transmission by small organisations in an upward horizontal pressure mechanism with industry bodies as indicated using a red circle in Figure 5.5. The larger organisations are pressure recipient along with the vertical directional pressure while the other small organisations are recipients along with the horizontal directional pressure with all as potential adopters. With the current lack of policy in place (Hamma-adama et al. 2018) and unwillingness from most of the more prominent companies to embrace the BIM process, the bottom-up diffusion dynamic would possibly continue.

5.3.1.4 Model D: Policy Actions model

The policy action model (Figure 5.6) has nine policy actions generated from mapping the three implementation approaches (passive, active and assertive) and the three implementation activities (communicate, engage and monitor) (Succar and Kassem 2015). The latter authors developed this model as an assessment tool to generate activities/tasks, which are used in comparing policy actions across many countries for structured policy intervention in achieving a market-wide BIM adoption.

Table 5.14: Evaluated Policy Actions for Nigeria

RESPONDENTS	COMMUNICATE Action	ENGAGE Action	MONITOR Action
Respondent 1	[1] Passive	[2] Active	[1] Passive
Respondent 2	[2] Active	[1] Passive	[1] Passive
Respondent 3	[2] Active	[2] Active	[1] Passive
Respondent 4	[2] Active	[1] Passive	[2] Active
Respondent 5	[2] Active	[1] Passive	[1] Passive
Respondent 6	[1] Passive	[2] Active	[1] Passive
Respondent 7	[1] Passive	[2] Active	[2] Active
Respondent 8	[3] Assertive	[3] Assertive	[1] Passive
Respondent 9	[1] Passive	[2] Active	[2] Active
Respondent 10	[1] Passive	[1] Passive	[1] Passive
Respondent 11	[3] Assertive	[2] Active	[3] Assertive
Respondent 12	[2] Active	[2] Active	[2] Active
Respondent 13	[2] Active	[3] Assertive	[3] Assertive
Respondent 14	[2] Active	[2] Active	[3] Assertive
Respondent 15	[2] Active	[2] Active	[2] Active
Respondent 16	[3] Assertive	[2] Active	[3] Assertive
Respondent 17	[2] Active	[3] Assertive	[2] Active
Respondent 18	[2] Active	[2] Active	[2] Active
Respondent 19	[2] Active	[3] Assertive	[3] Assertive
Respondent 20	[2] Active	[3] Assertive	[2] Active
Respondent 21	[2] Active	[1] Passive	[3] Assertive
Respondent 22	[2] Active	[2] Active	[2] Active
Respondent 23	[2] Active	[3] Assertive	[2] Active
Respondent 24	[2] Active	[2] Active	[2] Active
Respondent 25	[2] Active	[2] Active	[3] Assertive
Respondent 26	[2] Active	[1] Passive	[2] Active
Respondent 27	[1] Passive	[2] Active	[2] Active
Respondent 28	[2] Active	[3] Assertive	[2] Active
Respondent 29	[3] Assertive	[3] Assertive	[2] Active
Respondent 30	[2] Active	[2] Active	[2] Active
Respondent 31	[2] Active	[1] Passive	[1] Passive
Respondent 32	[3] Assertive	[3] Assertive	[2] Active
Respondent 33	[2] Active	[3] Assertive	[2] Active
Respondent 34	[3] Assertive	[3] Assertive	[1] Passive
Respondent 35	[2] Active	[3] Assertive	[1] Passive
Respondent 36	[2] Active	[3] Assertive	[3] Assertive
Respondent 37	[2] Active	[2] Active	[3] Assertive
Passive (frequencies)	**Passive: Make Aware - 6**	**Passive: Encourage - 7**	**Passive: Observe - 10**
Active (Frequencies)	**Active: Educate - 25**	**Active: Incentivise - 17**	**Active: Track - 18**
Assertive (Frequencies)	**Assertive: Prescribe - 6**	**Assertive: Enforce - 13**	**Assertive: Control - 9**

Question (question 19: Appendix – 9, p.301) was asked to the BIM adopters in Nigeria to determine the best Policy Action model fit for the market. Their responses are evaluated and presented in Table 5.14.

The Nigerian policy action pattern recorded a full active with a partial assertive at the engagement stage (see Figure 5.6). This suggests government intervention at both engagement and monitoring stages. Moreover, incentivise and enforce (Figure 5.6) are mostly prescribed by government/regulations. Therefore, the practitioners desired active government involvement approach.

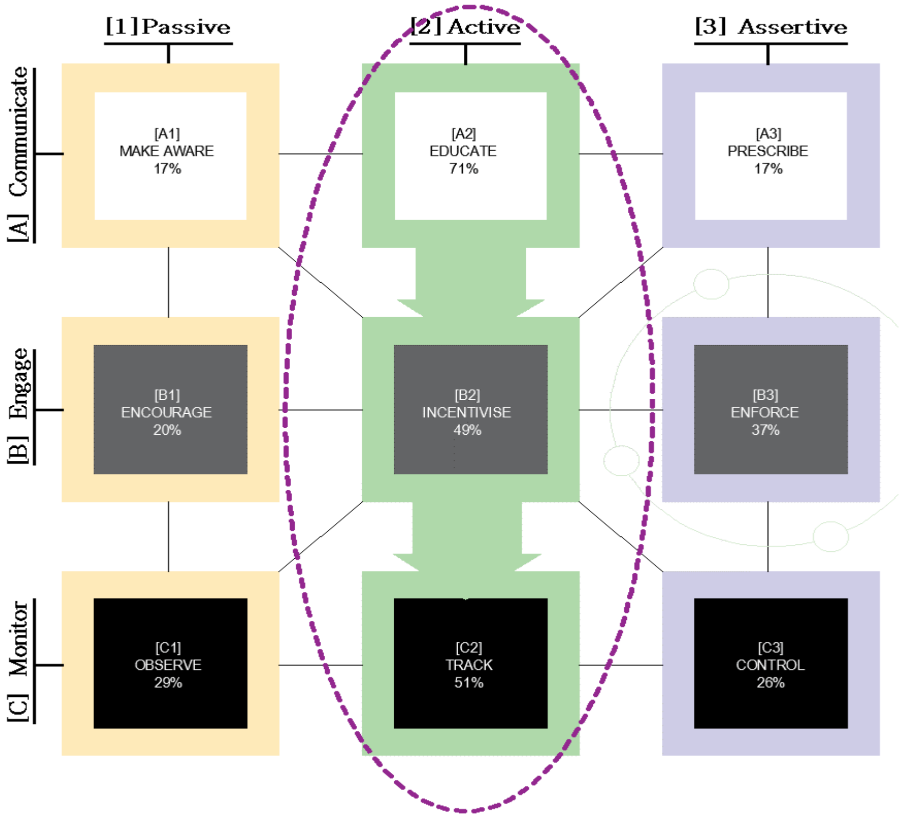


Figure 5.6: Policy Actions model of Nigeria

The evident result of diffusion of innovation within smaller organisations (bottom-up) has considerable influence in the behaviour of the bigger organisations or higher end of the supply chain (Geroski 2000).

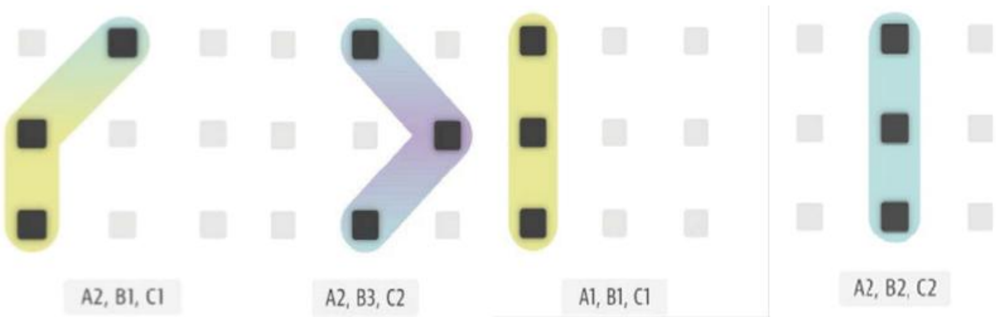


Figure 5.7: Policy Actions models of USA, UK Australia and Nigeria respectively

There are series of policy action model patterns at various country specifics that go along the vertical stripe, alternating within passive, active and assertive action along the three implementation activities. For example, Figure 5.7 presents different sets of policy action models of USA (A2, B1, C1), UK (A2, B3, C2), Australia (A1, B1, C1) and Nigeria (A2, B2, C2). The variation in policy action stripes revealed how dynamic construction markets are and how these processes change over time. It is not one process fits all, but many options to apply based on market specifics.

5.3.1.5 Model E: Macro-Diffusion Responsibilities model

The established BIM field types have their respective capability sets (that differ base on BIM stage) as a group of players within the construction industry and across the BIM field types (Succar 2009). This goes into the analyses of BIM diffusion through the players' (stakeholders) roles in the industry as a network of actors (Succar and Kassem 2015). The nine-player groups are technology advocates, communities of practice, policymakers, individual practitioners, construction organisations, educational institutions, technology developers, industry associations and technology service providers (Figure 5.8). Any of the player groups is either belongs to one of the three BIM fields type (Policy, Process & Technology) or intersection of any two; moreover, any player group has several player types as well.

A question (question 20: Appendix – 9, p.301 refers) for the assessment of macro diffusion responsibilities with respect to Nigeria construction market. The responses and evaluation are presented in Table 5.15.

Table 5.15: Evaluation of Macro Diffusion Responsibilities for Nigeria

Respondents	Policy Makers	Educational Institutions	Construction organisations	Technology developers	Technology Service Providers	Industry Associations	Communities of practice	Technology Advocates
Respondent 1	0.0	1.0	2.0	2.0	3.0	3.0	1.0	1.0
Respondent 2	0.0	2.0	1.0	0.0	0.0	0.0	0.0	0.0
Respondent 3	2.0	3.0	2.0	2.0	2.0	3.0	2.0	2.0
Respondent 4	0.0	1.0	0.0	0.0	2.0	1.0	0.0	1.0
Respondent 5	0.0	2.0	1.0	1.0	2.0	1.0	1.0	0.0
Respondent 6	2.0	3.0	1.0	0.0	0.0	2.0	1.0	0.0
Respondent 7	0.0	0.0	1.0	0.0	0.0	0.0	0.0	1.0
Respondent 8	1.0	0.0	1.0	1.0	1.0	0.0	0.0	0.0
Respondent 9	0.0	1.0	1.0	3.0	3.0	1.0	1.0	2.0
Respondent 10	2.0	3.0	1.0	2.0	1.0	2.0	1.0	2.0
Respondent 11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Respondent 12	2.0	3.0	3.0	3.0	2.0	2.0	1.0	2.0
Respondent 13	2.0	3.0	3.0	2.0	2.0	2.0	3.0	2.0
Respondent 14	3.0	3.0	1.0	3.0	1.0	2.0	3.0	3.0
Respondent 15	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Respondent 16	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Respondent 17	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Respondent 18	2.0	2.0	2.0	1.0	1.0	2.0	2.0	2.0
Respondent 19	3.0	3.0	2.0	2.0	3.0	3.0	3.0	2.0
Respondent 20	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Respondent 21	0.0	3.0	3.0	3.0	1.0	1.0	0.0	1.0
Respondent 22	0.0	0.0	0.0	0.0	0.0	1.0	1.0	0.0
Respondent 23	2.0	0.0	1.0	0.0	0.0	1.0	0.0	1.0
Respondent 24	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Respondent 25	3.0	3.0	3.0	2.0	3.0	3.0	2.0	3.0
Respondent 26	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Respondent 27	3.0	3.0	2.0	2.0	2.0	2.0	3.0	2.0
Respondent 28	1.0	1.0	2.0	0.0	1.0	1.0	0.0	1.0
Respondent 29	3.0	3.0	3.0	2.0	2.0	3.0	2.0	2.0
Respondent 30	2.0	3.0	3.0	3.0	2.0	3.0	2.0	2.0
Respondent 31	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Respondent 32	2.0	3.0	3.0	3.0	3.0	2.0	3.0	2.0
Respondent 33	1.0	1.0	1.0	1.0	0.0	1.0	0.0	0.0
Respondent 34	2.0	1.0	1.0	1.0	1.0	2.0	1.0	2.0
Respondent 35	0.0	1.0	0.0	0.0	1.0	0.0	0.0	1.0
Respondent 36	3.0	3.0	3.0	3.0	2.0	2.0	2.0	2.0
Respondent 37	3.0	3.0	3.0	1.0	1.0	3.0	1.0	1.0
Mean	**1.4**	**1.8**	**1.5**	**1.4**	**1.3**	**1.5**	**1.2**	**1.3**
Remark	**Medium - Low**	**Medium High**	**Medium - Low / Medium**	**Medium - Low**	**Medium - Low**	**Medium - Low / Medium**	**Medium - Low**	**Medium - Low**
Diffusion Capabilities (%)	**34%**	**44%**	**39%**	**34%**	**33%**	**38%**	**29%**	**32%**

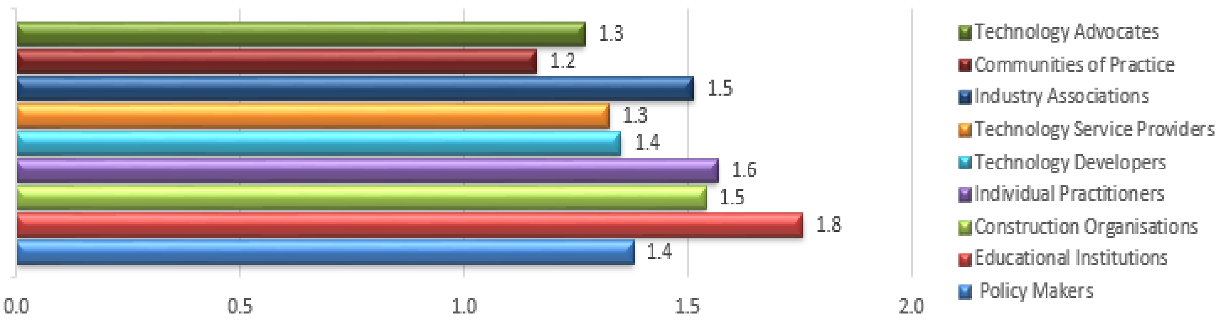


Figure 5.8: Nigerian Macro-Diffusion Responsibilities model

The survey result reveals that at present, the educational institutions and individual practitioners are the most influential players in the Nigerian construction market. In the same vein, construction organisations & professional associations were acknowledged as crucial process players. However, policymakers and communities of practice were the lowest players within this market. Figure 5.8 demonstrates the results of the model.

5.3.2 Development of BIM Policy Plans and Templates

The above models as equally explained in (McAuley et al. 2018) have assisted in a deeper understanding of BIM maturity in the Nigerian construction market and similarly revealed grey areas where attention is needed. Succar and Kassem demonstrated how these models are utilised to provide the basis for the BIM roadmap development at a national level.

The policy plan is developed through three phases (Initiation, Consultation and Execution). However, the execution stage is not considered here as it requires significant resources and political will or legislation to be accomplished.

5.3.2.1 Initiation Phase

The sequential input from model C and D are explained based on the survey findings; as such, model C (diffusion dynamics) identified the Nigerian market diffusion dynamic as predominantly bottom-up. This will subsequently influence the next input (model D – policy approach). The policy approach, as presented in model D (Figure 5.6) is most active, hence putting further pressure on the proposed BIM framework whose smaller organisations are currently leading.

Although there is no mandate in place, there is still a substantial awareness mostly at lower or individual level. The awareness in the education sector is moving very fast since the launch of BIM Africa Student Advocacy Program mostly led by Nigerian students of AEC related courses. This program (initiated in 2018) is serving as a medium to create awareness and training to students of higher institutions of learning around Africa. Although, the basic training can increase awareness; however, some of the critical issues that will subsequently arrive are the availability of up-to-date software and BIM expert for the training as a multi-disciplinary class (Hamma-Adama et al. 2018). The organisational BIM adoption represents discrete approaches that need profound consultations with the professionals' stakeholders to confirm the level of execution, successes and challenges.

The respondents largely agreed that the UK model provides a substantial guide once adopted. Other potential countries that are worth learning from are USA and Australia, they have potentials in technologies and terminology, and their BIM participation at the world stage and availability of noteworthy BIM publications are eminent (Kassem et al. 2013). Any remodelled framework for the study context must certify acceptability to the country and its ecosystem.

Primary website development as a source of valuable information for the Nigerian AEC industry is the last stage of the initiation phase. This portal/website also serves as a medium for awareness, guidance and source of Noteworthy BIM Publications (NBPs). AEC related professional regulatory bodies and the National Information Technology Development Agency (NITDA) are the key players in this aspect.

This initiation phase (for the Nigerian construction industry) is unique on its own way; therefore, it is different from that of other countries due to the deficit in the technology infrastructure, and the current champions and drivers leading the BIM adoption in the market. Moreover, the policy action from Nigeria is a middle vertical stripe as such suggests a different approach compared with the case study countries (Figure 5.7).

5.3.2.2 Consultation Phase

The consultation phase is explained as a stage where seed BIM framework is finally refined and transformed into a roadmap. The roadmap has a set of responsibilities that are assigned to selected stakeholders for action (Kassem and Succar 2017) [pp.295 fig.6]. Model E is then deployed with performance indicators and timeframes. The initial stage involves identifying (from the survey undertaken) experienced stakeholders and conducting face-to-face interviews as a replacement to the round-table discussions and workshops (McAuley et al. 2018). As a result, this process aids in capturing of challenges and recommendations of the stakeholders while identifying champions at the implementation stage.

The diffusion responsibility model helped in identifying sectors and areas where the Nigerian construction industry is lacking the needed attention as priorities are also considered; adequate resources are to be provided all through as a recommendation. A roadmap is therefore designed with important dates and milestones labelled and connected to policy deliverables through a Macro Roadmap Template generated in 2017 as explained by Kassem (Kassem and Succar 2017) [pp.296, Fig.8]. The consultation phase predominantly utilises data from interviews rather than from round-table discussion. This method explores high levels of individual firm's experiences and some collective (common) ones. Thus, the uniqueness of this phase is the utilisation of values and experiences derived at the firm level and at the market level.

5.3.3 Conclusions

The findings of this section provided the Nigerian construction industry's stand concerning current BIM adoption and significant information where the country is lacking that must be addressed to advance in macro adoption. These include the following: a low diffusion level of 11% and low maturity components (especially in the regulatory framework and NBPs) as suggested from the 'bottom-up' dynamic due to lack of regulations. The policy action model is slightly distributed across implementation approach and implementation activities with predominant 'active' approach (especially at the communication stage). Thus, this suggests government participation. As for the Macro diffusion responsibility, the result reveals that the educational institutions and individual practitioners are the most influential players in the Nigerian construction market. In the same vein, construction organisations & professional associations were acknowledged as crucial process players. This section also demonstrated briefly how the findings could be used further to develop a roadmap for an effective BIM adoption in Nigeria. A proposed roadmap will reflect these findings and some other challenges that are not mentioned here through a series of recommendations based on other results from subsequent collected data and analyses in sections 5.2 and 6.

5.4 CHAPTER SUMMARY

This chapter evaluated the most significant barriers and drivers to BIM adoption in Nigeria using RII. The Percentage Disagreement (PD) between adopters and non-adopters was also established. Ranking and scoring of barriers and drivers amongst adopters and non-adopters have nearly 50:50 PD to Percentage Agreement (PA) which suggests early adoption stage or low maturity level. Common and most significant barriers and drivers were established from the two set groups. The common and most significant barriers to adopters and non-adopters are Lack of standardisation and protocols; Lack of expertise within the organisations; Industry's Cultural resistance; Lack of additional project finance to support BIM; Lack of client demand; Lack of expertise within the project team; Lack of government policy; Lack of collaboration among stakeholders; and the Reluctance of team members to share information.

In addition, the common and most significant drivers to adopters and non-adopters are the availability of trained professionals to handle the tools; Proof of cost savings by its adoption; Clients interest in the use of BIM in their projects; Enabling environment within the industry; Awareness of the technology among industry stakeholders; Cooperation and commitment of professional societies to its implementation; and BIM Software affordability.

Remarkably, the BIM adopters or users are observed to be mostly in the North-Central (Federal Capital Territory) of the country, and the South-West and South-South (especially Lagos and Port Harcourt). These are places where huge and modern construction works are evident. These cities host huge construction businesses, and construction works are daily business.

Nigerian Macro BIM Adoption Maturity is also established using the five macro adoption models. The findings are as follows: a low diffusion level of 11% and low maturity components (especially in the regulatory framework and NBPs) as suggested from the 'bottom-up' dynamic due to lack of regulations. The policy action model is slightly distributed across implementation approach and implementation activities with predominant 'active' approach (especially at the communication stage). Thus, this suggests government participation. The Macro diffusion responsibility, on the other hand, reveals that the educational institutions and individual practitioners are the most influential players in the Nigerian construction market. In the same vein, construction organisations & professional associations were acknowledged as crucial process players.

To keep the research novelty, the quantitative section of this research (chapter five) is thus peer-reviewed, presented at international conferences and published (see Appendix – 8, p.298).

CHAPTER SIX: ANALYSIS OF INTERVIEW DATA (INVESTIGATIVE STUDY)

6.1 CHAPTER OVERVIEW

The preceded chapter presented the initial findings generated from the first phase of data collection (questionnaire), where the analysis was quantitative. This chapter presents the analysis of the coded script under different pre-identified themes. Findings from this study formed the major component in achieving the last objective (Developing a strategic framework for an effective BIM adoption and implementation in the Nigerian construction industry), and the entire aim of this research. The main themes identified and presented under this chapter are Understanding of BIM; BIM awareness in Nigeria; Readiness to adopt BIM; Motivations and drivers toward BIM adoption in Nigeria; BIM adoption benefits; BIM adoption barriers/challenges; and Solution to BIM fields' challenges. The analysis follows a qualitative content analysis sequence. The analysis is done thoroughly and rationally to achieve precise interpretation of interviewees' knowledge and abilities. Moreover, the interpretation of data is made together with literature support and exploratory findings from chapter four (4) and quantitative study from chapter five (5).

It is crucial to present the generated data from the coded transcripts in the Nvivo; however, the data size is substantial. Thus, the full extracted data (from the Nvivo) are presented in Appendix – 13 (p.313).

Out of the 68 valid responses from the questionnaire survey, 37 are those aware and using/adopted BIM (*Table 9.1* p.313 refers). Out of the 37 BIM adopters, 19 were deduced and considered as potential interviewees by considering the following criteria:

- Level of BIM awareness and adoption
- Extent of BIM utilisation
- Profession (to secure representation from different professional stakeholders)

- Role in the industry (to secure representation from different specialities)
- Size of organisation and years of experience
- Location of practice.

Sequel to that, eleven professionals from different organisations and backgrounds replied and accepted the invitation to participate in this study (see *Table 6.1*). The participants were individually interviewed. The interviews were audio-recorded and subsequently transcribed. An absolute anonymity is maintained, names and descriptions of participants were removed. NVivo 11 software was used as a tool to aid coding of the transcribed script based on generated themes from the literature (Kumar 2019). NVivo 11 (software for qualitative analysis) was adopted to enable efficiency and improve accuracy.

6.1.1 Demography of the Interviewees

This sub-section presents the demography of the interviewees. The participants' profile includes profession/educational background, occupation/role, age, gender, experience, size of their firms; *Table 6.1* presents the summary of the interviewees' profile.

Table 6.1: Demography of the Interviewed Construction Professionals in Nigeria

Interviewees	Profession/ Educational Background	Organization Role	Age and Gender	Years of Experience	Organization size	Organizational Annual fee volume	Project type
Interviewee 1 (ENG./CONS/01)	Engineering	Consultant/ Designer	36-40 Male	12	<10 staff (micro)	<$500K (small)	Building and Infrastructure
Interviewee 2 (ARC/CONS/02)	Architecture	Consultant/ Designer	26-30 Male	5	10-50 staff (small)	$500K-10M (small-medium)	Building and System Design
Interviewee 3 (ENG./CONS/03)	Engineering	Consultant/ Designer	51-55 Female	30	10-50 staff (small)	$500K-10M (small-medium)	Building and Infrastructure
Interviewee 4 (QS/CONS-CONT./04)	Quantity Surveying	Consultant & Contractor	31-35 Male	5	10-50 staff (small)	$500K-10M (small-medium)	Building and Infrastructure
Interviewee 5 (ARC/CONS/05)	Architecture	Consultant/ Designer	26-30 Male	3	10-50 staff (small)	$500K-10M (small-medium)	Building
Interviewee 6 (ARC/CONS/06)	Architecture	Consultant/ Designer	36-40 Male	12	10-50 staff (small)	$500K-10M (small-medium)	Building
Interviewee 7 (QS/CONS/07)	Quantity Surveying	Consultant/ Designer	36-40 Male	11	<10 staff (micro)	<$500K (small)	Building
Interviewee 8 (BUILD/CONS/08)	Building	Consultant/ Designer	41-45 Male	15	50-200 staff (medium)	$500K-10M (small-medium)	Building and AEC Tools Development
Interviewee 9 (BUILD/CONS-CONT./09)	Building	Consultant & Contractor	41-45 Male	15	>200 staff (large)	>$10M (large)	Building and Infrastructure
Interviewee 10 (ARC/CONS/10)	Architecture	Consultant/ Designer	31-35 Male	9	<10 staff (micro)	<$500K (small)	Building
Interviewee 11 (ARC/CONS/11)	Architecture	Consultant/ Designer	31-35 Male	9	10-50 staff (small)	$500K-10M (small-medium)	Building and BIM Tools' Training

NB: NOT all quotations are presented in the following analyses, few quotations are presented while the rest are just cited and can be traced from their respective headings in Appendix – 13 (p.313).

6.2 UNDERSTANDING OF BIM IN NIGERIA

Casting back from the literature, BIM may be defined as a set of interacting policies and processes being enabled by technologies in generating a methodology to procure building works from inception to completion down to the entire lifecycle of a building in a digital format (Succar 2009). BIM is defined in several ways, which mostly depends on context, profession, experience and even location. Understanding of BIM is more to how individuals interact with it, which is more to individual needs in terms of usage, knowledge and background.

At an early stage of this research work, exploratory studies were carried out in the Nigerian construction market (sections 4.3, 4.4, and 4.5). It was found that BIM is perceived or understood to be as utilisation of 3D CAD systems. Moreover, the exploratory studies revealed that the understanding of BIM is limited to just BIM tools (technology aspect of it) while a very low level of awareness on the other aspects (process and policy). Thus, the exploratory studies' results informed further investigations with larger sample size and more experienced BIM users within the study context.

The quantitative analysis of the questionnaire survey (5) established the level of BIM maturity in Nigeria as well as determining significant barriers and drivers to BIM adoption. This lead to the shortlisting of the interview sample of some BIM users.

In response to question 3 in Appendix – 12 (p.311) "based on your experience, can you describe what BIM is?" the interviewees' responses revealed different understanding or definitions of BIM. Some of the direct BIM definitions presented by the BIM users (interviewees) in response to their understanding of BIM within the study area:

> "…is a modelling system that allows 3D model-based system that allows every professional within the industry to work on the same model"

ENG./CONS/03

"…is a process that enable a collaborative Real-Time interaction between construction professionals on a project. …is a process that enable an efficient communication, a Real-Time communication between construction project stakeholders." QS/CONS-CONT./04

"…is an innovative process in the construction project delivery whereby intelligent 3D based models are used to generate information that aid in the design construction and operation of buildings." ARC/CONS/10

"…a process that is been enabled by IT to coordinate, communicate and collaborate information within the construction stakeholders. …is 3D enable process that brings about effective and efficient communication between stakeholders in the construction industry." ARC/CONS/11

Based on various definitions by the interviewees, the following keywords were established common to most of the research participants: process; collaboration/ integration/coordination; productivity/efficiency/effective; information; ICT/IT/ technology and model. As such, these keywords are examined and used to generate a unified definition or understanding of BIM by Nigerian professionals who claimed the utilisation of BIM. The unified definition or understanding of BIM by these construction professionals does not intend to change BIM definitions but, it is an ability to validate their level of understanding against the previous misconceptions of BIM by some of the interviewees at the exploratory stage (section 4.3).

BIM is a technology enabled process of generating, transmitting and coordinating data-rich building model from design (inception) to completion and extends to facility management for effective and improved project delivery process.

Although a unified definition is generated from individual understanding and experience with the BIM process, the fact remains that their roles/professions played a role in prioritising words to describe BIM. For example, builders emphasized information repository and were even carried away to present it as a process; while the remaining (ten participants) defined BIM as a process first before any other thing. Engineers like ENG./CONS/01 make more emphasis to digitalised process and enhancement of productivity while defining BIM, and this appears unique to someone involved in extensive construction projects, not just building. Thus, engineers looked at BIM beyond just buildings but included infrastructure (water, sewage, roads, rails and bridges).

On the other hand, Architects and Quantity Surveyors appeared more enlightened on BIM capabilities as well as their level of interaction with the concept regarding building. Their definitions are steady and flow in nearly the same sequence, as *technology-enabled process, information generation and management, coordination and collaboration, and better process*. Autodesk defined BIM as an intelligent 3D model-based process that gives AEC professionals the insight and tools to more efficiently plan, design, construct, and manage buildings and infrastructure. Considering this definition and others, the BIM users in Nigeria has considerable understanding of BIM-based on their roles in the industry. NBS defined BIM as:

"….a process for creating and managing information on a construction project across the project lifecycle."

And, the interviewees defined BIM as *a technology-enabled process of generating, transmitting and coordinating data-rich building model from design (inception) to completion and extends to facility management for effective and improved project delivery process*.

6.2.1 Means of Awareness

The awareness of BIM in Nigeria does not cut across the industry, and it's understood differently by those who are even aware of it. In response to question 2 in Appendix – 12 (p.311) "How and where did you know about Building Information Modelling", the Construction professionals revealed their first point of contact with BIM.

The defined sample of interviewees has various means to which they first get to know BIM. However, they happened to attend the same system of education ahead of their professional practises. For example, two of the interviewees have known BIM through the BIM tools vendors (Autodesk, specifically).

> “I know about Building Information Modelling from Autodesk representative in Nigeria, those that are selling Autodesk software…” ENG./CONS/01 and

> “I got introduced to BIM since 2008, I actually worked with Autodesk firm here in Nigeria, in Port Harcourt.” BUILD/CONS/08

Thus, those suggest a framework that can work with Autodesk to raise BIM awareness.

As reiterated above, conferences are another vital route for awareness of new concepts in the construction industry. One of the participants, a cost management consultant (QS) knew about BIM through a conference as he said:

> “I know about building information modelling through conference.” QS/CONS/07

On the other hand, out of the study sample, eight of them became aware of BIM through personal research or other professional(s). Individual research is playing an essential role in exploring new and diverse ways of doing things. In this case, four interviewees (ARC/CONS/02, QS/CONS-CONT./04, ARC/CONS/06 and ARC/CONS/10) knew about BIM through personal research, as they said:

> “…it was out of my personal research that I came across BIM as a concept for the first time.” ARC/CONS/02

> “The first mention I can recollect of BIM is undergraduate studies we were given an assignment, a course assignment to do on various topics I took BIM… BIM.” QS/CONS-CONT./04

In addition, the remaining four interviewees (ENG./CONS/03, ARC/CONS/05, BUILD/CONS-CONT./09 and ARC/CONS/11) grasped the opportunity of knowing BIM through other professionals (i.e. colleagues and mentors). This route appears dominant (4/11 or 36.4%) since the parties here are often generated and regenerated (continuity), while personal research is limited and often difficult in this practice domain. The participants who firstly know BIM through other professionals include an Engineer, a Builder and two Architects. Below are some of their statements:

> “…in my industrial training, I met someone, I met an enthusiast who took

> me through what it (BIM) is." ARC/CONS/05

> "I got to know BIM some couple of years back from a council member (CIOB), …who is a senior lecturer in Nelson Mandela University in South Africa." BUILD/CONS-CONT./09

Thus, BIM awareness in Nigerian AEC has been trending through professional contact (i.e. from other professionals, colleagues, mentors, etc.), personal research, BIM tools developers/vendors and conferences in descending order. Besides, the most dominant means is through professional contact, but that may be considered inefficient. The inefficiency of its ineffectiveness can be attributed to the low rate of awareness due to a smaller number of contacts at a time (i.e. one professional at a time). This is seen the same in terms of personal research coupled with the industry's culture; this can also be seen even within the adopters' domain. For instance, one of the participants proclaimed that the firm was not out looking for BIM; it only came to their way of practice.

> "…in all fairness we didn't go out looking for BIM, it fell into our lap." ENG./CONS/03

Going by the literature, a wider audience of professionals are reached through institutions of learning (i.e. taught course or module, seminars, etc.) or professional societies (i.e. workshops and conference or webinars). However, the broadest route to achieving BIM awareness and knowledge for professionals may be through Higher Education Institutions (HEI) (Underwood et al. 2015). On the other hand, clients mostly get aware of BIM through case studies and contact with construction professional(s) who have adopted BIM.

In summary, professional contact, personal research, BIM tools developers/vendors as well as conferences, are the route or means for BIM awareness in the Nigerian construction industry. However, these means of awareness seen quite ineffective due to the very limited number of contacts at a time as such required backup. Hence, the low-level of BIM awareness, these questions will be answered in section 6.3.

6.3 BIM AWARENESS IN NIGERIA

In section 6.2.1, the interviewees positioned their first point of contact with BIM as means of its awareness, and subsequent persuasion and its adoption. Their testimony revealed various ways to create awareness of BIM and their impact on its adoption. Next is an evaluation of their strengths and weaknesses, while proposing the most effective means to augment the vast shortfall in the current means of awareness considering the process in place.

To evaluate the means of BIM awareness, it is essential to look into some best practices by countries where BIM adoption is vibrant. These countries are the USA, the UK and Australia (2.8.1 referred).

In the context of Nigeria, BIM awareness is significantly low to achieve considerable acceptance. Before the full initiation of BIM Africa in 2018 and the subsequent student advocacy programme, there was no BIM awareness in the Nigerian HEIs (BIM Africa 2018). The interviewees indirectly lamented the awareness level and felt that once awareness increases, the adoption will speed up amongst the key players. 4/11 (ENG./CONS/01, ARC/CONS/02, QS/CONS/07 and BUILD/CONS-CONT./09) of the interviewees agreed that awareness is the main issue to be tackled first.

> "I think with time and with the right information and awareness, in no time I think, I believe the Nigerians and the Nigerian construction industry will tend to start using BIM." ENG./CONS/01

> " …through professional networking. …the awareness should be more so that the government can look at it." BUILD/CONS-CONT./09

The respondents vindicated the earlier exploratory study and questionnaire survey that BIM awareness in Nigeria is significantly low; therefore, strongly recommends prompt action on awareness to achieve wide BIM acceptance. Although the diffusion dynamic of the Nigerian construction market is predominantly bottom-up (Hamma-adama 2019a), a respondent also suggested bottom-up awareness (ARC/CONS/02). Another interviewee finds it helpful in creating awareness, especially in proving its efficacy to realise its full acceptance by clients (ARC/CONS/11).

> "I think more efforts should actually go into awareness to people that are involved in the industry, the bottom-up awareness." ARC/CONS/02

Thus, it is very clear that the awareness level is low, and it is the first issue to deal with. Primarily, awareness through conferences is recommended with successful case study projects.

6.4 READINESS TO ADOPT BIM

How ready Nigerian AEC is to adopt BIM is a subject that has been in academic discussion since 2013 (Abubakar et al. 2013); however, all efforts made to determine a comprehensive readiness of the industry to adopt BIM encountered several limitations whether in context or robustness. This section brings to light the adopters' perspective on how ready the industry and the government are to adopt BIM. Also, specifically, how ready the participating firms are to fully deploy the BIM process in their workflow. The evaluation is done based on the interviewees' responses to question 29 in Appendix – 12 (p.311) "how ready your firm is to fully adopt BIM? And how ready do you think the industry and the government are to adopting BIM as well?"

Majority of those who adopted BIM in Nigeria are ready to fully deployed BIM on their projects but lamented lack of industry's readiness and the government commitment. Although, two participants hold contrary opinion regarding the industry's readiness; they consider the industry's current challenges and competition as the motivations that, the industry is ready once the government introduces such a process. BUILD/CONS-CONT./09 specifically described the BIM process as a potential to ease project management; thus, he is looking forward to resolving project management challenges through BIM adoption.

> "Yeah for the industry, they are ready; there is competition everywhere you know. …the problem I see with the government is that most of the people at the decision-making, managerial level they don't know anything about it and they believe in the conventional method." BUILD/CONS/08

> "Well the industry for now, we are ready because we have a lot of challenges in Nigeria in project system you understand; and since the concept of BIM is ease out the project management, definitely we are ready to have the BIM adoption." BUILD/CONS-CONT./09

Interestingly, the two respondents are from the same profession; they closely play the same role (building production management) within the industry. However, the remaining nine interviewees felt that the industry is generally at the infant stage of BIM adoption as such vindicated the study on adopters and non-adopters from the previous chapter (section 5.2). Also, the industry is mostly ignorant of BIM hence requires awareness and enlightenment as proclaimed in section 6.3. Below are opinions of most of the participants (9/11 of them) in the exception of two who felt that their firms are not ready to adopt BIM fully. On the other hand, they (9/11 of them) mostly believe that the industry and the government are not in any way ready for the process change.

> "The problem now is the country, for the country to adopt it is the challenge." ENG./CONS/01

> "…industry at large is not so BIM ready because they are still that level of ignorance pertaining BIM in Nigeria." ARC/CONS/02

> "…but in government and the construction industry, they are those that don't seem changed, because they are afraid of adopting it and then let me say change." QS/CONS/07

By comparison, the two participants who appear less ready or insufficient to deploy BIM on their projects fully, they also hold the opinion that the industry and the government are not in tune to adopting BIM processes. Their opinions are as follows:

> "Infrastructure wise, machinery wise, I am not ready. Knowledge wise, the industry is coming up, infrastructure and technology wise the industry still have a lot of challenges." ARC/CONS/06

> "Currently, my firm still operates in 2D non-collaborative process. However, as a small firm with individuals who are open to new ideas, it may not take long to transition to 3D BIM once everyone sees the benefits. The industry and government may not be ready to adopt BIM due to the bottleneck of bureaucracy." ARC/CONS/10.

Their testimony as to readiness to adopt BIM entirely is another indication of pending challenges to BIM adoption in the Nigerian construction industry. The challenges could be either the capability set or social issues; but what is clear is that, for these adopter organisations, it is more of capability sets than social problems since they have gone beyond persuasion stage. On the other hand, the clients and or authorities are still battling with knowledge/awareness as revealed by the interviewees.

6.4.1 Available BIM Tools

Readiness to adopt an innovation has different perspectives; BIM as a new way of working has various aspects to look-in to ascertain the level of readiness to embrace it. Just as how HEIs are assessed from the beginning of this study on their readiness to offer BIM-related training. Availability and capacity of hardware or infrastructure, software as well as trained personnel, are evaluated in section 4.4. This section of work looks into the availability of BIM tools (software) in terms of accessibility and affordability.

The interviewees' responses to question 4 in Appendix – 12 (p.311) "What BIM tools or systems have you used or have seen being used by colleagues/clients, etc.?" reveals the available BIM tools in the market and those they use in their firms. The following are some of the respondents' direct statements regarding BIM tools in the Nigerian construction market:

> "…Civi3D is one of the BIM tools that we use vastly…. …we have InfraWorks. ENG./CONS/01
>
> I have seen people that use MEP, Revit Structure, Navisworks, Management and BIM 360 for data management like common data environment during design." ARC/CONS/02
>
> "…major BIM tool that I am use to is Autodesk Navisworks. …seen Autodesk Revit been used, I have seen BlueBIM been used, I have seen Synchro, I have seen Vico." QS/CONS-CONT./04
>
> "Tekla, PlaGrid and Autodesk Revit." BUILD/CONS-CONT./09
>
> "Revit architecture, Revit structure, Dynamo and many more in the Autodesk and Solibri tools." ARC/CONS/11

The interviewees revealed a substantial number of available BIM tools used in the

Nigerian construction market; these tools are predominantly Autodesk products. The variety of available BIM tools disclosed by the interviewees are mostly associated with participants' professions, though there are common tools they mostly made mention of. The BIM tools available in the Nigerian market and used mainly by those who deployed BIM in their firms are presented in Table 6.2. These set of BIM tools are summarised based on availability and those in use by the adopters in the industry. Note that, the available tools include a reflection of those BIM tools available for training in the HEIs generated from the questionnaire survey in the exploratory study (4.4).

Table 6.2: BIM tools available and those in-use by the BIM adopters

Available BIM tools in the market	**BIM tools used by the adopters**
1) Autodesk Revit (Architecture, Structure & MEP)	1) Autodesk Revit (Architecture, Structure & MEP)
2) Civil3D	2) Civil3D
3) Tekla	3) Navisworks
4) InfraWorks	4) BlueBIM
5) Navisworks	5) BIM360
6) BIM360	6) ArchiCAD
7) BlueBIM	7) Dynamo
8) Synchro	8) Robot Structure
9) Vico	
10) ArchiCAD	
11) PlaGrid	
12) Dynamo	
13) Solibri	
14) Robot Structure	
15) ECOTECT	

According to those who adopted BIM in Nigeria, there are a variety of BIM tools in the market to lay hands on. Availability and knowledge of BIM tools to be deployed within organisations do not seem to be of a challenge by these adopters, but the affordability of the tools is of major concern. Succinctly, there are sufficient BIM tools in the market to enable the deployment of the concept on projects; however, the affordability of these tools is discussed in 6.7.3.

6.4.2 Level of BIM Usage (Implementation)

Level of BIM usage in this context refers to the BIM implementation or level of BIM implementation on the project. This includes the percentage of projects benefited from the deployment of BIM on projects and to what extent or stage does BIM operated on those projects. Knowing the level of application is essential to positioning the status of users and making provision to advancing to the next level of implementation while pulling up the remaining early majority, the late majority and the laggards (refer to the diffusion of innovation at the exploratory study 4.5).

Under this section, responses to questions 7 & 8 in Appendix – 12 (p.311) are discussed. The following are some of their direct statements regarding the level of BIM implementation with respect to the number of their projects.

> "I witnessed is less than 30% usage in construction.
>
> "…especially BIM we use in design process in most cases and the roles were itemised by corporal document to state the rule of any working thing on it, not in construction." ENG./CONS/01
>
> "…that would be like less than 10%." ARC/CONS/06
>
> "… about 40% that is the proportion." QS/CONS/07
>
> "… in a scale of 5 maybe ⅖." BUILD/CONS/08

BIM implementation from the project point of view has been in appreciable percentage (about 40%) from those adopted the new concept. Some believe to have adopted this concept to about 40% of their projects, some less than 40% while some are still at the beginning. Only one firm (participant) disclosed to have deployed BIM on all its projects, 100% on the BIM process. On the other hand, only one public project is currently benefiting from the use of the BIM process at stage 3 (construction stage). All those who adopted BIM in their workflows do that at the design stage but never been at construction stage in the exception of one firm (ARC/CONS/11).

> "…on the area of lecturing and mentoring people on BIM, I can tell you excellent, I have really dealt with. To a project level, no, no, no. … It has never gone to the site (construction stage)." BUILD/CONS-CONT./09
>
> "I can say 100% of our projects are so far using BIM." ARC/CONS/11

BIM implementation from the level of usage like the UK definition of BIM levels (0-3) (BIM Industry Working Group 2011) point of view is predominantly level 1 from those who adopted the BIM. Some believe to have adopted this process to level 2 based of the UK framework. However, there is still a very low level of collaboration not to talk of integrating the entire workflows. Their level of usage is predominantly model-based in-house collaboration. Below are some of their statements regarding the level of BIM usage:

> "…the collaboration is still low. …most of the projects are modelled but the true benefits of BIM like collaboration and all that is still very low." ARC/CONS/02

> "…we have been trying to move most of our project from CAD base (2D CAD) to BIM base although it is still on or base on level 1." ARC/CONS/05

Level of BIM implementation in the Nigerian construction industry is low; for those who adopted BIM, their level of implementation on projects is less than 50%, and the application is generally at design stage with limited sharing of design information (collaboration).

6.4.3 Availability of BIM-Trained Personnel

Availability of BIM-trained personnel has been an issue not only in the developing countries but also in the developed countries where BIM awareness is nearly universal, and its adoption is substantial. For instance, BIM development and adoption in the UK is quite progressive. Still, the industry struggles for BIM-trained personnel (Richard 2017), though this may be associated with a lack of clarity on the training requirements for professional participation. In the same way, lack of experts and knowledge of BIM innovation has been amongst significant barriers to adopting BIM in Australia (Hosseini et al. 2016).

The interviewees responded to question 23 from section 9.12 to determine availability of BIM trained persons in this construction market. They confirmed that firms who adopted BIM tend to train their staff in-house. Seven out of the eleven interviewees (63.6%) have attested that there is lack of BIM-trained persons to employ; these adopters are ENG./CONS/01, ENG./CONS/03, QS/CONS-CONT./04, ARC/CONS/05, QS/CONS/07, BUILD/CONS/08, BUILD/CONS-CONT./09 and

ARC/CONS/10. Below are for of their statements:

> "No, we don't have (trained personnel), you have to train them; they need to be trained." ENG./CONS/01

> "Presently in the country, we have very few people that we regard as BIM trained personnel." QS/CONS-CONT./04

> "Is an insignificant number they (BIM trained personnel) are not readily available." ARC/CONS/10

The participants' revelation vindicated the quantitative findings on barriers to BIM adoption in Nigeria (Hamma-adama and Kouider 2019b; Hamma-adama et al. 2020) where Lack of expertise within the organisations ranked top barrier against the BIM adoption in Nigeria. The Nigerian construction industry has followed the same suite to that of the UK and Australia, and of course, other developing countries. Although the shortage of BIM-trained personnel in Nigeria cannot be quantitatively compared to that of the UK and Australian construction sectors, the impact remains the same as a hindrance to speedy BIM adoption. The research participants in this context proclaimed lack of trained persons on BIM technology amongst the barriers to BIM adoption and implementation in the Nigerian construction industry. Succinctly, there remain personnel deficit in the market to move the adoption further; thus, formal and informal training are essential.

6.4.4 Availability of Technology Infrastructure

Availability of technology infrastructure is one of the gaps between the developed and the developing countries. Three technology infrastructure indicators (Internet, telephony and electricity) are considered as they go in line with the three major 20th industrial revolutions (Louca et al. 2001) and as being the necessary infrastructures for social life and economic growth (Archibugi and Coco 2004). Thus, the interviewees are mostly on point when responding to question 25 from section 9.12 on the availability of technology infrastructure to support the BIM process. They stressed more on the internet and electricity, and these are the important needs to effectively manage IT-related, process especially when the intent is to collaborate or and integrate virtually.

Below are some of the direct words from the interviewees who lamented the state of technology infrastructure as to supporting BIM adoption in Nigeria.

> "…is the lack of infrastructure and when I mean infrastructure meaning we are referring to the internet system, …we don't have the basic infrastructure needed and that is not only in the construction industry is across board." QS/CONS-CONT./04

> "I still feel we need more infrastructure development for us to this to support BIM." ARC/CONS/05

> "…it brings actually a challenge when it comes to talking about the technology infrastructure for BIM; so, the power infrastructure is a huge challenge, the communication infrastructure is still a work in progress." ARC/CONS/06

Therefore, what can be deducted from the technology infrastructure challenges are as follows: the infrastructural challenge does not stop those interested in BIM to adopt it, but, it limits their implementation level; one has to improvise means for power and internet; the infrastructural deficit has limited effect on readiness to adopt BIM as these interviewees claimed to be ready for full BIM adoption. The interviewees' revelation provided a strong link between the persuasion stage and the decision to adopt this innovation. This is quite important to evaluate how ready a country is to adopt a technological process. Consequently, *there is a considerable gap in the technology infrastructural readiness to adopt BIM in Nigeria as a whole*. Besides, most firms who happened to use IT to aid their workflow (i.e. BIM), they improvised ways to generate their electricity (power) and internet to meet their daily demands.

6.5 Motivators and Drivers toward BIM Adoption

Drivers happen to be the key motivators to embark on a change journey. Potential drivers to BIM adoption were first compiled from literature and used in the quantitative part of this study (section 5.2); the study reveals the most significant drivers to facilitate wide BIM adoption in Nigeria as follows:

- Availability of trained professionals to handle the tools
- Proof of cost savings by its adoption, BIM Software affordability

- Awareness of the technology among industry stakeholders
- Clients interest in the use of BIM in their projects
- Cooperation and commitment of professional societies to its implementation
- Enabling environment within the industry.

Further question (11 from 9.12) asked at the interview stage as to explore more on the essential reasons behind them adopting BIM and their motivations in keeping it. The sub-section below presents the facts tendered by the research participants on what inspired them to adopt BIM and what is keeping them motivated despite all challenges. The motivators will be evaluated and act as a significant tool to enticed other firm and individuals to adopt the new process.

6.5.1 Evaluation of Drivers Toward BIM Adoption

Drivers or motivators to foster innovation are critical to the successful implementation of such innovation. Thus, further exploration of the drivers to BIM adoption is carried out within this study (section 6.5). Some of the interviewees were more concerned with what inspired them to adopt BIM, while some are of what is keeping them motivated to its implementation.

For instance, ENG./CONS/01, QS/CONS-CONT./04 and ARC/CONS/11 described successes recorded on a project where BIM was utilised as the major motivator, and ARC/CONS/11 subsequently refer BIM as an international best practice that inspired them to adopt it. ENG./CONS/01 started by:

> "Yes, because of the benefits, that we have seen that it will give us, relating it to what normal way of doing things…" ENG./CONS/01

While ARC/CONS/11 is very confident on their move to implement BIM, he attributed their market penetration to a competitive advantage of using BIM as he says:

> "…most of the market we penetrate today is using the BIM. …competitive advantage here in Nigeria. …(BIM) is international best practice; it has proved itself, it's efficacy is been proven by a lot of countries and there a lot of successes." ARC/CONS/11

ENG./CONS/01 and ARC/CONS/02 then proclaimed that an improved or efficient process motivated them to keep onto the BIM adoption.

> "…we deploy BIM solutions to do the corrections; …we save a lot of time when we adopt BIM than using the normal CAD process. …my experience of BIM is that we are trying to improve the way we do things which is more better, because it make things easier…" ENG./CONS/01

ENG./CONS/03 and QS/CONS-CONT./07 disclosed that desire to exploring current trend and commitment to adopt innovation are their motivators to BIM adoption at the beginning; while resolving interface issues (by BIM) is the advantage considered in keeping to the BIM adoption crusade.

There are mixed affirmations to either what motivates them to adopt BIM or keeps them motivated. Saving time, better buildings in terms of effective cost, as well as improvement of workflow are the motivators according to ENG./CONS/01, ENG./CONS/03, ARC/CONS/05, ARC/CONS/06 and ARC/CONS/10.

> "What motivated us was the success stories." QS/CONS-CONT./04

> "I always like to be on the edge of the technology." BUILD/CONS-CONT./09

> "I personally, I'm the kind of person that I'm always open to innovation, I'm always open to applying new approaches to doing things in life." ARC/CONS/10

On another dimension, ARC/CONS/02 considers rich information generated in the BIM platform as a major benefit that derived them to BIM adoption.

> "…there a lot of information you can't get from CAD that you are able to get from BIM and such things are able to help you plan your project like 4D and cost your project from the same data and model of course these are benefits that someone wants to adopt BIM." ARC/CONS/02

The participants responded to the interview questions regarding drivers and motivators to adopt BIM without presenting them with options to choose from; they showed their views that appeared more of BIM benefits than BIM drivers, also seemed more of motivators. Their mixed reactions revealed the following as facilitators that derived them to BIM adoption:

- Success stories of BIM adoption from other countries (case studies)
- Improving workflow (efficiency)
- Rich information generation and transmission (quality info and effective communication)
- Savings cost and better building
- Quest for innovation

Consequently, these add to the already established significant drivers (section 5.2) to BIM adoption BIM in Nigeria. The quantitative study reveals seven drivers significant to facilitate BIM adoption in Nigeria (5.2); and the seven drivers in section 5.2 were agreed to be significant by both adopters and non-adopters of BIM in Nigeria.

On the other hand, utilisation of BIM brings competitive advantage and market penetration to many of these adopters. However, some lamented the lack of project requiring BIM due to additional cost of deploying the BIM on a project. Hence, the competitive advantage provided by using BIM on a project (even without client paying for it) is what keeps some adopters motivated.

6.6 BIM ADOPTION BENEFITS

For every innovation, there are anticipated benefits; that perhaps financial or ease of the process and better outcome (Black and Lynch 2004; Leiponen and Helfat 2010). In this note, the sophisticated ability to generate and share information proved viable in closing the information (details) gap from the design stage. Thus, the following section (6.6.1) presents context benefits of BIM adoption. In brief, the benefits established by the interviewees are Enhanced communication; Better (rich) information/data; Better workflow; Visualisation; and Time management.

6.6.1 Context Benefits of BIM Adoption

There are various benefits derived from the use of BIM by the interviewees, and these benefits cut across professions and specialities. The BIM benefits derived here are in response to questions 10 & 15 from Appendix – 12 (p.311). The participants disclosed the advantages of using BIM-based on their personal experiences. For example, ENG./CONS/01, ARC/CONS/02 and QS/CONS/07 directly benefitted with a better workflow in their built asset procurement process, e.g.

> "…the workflow is more better than the previous method (traditional) that we are using, I think that is one of the major of benefits that I am using BIM as I have seen." ENG./CONS/01

Better management of time and constraints are some additional benefits of using BIM brings as described by ARC/CONS/02, QS/CONS-CONT./04 and BUILD/CONS/08. Example ARC/CONS/02 says:

> "…they can be better managed and time constraints can be much more efficient if BIM was to truly leverage on them which of course is what we are still encouraging our client to." ARC/CONS/02

Most participants believed to have benefitted from better documentation, information management and enhanced communication between stakeholders. Participants such as ENG./CONS/03, QS/CONS-CONT./04, ARC/CONS/06, QS/CONS/07, BUILD/CONS/08, BUILD/CONS-CONT./09 ARC/CONS/10 and ARC/CONS/11 attested to that. For example, QS/CONS-CONT./04 says:

> "BIM just helps to improve and enhance our communication. …real time communication clients they really really appreciate that, for them to be able to understand the stage at which the constraints at that point, requirements and everything real time." QS/CONS-CONT./04

Better building representation model is becoming universal to the Architects (mostly) because clients who only appreciate the graphical views and expressions are requiring 3D visualisation of their buildings ahead of the construction stage. ARC/CONS/05, QS/CONS/07, ARC/CONS/10 and ARC/CONS/11 revealed that BIM adopters realise their potentials through rendering and production of 3D models for visualisation.

> "…things BIM has allowed us to offer them is realistic renders of their projects at the moment." ARC/CONS/05

> "…a good visualisation of project before the construction commenced."

QS/CONS/07

> "Visualisation of their proposed project, I think that is just the only services for now." ARC/CONS/10

On a scanty note, BUILD/CONS/08 disclosed further that ability to predict time allows him to cut down cost; in the same vain ENG./CONS/01 and BUILD/CONS-CONT./09 strongly appreciate the ability to bringing solutions on design issues. As ARC/CONS/11 uses BIM for competitive advantage, ENG./CONS/03 is sceptical in finding business opportunities from BIM usage.

BUILD/CONS-CONT./09 perceived potential benefit to ease project management, especially from the current industry's challenges. Thus, resolving project management challenges is one of the very critical aspect considered to be achieved through BIM adoption.

> "Well the industry for now, we are ready because we have a lot of challenges in Nigeria in project system you understand; and since the concept of BIM is ease out the project management, definitely we are ready to have the BIM adoption." BUILD/CONS-CONT./09

It is established from the literature that, the Nigerian construction industry is genuinely fragmented (Onungwa et al. 2017), the industry has a record of poor performance, repeated building failure and collapse for decades (Ede 2013; Hamma-adama and Kouider 2017). It also has abandoned construction projects due to project cost overrun. Use of substandard building materials in the production of structural elements is one of the major challenges that lead to building collapse in Nigeria (Hamma-adama and Kouider 2017); this is attributed to poor quality control. Quality control is significant in ascertaining the ultimate quality of a product. BIM offers quality control ability as part of its management benefits (Boukamp and Akinci 2007). A BIM process provides and supports offsite fabrication of the building components (Lu and Korman 2010), and this set to achieve quality control, improve accuracy reduced material waste and facilitate speedy production. In addition, building behaviour simulation is another powerful BIM tools' capability (Ghaffarianhoseini et al. 2017); it establishes structural stability of the building and its behaviours while subjected into different scenarios of forces/stresses. Thus, this helps in design checks and future planning.

BIM ability to improve cost control mechanism, reduce errors, omissions, as well as conflicts (Ghaffarianhoseini et al. 2017), is reliable as a panacea to project cost overrun. Moreover, accurate provision of building materials and components quantities by BIM tools (Grilo and Jardim-Goncalves 2011) is powerful in generating accurate cost; as a result, reduces waste on the construction site.

In summary, there are five main advantages derived from the use of BIM in Nigeria as described by the interviewees; this is truly based on their level of usage. The derived benefits or additional services provided are:

1. Enhanced communication
2. Better (rich) information/data
3. Better workflow and project management
4. Visualisation
5. Time management

However, the current derived benefits (spelt out by the interviewees) do not translate into the limitation of BIM benefits in Nigeria. Level of BIM usage, purpose and challenges at hand mostly go hand-in-hand with the derived benefits.

6.7 BIM ADOPTION BARRIERS/CHALLENGES

This section presents the most prevalent challenges facing the Nigerian construction industry to adopting BIM. The challenges were evaluated under three BIM field types (Technology, Process and Policy). Responses to questions 12 & 13 (9.12) explained more specific challenges to Nigeria AEC to adopt BIM than the generic. The findings revealed the following as the most significant barriers to BIM adoption before, during, and after the adoption in the Nigerian AEC:

1. Internet issues
2. Electricity (power)
3. High cost of BIM tools (affordability issue)
4. Lack of BIM-trained or skilled personnel

5. Resistance and rigid nature of the professionals
6. Low level of collaboration by professionals
7. Lack of case study projects to set examples
8. Lack of clients' will
9. Lack of policy or legislation
10. Lack of standardisation of objects contextual to Nigeria
11. Lack of guide and protocol
12. Lack of education and training on BIM
13. Lack of BIM role recognition and incentives by clients.

6.7.1 BIM Process

The process is an important field type of BIM fields, is an entity without which BIM definition is incomplete. The process aspect of BIM is reported to have many challenges that hamper the realisation of BIM process in the Nigerian construction industry. Majority of this research participants lamented on the shortage of skilled personnel on BIM, lack of BIM-trained professionals to lead the process. ENG./CONS/01, ENG./CONS/03, QS/CONS-CONT./04, QS/CONS/07, BUILD/CONS/08, BUILD/CONS-CONT./09 and ARC/CONS/10 have all hold this opinion and also vindicated the quantitative finding that lack of BIM experts is the most significant barrier to BIM adoption; and below are some of their responses concerning that:

> "…these are the two major challenges; from the client and from a skill acquisition for the staff of company that want to adopt BIM." ENG./CONS/01

> "…we don't get BIM trained personnel, no." QS/CONS/07

> "No (BIM trained personnel). In Nigeria for now, no." BUILD/CONS-CONT./09

> "Is an insignificant number they (BIM trained personnel) are not readily available." ARC/CONS/10

On another critical barrier, ENG./CONS/01, ARC/CONS/02, QS/CONS-CONT./04, ARC/CONS/05, BUILD/CONS/08, ARC/CONS/10 and ARC/CONS/11 unanimously attributed lack of BIM adoption to the rigid nature of the professionals in changing the way they operate. Most of the professionals do not want to leave their comfort zone; hence, turned back at BIM, perhaps due to lack of awareness or knowledge of its benefits. Moreover, the clients are not willing and or asking for BIM, mostly due to the awareness issue (see section 6.3). Here are some of the study participants' comments regarding that:

> "…the first one is resistance from people, people are more used to the CAD workflow so they find it difficult to transition from BIM because they don't want to leave their comfort zone." ARC/CONS/02

> "…a lot of people are resistant to new innovations so my experience is seeing people wanting to isolate from BIM, you see a professional when you explain a BIM concept and he refused, he doesn't need that, his normal procedures are working fine." QS/CONS-CONT./04

> "…is the innate resistance to innovation, I think is something that is structured, probably structured within our society there's always fear of trying something new…. lack of knowledge, lack of knowledge of the benefits…." ARC/CONS/10

Low level of collaboration also played a significant role in discouraging BIM adoption as BIM hinged on collaborative working. ARC/CONS/02, QS/CONS-CONT./04, ARC/CONS/05, QS/CONS/07 and ARC/CONS/11 append low level of collaboration by some other professionals as a serious challenge to their BIM adoption process. It appears to them vogue to convince and even trained some professional colleagues to adopt BIM workflow; though, some are not willing to accept BIM. Find here some of their responses:

> "…in terms of collaboration it is at very low level. …the collaboration is still low." ARC/CONS/02

> "…the challenge I face was that, I was the only one trying to use it (in our firm), nobody is trying to buy into the idea for now…" QS/CONS/07

The resistance is only within the industry alone; it is even within the same work domain (same firm). QS/CONS/07 faced a challenge within his work domain in terms of embracing the idea of collaborative working.

> "…because of our rigid professional structure, because in our professionalism here in Nigeria when you see the Architect rigid, too much rigid on their own on the professionalism; so, lack of really collaboration, …" ARC/CONS/11

ARC/CONS/11 further his observations that too much independence of professionals and lack of case study projects (to practically convinced clients) are challenging the acceptance of BIM in the Nigerian AEC.

In summary, five significant process challenges to BIM adoption are established as follows:

1. Lack of BIM-trained or skilled personnel
2. Resistance and rigid nature of the professionals
3. Low level of collaboration by professionals
4. Lack of case study projects to set examples
5. Lack of clients' will.

The five significant challenges spelt out above are reported from the literature in section 5.2 and are also amongst the most significant barriers to BIM adoption in Nigeria. Thus, this vindicated the quantitative findings of this study.

6.7.2 BIM Policy

As recognised in some countries, regulations played significant roles to BIM adoption and implementation. The policy is another type of BIM field that deals with capability sets in terms of guides, protocols and mandate.

The interviewees reported up to five significant barriers (policy-related) against wide BIM adoption in Nigeria. For instance, ENG./CONS/03, QS/CONS-CONT./04, ARC/CONS/05, ARC/CONS/06 and QS/CONS/07 attributed slow or lack of BIM adoption to lack of legislation or policy; there is no policy to BIM deployment while the government is amongst the major key players of the industry. Below are some of their statements as relating to challenges (policy-related) against wide BIM adoption in Nigeria.

> "…there is also the fact that we do not have legislation in place in Nigeria to support the adoption of BIM widely." ARC/CONS/06

> "A government policy and low collaboration between the team members, between the different professionals." QS/CONS/07

Lack of standardisation in terms of materials and building objects are other points of concern. Standardisation for local manufactured objects and incorporation of the local or available objects attributes to object libraries (as in the BIM tools) are issues of concern raised by ARC/CONS/06, BUILD/CONS/08 and BUILD/CONS-CONT./09. Moreover, BUILD/CONS/08 particularly laments on the availability of standard objects (mostly foreign) in the Nigerian market, and the local objects are not standardised and incorporated in the objects' library.

> "…first barrier is standardisation, standardisation incompetence. …we do not have a collective where local manufacturers have their model unlike the British system where they have an NBS plugin that you can actually use to select objects from manufacturers worldwide not just in UK alone" ARC/CONS/06

> "…some of the things we are doing is not up to international standard; and so you know once you are doing below standard, for you to accept anything innovative it will be very very difficult." BUILD/CONS-CONT./09

> "…but most times you getting material but you can like it, you go to the market and look for it, you don't see it; it's a problem." BUILD/CONS-CONT./09

Guide and protocol to utilise BIM are not there in Nigeria; hence, such attributed to slow BIM adoption (Valappil and Saleeb 2016). For instant, BUILD/CONS/08 and ARC/CONS/10 pronounced the following:

> "There's no guide, none!" BUILD/CONS/08

> "There are no guides for now." ARC/CONS/10

On the other hand, training is importantly considered as another bottleneck to wide

BIM adoption going by the varied BIM skilled gap (refer to section 6.4.3). BUILD/CONS/08 and BUILD/CONS-CONT./09 disclosed their concern over BIM skill shortage and its rippling effect; mentoring new professionals into the BIM process of working is not there. They reported that:

> "…after you trained people they just leave. …training the younger ones on this software because of there's this fair that once you trained these people, before you know it they leave you." BUILD/CONS/08

> "The only challenge I have is mentoring, I find it very difficult to see somebody who would mentor me. So, it was difficult, yes there are no BIM experts in Nigeria." BUILD/CONS-CONT./09

Lastly, the only firm that takes BIM to the construction stage laments lack of recognition of BIM on the national scale of fees (in public built asset procurement). He resolutely stays firmed to using the BIM process even though the client did not make different arrangement to the additional services provided in deploying the BIM on the project. Moreover, his firm subsequently takes the role of project managers, simply referred to as "BIM-based project management" consultants. Thus, the government has no provision of BIM managers' role or incentives for deploying BIM on its projects. He says:

> "I think if there's anything that we have recorded is a bit of uncomfortable is the fact that the use of BIM is still has no particular scale of fee. So, the additional task of using the BIM is not really been paid because we are still BIM based project management; but what we being regarded is first project managers and there's no any different arrangement that was made for the fact that we are using BIM. And, so we are just using for a competitive advantage, so clients are not paying for the BIM that is it." ARC/CONS/11

In summary, the Nigerian AEC industry has six significant BIM adoption barriers (policy related) facing the industry, and these are:

1 Lack of policy or legislation

2 Standardisation of objects contextual to Nigeria

3 Lack of guide and protocol

4 Education and training on BIM

5 Lack of BIM role recognition and incentives by clients.

6.7.3 BIM Technology

The BIM technology is one of the BIM field types of BIM fields; is a critical field component of BIM field types that aids the effectiveness of the process. The technology of BIM includes both the software (BIM tools) and the hardware (infrastructure). The technology appears to be the backbone of BIM understanding in Nigeria because many professionals understand BIM from the software (BIM tools) angle, through the utilisation of these tools. One of the major challenges facing the industry in terms of needs to adopt BIM is technology-related issues. This section presents answers to questions 24 & 25 in Appendix – 12 (p.311) for the availability of technology to support BIM deployment on projects.

The entire participants (excluding ARC/CONS/11) lamented about affordability (high cost) of the BIM tools; although some attributed that to the economic situation of the country and the inability of clients to pay for these services. Below are some of their direct responses to challenges faced regarding the technology field:

> "…the second barrier is also the cost of the tools and the infrastructure required." ARC/CONS/02
>
> "I think first of all is the fact that the software is not... it's expensive. I don't think if you are looking for a licensed system is affordable." ENG./CONS/03
>
> "…we had the challenge of high cost of implementation especially as regards to software." QS/CONS-CONT./04
>
> "…they (BIM tools) are available but is not affordable." BUILD/CONS-CONT./09

Regarding the second aspect of this critical field, technology infrastructure is essential to the developing countries, especially in Nigeria, where electricity (power) is still a challenge not to talk of internet facilities. Internet access in Nigeria often has downtime as powerfully revealed by some of the interviewees.

ENG./CONS/01, ARC/CONS/02, QS/CONS-CONT./04, ARC/CONS/05, ARC/CONS/06 and QS/CONS/07 explained that technology infrastructure gap in the country is a challenge, and I quote:

> "…we don't have the basic infrastructure needed and that is not only in the construction industry is across board. A lot of the industries are having issues with technology because there's no basic infrastructure to support technology across board." QS/CONS-CONT./04

> "Before we go to the technology infrastructure, you have to look at infrastructure on ground. You have to look at the power infrastructure, you have to look at the communication infrastructure; so, it brings actually a challenge when it comes to talking about the technology infrastructure for BIM; so, the power infrastructure is a huge challenge, the communication infrastructure is still a work in progress." ARC/CONS/06

While on a lighter note, ENG./CONS/01 laments on a specific technical skill gap that, they could not find M&E BIM specialists to handle BIM deployment (even) at the design stage. Although, this may be a specific skill gap for a particular location; that still reveals the level of the skill gap in the Nigerian market.

> "…the challenge with that project is that, we couldn't get someone that can integrate the M&E so that means just like we couldn't deploy the solution with that design, so we later have to come back to CAD output (2D CAD); not as BIM finished product before taking it to construction." ENG./CONS/01

In summary, two main technological challenges or barriers are identified dominant against BIM adoption in Nigeria, and these include inefficient technology infrastructure (mainly internet and electricity) and high cost of BIM tools (affordability issue).

6.8 SOLUTION TO BIM FIELDS CHALLENGES

Several challenges were established as barriers against wide BIM adoption in Nigeria (both quantitatively and qualitatively). These challenges covered the entire BIM fields, from the technology infrastructure and BIM tools' challenge to processes issues and mainly to policy-related matters. This section presents the analyses of proposed actions required to phase-out the significant challenges (identified) and the contextual challenges faced by those who adopted BIM in Nigeria.

This section of work presents solutions to challenges mostly highlighted by the interviewees in section 6.7. Answers to questions 14, 30, 31, 32, 35 and 36 in Appendix – 12 (p.311) are presented and discussed under the three BIM field types (Process, Policy and Technology). Thus, solutions are proposed to the outlined challenges in section 6.7. The solution to technology matters is dominantly on BIM tools solution and very little on the infrastructural issues. Under process field type, there are management of BIM and suggestions to who to lead the BIM implementation; while BIM policy (mandate) and adoption timeline are the two sub-sections generated under the policy field.

6.8.1 Solution to Process Challenges

There are substantial process challenges to adopt BIM in Nigeria; these are more of social issues than technical or policy. A combination of "push" and "pull" strategies is suggested to bridge the gap between those in the forefront of BIM adoption (through individual efforts) and those lagging behind. ARC/CONS/06 and QS/CONS/07 felt that the ability to push individuals and encourage them is of great benefit to meeting up with BIM adoption.

> "…by the time it becomes a strict requirement, everybody would have to push themselves and meetup." ARC/CONS/06

> "I manage the challenge by myself and like by encouraging myself and trying to read more and work more using BIM. This has benefitted for me." QS/CONS/07

While on the other hand, ARC/CONS/02 and QS/CONS/04 suggested for sensitization or training of professional colleagues (on the same project) to embark on BIM journey. Although, the professional colleague may not necessarily become expert, but can allow you to collaborate with him, knowing the main purpose of the process will help to collaborate. For instance, QS/CONS/04 says:

> "…like I said, we had to do some preliminary trainings for every other stakeholder on the project ensure that every other person understands what the BIM workflow is. Although, they didn't become BIM compliant but at least they to some extent understood what BIM process was and then they

were able to key in to drive." QS/CONS/04

These also bring about collaboration; collaborative working is the main advantage taken in utilising the BIM process. ARC/CONS/02 and ARC/CONS/11 advised for pure collaboration from the onset of a project.

"It's needs to be more collaborative from the onset" ARC/CONS/02

The collaboration is achieved through wide awareness (ENG./CONS/01, ARC/CONS/02, QS/CONS-CONT./04, ARC/CONS/05 and BUILD/CONS-CONT./09); at the same time through trust (BUILD/CONS/08) between the construction stakeholders. The awareness can be effectively achieved through seminars and professional networking as suggested by QS/CONS/07 and BUILD/CONS-CONT./09, respectively.

"If we were able to enlightened people the more on benefits of this process, I believe the adoption will skyrocket. …lets people be aware of the BIM, awareness is everything, I can't do what I have not heard of…" ARC/CONS/05

"Then the professionals should also trust themselves because that's the major issue we have in Nigeria, you know." BUILD/CONS/08

"…so, with the little seminars we have done, more people are coming up." QS/CONS/07

Lastly, some of the interviewees suggested that educating the clients on BIM benefits (ENG./CONS/01, ARC/CONS/02 and ARC/CONS/05) and proof of such benefits (ARC/CONS/11) are the way out to convince clients to accept or request BIM willingly. Through case study projects, clients are often convinced to embrace and even asked for BIM on their projects.

"…whenever they are giving them training on how to use BIM solutions they always have feedback report from them and most of the feedback is related to, what is the return on investment if those people get it (BIM)." ENG./CONS/01

"If we were able to enlightened people the more on benefits of this process, I believe the adoption will skyrocket." ARC/CONS/05

In summary, those who adopted BIM or are adopting BIM (interviewees) in Nigeria recommend the following:

1. Push-pull strategy between the stakeholders
2. Build trust and collaboration between professionals
3. Create awareness through seminars and professional networking
4. More education on BIM benefits
5. Proof of BIM benefits through case studies

6.8.1.1 Management of BIM

It is of great importance to tactically have a coordinator who manages collaborative working. This role is referred to as "BIM manager" in many countries. For a country where BIM is not well established, identifying who manages the information database will be of big concern. Those who are at the forefront of BIM adoption in Nigeria disclosed their opinion based on their own experience and the perceived role of the manager.

For example, ENG./CONS/01, ENG./CONS/03 and ARC/CONS/05 suggested the Architect as the most appropriate stakeholder to manage the BIM process on building projects while on the other hand, recommended Civil Engineer as the most preferred for infrastructural projects.

> "I believe Architects and Project Managers that work in building industries that is for BIM in buildings; but for infrastructure, I believe Civil Engineers should take much role." ENG./CONS/01

> "I still actually feel the Architects should take this role…" ARC/CONS/05

In additional, ENG./CONS/03 highlighted that the lead consultant or one with a higher volume of work or complexity of work should take the lead on a project where BIM is deployed. In another narration, one who started the design should take that responsibility. Thus, this is still reiterating the above suggestions.

> "…I believe that, that lead should be based on volume of work or complexities; either volume or complexity of work" ENG./CONS/03

Another strong proposal is made by ENG./CONS/01, QS/CONS-CONT./04 and ARC/CONS/11 that, a project manager should head the BIM process because of his position as coordinator of the project. Moreover, any of the professional stakeholders is capable of being a project manager, according to ARC/CONS/11.

> "I feel the project manager is in the best position to implement BIM. In advanced countries, we have a separate role called BIM manager, but I feel that the Nigerian construction industry may not be ready for that yet. So before we get there we can start with having our project management professionals BIM compliant and then pushing the BIM implementation on projects." QS/CONS-CONT./04

> "I always advocate that it (BIM management) should come as a project management consultancy. …That's why if you attach BIM on to project management consultancy, is the justice you will do for BIM because at such all the stakeholders will have the equal right to be the BIM managers." ARC/CONS/11

There are other mixed suggestions that the builder should take the lead according to BUILD/CONS-CONT./09, quantity surveyor should take the lead according to QS/CONS/07; ARC/CONS/06 is in the view of having ICT experts taking the management of BIM process. In case of BUILD/CONS/08, he prefers anyone who is more proficient in the utilisation of BIM tools, or anyone within the AEC who understands the construction delivery process (according to ARC/CONS/11).

> "…in the building industry, it is the builder; because the responsibility of any structure is solemnly on the builder." BUILD/CONS-CONT./09

> "What it should concentrate is that person should have the sufficient skills, knowledge and the experience needed to manage that project, BIM-based project." ARC/CONS/11

Summarising the entire suggestions, the following are prevalent possibilities of whom may coordinate a BIM working process amongst the professional stakeholders:

1. Architect for building project

2. Civil Engineer for infrastructure
3. Mechanical Engineer for factory
4. Electrical Engineer for power station
5. Project Manager (who could be any of the AEC professional)
6. Builder
7. Quantity Surveyor
8. Expert in using BIM tools

According to ARC/CONS/11, Bureau for Public Procurement (BPP) of Nigeria do not know about BIM management role, and they do not have financial provision for any role outside the recognised professionals (i.e. Architects, Quantity Surveyors, Project Managers, Civil/Structural, Electrical and Mechanical Engineering) by law. Thus, their firm (ARC/CONS/11) is positioned as a Project Managers, coordinating the project while playing the additional role of deploying BIM on the project. Thus, Project Managers (regardless of their academic background) stands a better position in managing BIM deployment on a project. Moreover, project managers may be selected on a project to project basis by considering their professional background.

6.8.1.2 Who to Lead BIM Implementation?

The issue on who to lead BIM implementation is mostly based on country's specifics. If the government is involved, then the responsibility can be highly streamlined than individual or group decisions. From the respondents' perspectives, three of the professionals advocated for the professionals to take the lead of BIM implementation. For instance, ENG./CONS/01, ARC/CONS/02 and ARC/CONS/06 believed that professionals are in the right position, especially the project managers (ARC/CONS/02 and ARC/CONS/06).

> "Maybe the project manager which if you have actually look at the project management anybody can still be a project manager, the Architect can still be a project manager, Structural Engineer can be a project manager, so probably the project manager on the project can still be the BIM manager."

ARC/CONS/02

On the other hand, ENG./CONS/03 and BUILD/CONS/08 believe that the leadership of BIM implementation in Nigeria should be collaborative efforts of government and professional societies. Furthermore, BUILD/CONS-CONT./09, ARC/CONS/10 and ARC/CONS/11 tendered this responsibility to the professional societies because of their connection to government, industry and the academia.

> "…it comes in two ways, in one-way professionals in the other way government just like what it happened in the UK." BUILD/CONS/08

> "I think the professional societies. Why am I saying the professional societies is because the professional societies are like the gatekeepers, they have link to the government, in academia, in practice, in business, even in politics so is like they are more of the gatekeepers" ARC/CONS/10

In summary, there are three derived bodies suggested by the interviewees as to whom to lead the BIM implementation in Nigeria; these bodies are:

1. Professionals
2. Government and professional societies
3. Professional societies

The most dominant of these suggestions is *professional societies*; moreover, the professional societies are representing various professionals as a whole for each profession. Thus, marrying the entire ideas together reveals ***government and professional societies*** as a viable team to lead the BIM implementation.

6.8.2 Solution to Policy Challenges

Policy matter is one of the significant issues of discussion in the domain of BIM adoption and implementation around the world. There are number of countries where BIM mandate pushed the industry's rate of BIM adoption; some appeared to have a partial BIM mandate, while some are moving on without government effort of enforcement (McAuley et al. 2017).

Eight of the eleven interviewees advocated for a mandate, their desire for BIM adoption in Nigeria is so keen to have also recognized alliance with international organisations as another step to BIM development. Moreover, they described the government effort as the most influential to BIM adoption, and QS/CONS-CONT./04 said: "…government is the greatest client that we can have."

> "That (government policy) is a best option for us here in Nigeria, that's what we need; …if the government can take that step (policy), then a lot of people that are working for government would definitely follow the steps. So is a good thing if government can take that step." ENG./CONS/01

> "Yes, government on adopting BIM like mandating for all public projects at first, like in the case of UK." QS/CONS/07

Those in support of the above (government mandating the BIM) include ENG./CONS/03, QS/CONS-CONT./04, ARC/CONS/05, ARC/CONS/06, BUILD/CONS-CONT./09 and ARC/CONS/10. Such includes creating an enabling environment for the private sector through policy (ENG./CONS/01, ENG./CONS/03 and QS/CONS-CONT./04). Moreover, BUILD/CONS-CONT./09 suggested that such policy should be implemented from the development control level of 36 states in the country (i.e. approval for any development at the state level).

> "Yes, it (BIM policy) will be good. And the very first place they need to start from it should be on the development control and across the 36 states…" BUILD/CONS-CONT./09

On the other hand, ARC/CONS/02, ARC/CONS/06 and ARC/CONS/10 suggested incentive to BIM adopters by the government to encourage and bring more professionals on-board.

> "…this software can be available on the enthusiast that may not really be relevance based provide incentives for adoption by firms, may be tax incentives and then like exotic incentives because is just like adopting e-payments, e-payments has saved government a lot. This will be now e-planning, this is basically electronic planning, electronic planning management. So, the government has nothing to lose supporting the adoption of BIM." ARC/CONS/06

Regarding training on BIM tools, for example, ENG./CONS/03 took advantage of individual efforts on training and development to upskill their firm's staff. While BUILD/CONS-CONT./09 proposes sponsored training by the government as a pilot training to upskill the professionals on BIM use.

> "…adopt an in-house training system so we challenge ourselves; somebody that is good in understanding of that things would have…" ENG./CONS/03

> "And if government now say okay, I gonna sponsor 1000 professionals in Nigeria as a pilot stage, you understand, whether they bring the resource person from neighbouring country or they send us there, it's a whole lot." BUILD/CONS-CONT./09

About half of the interviewees revealed a strong need for National guide; and more than half (ENG./CONS/01, ENG./CONS/03, ARC/CONS/05, ARC/CONS/06, QS/CONS/07 and BUILD/CONS-CONT./09) of them agreed to have an alliance with international organisations or countries. And eventually, contextualise other countries' guide to suit the Nigerian AEC industry's needs/requirements. QS/CONS-CONT./04 and ARC/CONS/11 explained further how geographical differences affect the way things are carried out in the construction business. Local practices are to be considered in guide and or protocol for the BIM process.

> "A national guide would be appropriate for extra local requirements like… if Nigeria want to step up the game after looking at other countries' standards it will be proper to just coop some principles from international standards and add the few things we think could make Nigeria BIM adoption have the cutting age over what other countries currently do." ARC/CONS/06

To summarise the solution to policy challenges, the research participants suggested the following actions:

1. Mandate BIM especially on public projects
2. Provide enabling environment for BIM-based process by government
3. Mandate may be enforced through 36 states development controls
4. Develop national BIM guide
5. Other countries' guide can be of starting point

6. Collaboration with international bodies
7. Provision of incentives for adopters
8. Involve in the BIM tools training

6.8.2.1 BIM Policy – Mandate Timeline (for the industry)

To mandate BIM in Nigeria, there is a set of preparations and provision to the AEC industry. Therefore, BIM adopters in the Nigerian construction market were asked of a timeline sufficiently possible for the industry to be ready for BIM. Their responses suggested 1 to 10 years; ENG./CONS/01, QS/CONS-CONT./04, ARC/CONS/05, ARC/CONS/06 and QS/CONS/07 feel at least five years is okay to get everyone on-board for BIM adoption.

> "To achieve the implementation, that one will take five (5) years." ENG./CONS/01

> "Well, I would say… I would say five (5) years." ARC/CONS/06

On the same trend when BUILD/CONS-CONT./09 was suggesting 1 year, others (ENG./CONS/03, BUILD/CONS/08 and ARC/CONS/10) are proposing up to 10 years of preparation ahead of mandating BIM.

> "It shouldn't be more than a year… a year minimum." BUILD/CONS-CONT./09

> "We were in 2018, we are in 2019 next year will be in 2020... I will say, I will say a decade (10 years)." ARC/CONS/10

Succinctly, their assertions are based on their experiences with the other professionals in the industry and current challenges of the industry in terms of the three BIM field types. By considering their holistic responses, there should be an average of 6 years duration to prepare for BIM implementation in the industry.

6.8.2.2 BIM Adoption Timeline (for the interviewed firms)

Another question was also asked regarding their level of preparedness to adopt BIM in their workflow fully. Out of the 11 participants, only one has fully adopted BIM, and currently using it to construction stage.

> "We are really using it, really fully." ARC/CONS/11

While the remaining respondents have varied preparation period ranging from 1 to 7 years at least. For example, ENG./CONS/01 and BUILD/CONS-CONT./09 believed that, with the right funding, within a 1-year period, they can be ready it.

> "…have the right funding within one year we can change as organisation, have the process with us." ENG./CONS/01

ARC/CONS/02, ARC/CONS/05 and ARC/CONS/06 proposed at least 2 years to full get things right to implement BIM process. In contrast, ARC/CONS/10 feels that 3 years is okay as conservative as possible.

> "To fully adopt BIM, it shouldn't take more than two years to fully gets use to the right tools and setup the right processes." ARC/CONS/02

> "I want to be as conservative as possible, let's just give me three years. I am trying to be as conservative as possible, just give me three years." ARC/CONS/10

Finally, QS/CONS/07 and BUILD/CONS/08 are of the belief that things within their offices will be perfect for BIM adoption in about five years; while ENG./CONS/03 is of the belief that, as Nigerian, they need at least seven years to embrace this change.

> "…in the next five years. We should have stable staff in the office adopting it we're actually have plans for that." BUILD/CONS/08

> "7 to 10 years, I am also in Nigeria." ENG./CONS/03

It appears that Architects are more prepared to adopt BIM and are much ahead in terms of usage. ARC/CONS/11 is the only firm who has taken BIM to site on BIM-based project as "project managers." To have an idea of their cumulative level of preparedness to adopt BIM, the average of their collective responses of duration revealed three years. Thus, three years is the least time required by the top firms (BIM adopters) to get set for full BIM adoption.

6.8.3 Solution to Technology Challenges

From the previous section 6.7 above, the following technical challenges were established:

1. Internet issues
2. Electricity (power) and
3. The high cost of BIM tools (affordability issue)

Responses to the above challenges by the interviewees are dominantly inclined to BIM tools availability and electricity; while having an additional aspect of a tool called "object library." ARC/CONS/02 and BUILD/CONS/08 suggested the use of cheaper BIM tools available no matter how low level it is; at the same time ARC/CONS/10 feels, educational versions of these software can be of starting point.

> "You can start small you can start on a little you can; start with the little (software) ones you have, you know so they can start with that and gradually move on." BUILD/CONS/08

> "…they are available in the sense that you can always have free version software downloads from the vendors but is only limited to educational purposes…" ARC/CONS/10

He (ENG./CONS/01) furthermore advised that the use of funds provided by clients (i.e. government) to enhance products (built asset) could be used to procure or maintain the utilisation of BIM tool.

> "…government is giving out to contractors, they do have cost of tools that are going to enhance their product, is always stated in the bill, so already government is supporting it. Is left for the construction personnel to now integrate those funding given to deploy BIM." ENG./CONS/01

On the same vain QS/CONS/04 revealed that they succeeded in raising fund to cover the cost of BIM tools through redistributing the cost over their projects, also share the cost burden with the clients without clients been aware of that. The client's share is distributed over items' cost without informing that to the client.

This has gone in line with what is happening in the UAE (Cusack and Saleeb 2016)

> "…we have overcome that through trying to split the cost of software on all of our projects…" "…and we look for ways to how to implement and subsidise this through a support by us and by our clients" QS/CONS/04

On different revelations, objects library issue captures the attention of ARC/CONS/02, QS/CONS/04, ARC/CONS/05, and BUILD/CONS/08. One hardly gets (to procure) the objects (standard) used in the BIM model within the Nigerian market while those available in the market cannot be found within the object libraries while developing your BIM model. ARC/CONS/02 and ARC/CONS/11 disclosed that they use free online object libraries and sometimes build their own by customising those available in the library. While, QS/CONS/04, ARC/CONS/05 and BUILD/CONS/08 suggest to bringing the manufacturers and production companies on-board for the objects model development.

> "…there are a lot of libraries online that you can download, and I can also model it myself so I don't really have problem with all this." ARC/CONS/02

> "So, I feel that also part of the requirements is to have manufacturers and production companies begin to produce BIM models of the products which will be available for Architect at the design stage." QS/CONS/04

Lastly, provision of power has been a significant challenge in Nigeria in general. ARC/CONS/06 described the availability of power as a gateway to overcoming the challenges after awareness.

> "We also at least need power in Nigeria to surmount challenges…" QS/CONS/04

In summary, the ways of handling the leading technological (software and standard objects) issues as highlighted by the interviewees are:

1. Use of cheaper software available
2. Splitting the software cost over projects and sharing the cost with the client
3. Use of funds provided for other added value on the project to procure BIM tools

4. Use of free online libraries and customisation of object properties
5. Bringing building products companies on-board for standardisation and development of objects library.

6.9 CHAPTER SUMMARY

This chapter analysed the interviews conducted with the eleven construction professionals from the Nigerian construction industry who adopted BIM, early adopters. The analysis revealed the following:

1) The interviewees (who are in one way or the other using BIM) have a substantial understanding of BIM. Furthermore, they generally know about BIM through professional contact, personal research, BIM tools developers/vendors as well as conferences; with a limited level of awareness at collaboration stage or BIM level 2.
2) There is a low level of awareness of BIM in the Nigerian construction market as proclaimed by the adopters; and, it is the first challenge that needs to be addressed. It is recommended that a higher level of awareness should be achieved through conferences and successful dissemination of case study projects.
3) In terms of readiness to adopt BIM, the adopters are generally ready although they lamented on the shortage of BIM trained personnel and cost of the tools required deploying BIM on projects; as, for the industry at large, it is not fully ready. On the other note, clients and authorities are not yet ready to adopt BIM due to the substantial awareness and knowledge gaps.
4) The analysis also, deduced that enhanced communication, better (rich) information/data, better workflow and project management, visualisation, and time management are the substantial benefits of utilising BIM in the Nigerian AEC.
5) The Nigerian construction market faces challenges that impede the wide adoption of BIM. These include lack of policy and standardisation of BIM, lack of technology infrastructure and BIM tools, education/training on BIM, lack of BIM skilled personnel, lack of BIM role recognition and clients' will to

requesting BIM, lack of collaboration and resistance by professionals, and lack of case study projects as precedent.

6) The analysis revealed suggestions on how the challenges can be dealt with and how BIM can be widely adopted in Nigeria. These include:
   a) Push-pull strategy between the stakeholders
   b) Build trust and collaboration between professionals
   c) Creating awareness through conferences/seminars and professional networking
   d) More education on BIM benefits, and Proof of BIM benefits through case studies
   e) The Project Managers (regardless of their academic background) are considered suitable professionals to manage BIM deployment on projects. Moreover, project managers may be selected on a project basis by considering their professional background.
   f) Consideration of ***government and professional societies*** as a viable team to lead BIM implementation
   g) Government providing an enabling environment for BIM-based process
   h) Mandating BIM especially on public projects; an average of 6 years is required to get set for BIM implementation and mandate BIM
   i) Enforcement of the mandate should be through 36 states development control authorities
   j) Collaboration with international bodies and considering other countries' guide as a starting point. But national guides should be developed subsequently
   k) Providing incentives for adopters
   l) Government and professional societies' involvement in BIM tools training
   m) Use of affordable software programmes available
   n) Splitting the software cost over projects as well as sharing the cost with the client
   o) Use of funds provided for other added value on the project to procure BIM tools
   p) Use of free online libraries and customisation of object properties to meet the local needs
   q) Use of building products companies (local) to standardise and develop

objects library.

7) Need to mandate BIM especially on public projects; Mandate may be enforced through 36 states development controls

8) Need to provide enabling environment for BIM-based process by the government

9) Need to develop national BIM guide; although, other countries' guide can be of starting point

10) Need to collaborate with international bodies.

Figure 6.1 presents a summary of the above-outlined findings from the qualitative section of this investigation.

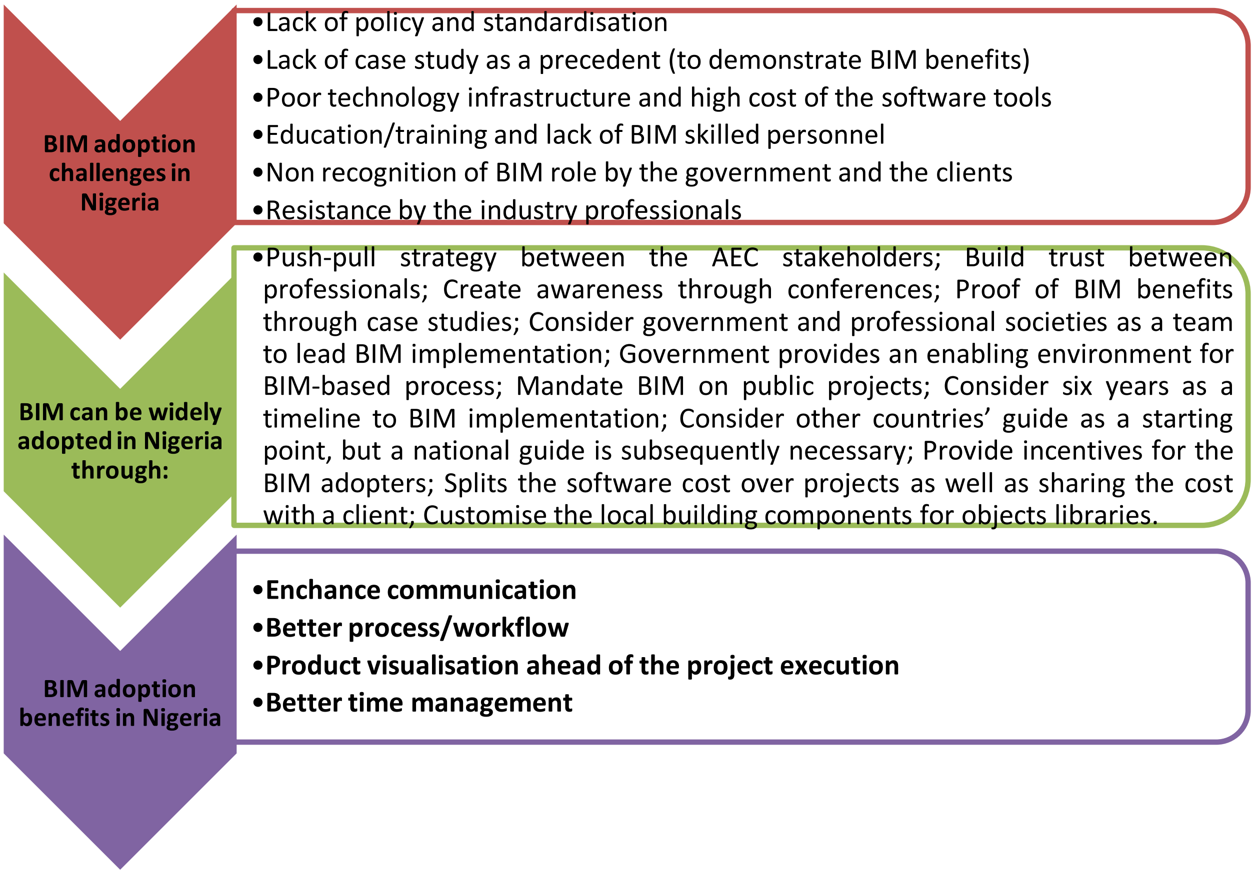


Figure 6.1: Summary of findings from the qualitative study (Interview)

Therefore, with the outlined findings and suggestions, the next chapter (7) will amalgamate the sets of findings from section 2.8.1, 4, 5.2, 5.3 and 6 to come up with a unified framework (as a conclusion) to the entire research work.

CHAPTER SEVEN: FINDINGS, CONCLUSIONS AND RECOMMENDATIONS

7.1 CHAPTER OVERVIEW

The chapter introduces the research findings and presents the developed framework in both narrative and graphical forms as an overall response to the aim of this research, as defined in section 1.4. The study recommendations are presented and further actions where necessary.

7.2 COMPARATIVE CASE STUDY FINDINGS

Having BIM as a new paradigm in the construction industry and the uniqueness of every construction market, there is no unified framework for BIM adoption currently. The comparative case studies targeted active countries on the BIM implementation journey and set a pace to BIM best practices. The case studies informed the main research in different ways to move BIM adoption further, such as policy-related issues, basic requirements in terms of technology and infrastructure, as well as government and professional societies participation. This has ultimately delivered the second objective (Explore BIM development and adoption in the countries where BIM is dynamic and its success was proven) of this study.

7.3 RESEARCH FINDINGS

In developing a framework, a basic conceptual model (conceptual description) is therefore adopted. In the theory building through conceptual methods, conceptual descriptions model '*is primarily descriptive in its modelling of an event or phenomenon*.' Moreover, the conceptual model is expected to generate an extensive or simplified description of a well-structured diagram or chart. Thus, the framework is generated in a structured diagram from the quantitative (adoption policy from section 5.3) findings and the qualitative content analysis (chapter 6). The structure also considers the theoretical framework from the innovation diffusion in section 3.1.1 and that of the macro-BIM adoption in section 2.7.1.6.

The proposed framework is illustrated in Figure 7.1, and the sequential activities with the timeline needed for effective BIM adoption in the Nigerian construction industry are presented in Figure 7.2.

Figure 7.1: The Proposed Framework

The proposed framework (Figure 7.1) is further developed into a more detailed one with a timeline and deliverables. This has been achieved using the template for the macro BIM adoption model, as described in section 2.7.1.6, p.66. The action plans were derived from the quantitative and qualitative analyses outputs. The summaries of their outputs were outlined in sections 5.2.3, p.181; 5.3.3, p.200 and 6.9, p.245.

The details of the framework are generated from both quantitative and qualitative findings, while the framework structure utilises the template for roadmap development at country level. The adoption timeframe (six years) was deduced from the average proposed timeline by the country's adopters [see 6.9 (6)h), p.246].

7.3.1 Objectives, Stages and Milestone

BIM awareness is the first and most critical challenge in the Nigerian construction market, and it is thus considered first. The most viable means to advance a wide BIM awareness are through conferences and workshops [section 6.9 (2), p.245].

Modelling capabilities are targeted considering the current stage of the industry [Figure 5.3, p.187]. The modelling stage capability is the only stage capacity matured (59%) to be deployed on a project. Further stage capabilities continue to build up taking advantages of 'educate', 'incentivise' and 'track' [refer to Figure 5.6, p.195] the use of IFC compliant BIM tools. Finally, limited (on project size or cost) implementation became feasible as BIM tools become much affordable [refer to section 6.9 (6)o), p.246].

7.3.2 Champions and Drivers

To structure the BIM adoption within a construction market, someone (individuals or organisation) has to champion that. In the macro BIM adoption study, establishing a task group is paramount [section 5.3.2.1, p.198] which falls under the initiation phase of macro adoption project. Six zonal task groups are considered due to the diverse nature of the market in terms of awareness and development levels. This is necessary for reachability and effectiveness. BIM-based pilot/case projects are proposed [refer to section 6.9 (2, 5, 6)d), p.245] at each zone as support to drive the knowledge and experience as well as the benefits. The procurement of the BIM-based pilot project will benefit from assistance provided in the procurement of BIM tools through cost-sharing [refer to section 6.8.3, p.243 and 6.9 (6)n), 246].

The task groups are to be unified at the end of the fourth year (by which uneven strengths are balanced) to allow a single control structure while using the various groups for monitoring and enforcement of the partial BIM mandate.

7.3.3 Regulatory Framework

The involvement of AEC professional bodies is necessary as the change process affects them directly. It can be realised that the driving, monitoring and leading the BIM implementation are supported by the professional societies [Figure 7.1]. The professional societies shall be involved in the re-alignment of the procurement process to accommodate the process change. Moreover, monitor and review the BIM-based piloted projects as in "Champions and Drivers". With a higher level of awareness and knowledge of BIM (in the first year) coupled with the experience from the pilot projects (in the second and third year), BIM is legislated in the fifth year to allow implementation in the sixth year [refer to section 6.9 (6)h)i), p.246].

7.3.4 Noteworthy Publications

Temporary guideline, protocols and standards should be considered at an early stage (first) due to lack of standardisation in this area (which is one of the major challenges to adoption of BIM in Nigeria) [refer to Table 5.4, p.175 and Table 5.5, p.176]. There is a crucial need to develop BIM national guide; although, other countries' guide may be utilised as a starting point [refer to section 6.9 (8), p.247]. The UK BIM guideline, protocols and standards were proposed considering the substantial similarities and common utilisation of standards by the Nigerian construction market [refer to sections 4.3.3.3, p.142 and 6.8.2, p.238].

The BIM-based pilot project report must be ready in the fifth year. The report would set a pace, demonstrating the benefits and experiences acquired while setting a path to the implementation phase in the sixth year. The reviewed pilot project report should be published as business value of BIM in the sixth year to keep track of developments in this field.

7.3.5 Learning and Education

Learning and education are determined to solve an essential issue of BIM skilled shortage [refer to section 6.9 (3, 5), p.245]. The education and learning require the development of the teaching framework, BIM software tool, and the trainers [refer to chapter 4.4 and section 6.9 (6l), p.246]. The HEIs may consider educational version BIM tools software in the case of financial or cost issue [refer to section 6.8.3, p.243]. The institutions require piloting teaching modules to assess the framework effectiveness for possible review. After that, the HEIs continue with BIM training to keep a steady supply of human resources to the market.

Train the trainers is the first step to generate the knowledge transfer where HEIs benefit from it. On the other hand, the professionals (already practising) would be up-skilled through the development of a CPD programme [refer to section 4.4.5, p.158].

7.3.6 Measurements and Benchmarks

Measurement, assessment and benchmarking are necessary to keep track of the BIM development and adoption (Kassem and Succar 2017). The development of organisational assessment metrics is based on the deliverables for the BIM-based pilot projects which will be used to assess the firms delivering these projects. The pilot-projects are continuously assessed while the project progresses. More AEC firms are to be registered based on BIM capabilities, while pilot-projects are closing out. Bureau for Public Procurement (BPP) is responsible for the registration and management of the AEC firms [refer to section 6.8.1.1, p.235].

7.3.7 Standardised parts and Deliverables

Unavailability of standardised building components (used from BIM object libraries) in the Nigerian construction market is another bottleneck to its utilisation [section 6.7.2, p.228 referred]. Standardisation of locally available building components should be achieved in triangular collaboration between a regulatory agency, professionals and building components manufacturers [section 6.7.2, p.228 and 6.9q), p.246]. The database would be developed for the standardised locally available building components to allow add-ins to the software tools used [refer to section 6.7.2, p.228].

7.3.8 Technology Infrastructure

The deficit in technology infrastructure needs to be filled up [refer to section 6.4.4, p.218]. Similarly, the lack of protocol for software requirements in the industry makes it difficult to regulates and assesses firms. Also, inadequate and unaffordable internet access is of concern by many [refer to section 6.9 (5), p.245]. Developing minimum requirements for both software and hardware tools is significant, and that would be achieved with the help of a Government Agency regulating IT related tools in the country. The support can be provided on the internet access and data storage facility (including the BIM federated model information for FM and other usages) with the help of the government [refer to section 6.7.3, p.231].

	FIRST YEAR	SECOND YEAR	THIRD YEAR	FOURTH YEAR	FIFTH YEAR	SIXTH YEAR
OBJECTIVES, STAGES & MILESTONE	Create wide awareness through conferences & workshops with the aid of professional societies	Targets minimum of modelling capabilities, and data-rich model sharing Apply above on medium and large scale projects	Attain collaborative capabilities (i.e. BIM Level 2) Use of IFC compliant BIM tools and model-base collaborative working		Encourage and incentivise the use of IFC compliant tools on medium and large scale projects	Commencement of mandate at the end of this year to a BIM Level 2 on medium and large scale projects (limited mandate) Deploy BIM Level 3 training
CHAMPIONS AND DRIVERS	Establish task group with representation from all professional societies + ministry of works & housing, and NITDA	Establish zonal task group with representatives from: states works & housing ministries, states professionals bodies, and a higher institution Award at least a BIM-base pilot project in each of the six geopolitical zones to demonstrate BIM Level 2 process		Introduce the published guide, standards and protocols Provide support in procuring BIM tools by sharing the cost	Integrate the six zonal task groups Utilise the zonal task groups to monitor BIM adoption	Enforce the limited mandate by government supported by the professional societies
REGULATORY FRAMEWORK	Involve the AEC professional regulatory bodies in all BIM processes Move away from disjointed traditional procurement process		Monitor BIM-base pilot projects, review them & deploy adjustment where necessary			Full BIM Level 2 compliance within specified project size/cost and complexity
	Modify the traditional method to accommodate early involvement of contractor Encourage design and built procurement strategy on less complex projects				Legislate the BIM deployment on the public projects	
NOTEWORTHY PUBLICATIONS	Adopt: UK BIM guideline UK BIM standards UK BIM protocols	Considering ISO 19650, develop context base: BIM guideline BIM standards BIM protocols	Continuous publications of context based: BIM guide BIM standard BIM protocols		Publish the BIM-base pilot projects	Publish reviews on BIM-based pilot projects, and their business values Publish standardised BIM deliverables
LEARNING AND EDUCATION	Develop BIM teaching framework, and initiate validation		Create CPD tailored to industry professionals	Continue the BIM training at higher institutions Invest in research and development on BIM		
	Train the trainers	Pilot the BIM teaching modules, assessed and reproduce working framework				
MEASUREMENTS & BENCHMARKS	Develop organisational assessment metrics by task group Assess organisational capabilities ahead of BIM-base pilot projects' award		Continuous assessment of pilot projects Register all firms with BIM capabilities		Continuous registration of all firms with BIM capabilities Firms information manage by BPP data-base	
STANDARDISED PARTS & DELIVERABLES	Standardisation of object with the help of building components manufacturers, professionals & regulatory agencies		Develop data-base for locally available building objects/item as context-base object library		Continue to update the context-base object library	
TECHNOLOGY INFRASTRUCTURE	Develop protocol for minimum software and hardware requirements in the industry – Supported by NITDA		Support adopters with secured internet access – Potentially by GALAXY BACKBONE		Develop data storage platform for storage and retrieval of information for facilities management and emergency needs (i.e. fire service, security treat, disaster management etc.) – Potentially support by GALAXY BACKBONE	

Figure 7.2: The Framework for BIM adoption in Nigeria

The first-year of the framework timeline deals with some of the critical challenges that hamper BIM adoption in Nigeria and the establishment of six BIM task groups; the challenges include BIM awareness, BIM knowledge, BIM guidelines, standards, and protocols.

The second-year timeline inherits some of the first year's deliverables plus new sets of tasks of establishing task groups for monitoring, introducing regulations, piloting BIM-base projects, contextualising guidelines, standards and protocols, modifying the industry's procurement methods; developing a BIM teaching framework for higher institutions, developing BIM assessment metrics, standardising the locally available building objects, and developing the BIM tools' requirements.

The third-year timeline equally inherits some action plans from the second year. This timeline initiates the advancement of collaborative working and the use of IFC compliant tools, monitoring of BIM-base pilot projects, continuous development of context base NBPs, BIM training for industry professionals as CPD, assessment of BIM-base pilot projects, registering firms with BIM capabilities, development of a database for the standardised locally available building objects, and providing ICT support to the BIM adopter.

By the end of the fourth-year timeline, most deliverables from the previous years should be completed, and only a few are initiated. These include the introduction of the published guides, standards & protocols; providing support in procuring BIM tools through sharing of cost amongst stakeholders and allocation of cost amongst a firm's projects, continuous BIM training in the higher education institutions, and investment in BIM research and development.

The fifth-year targets to deliver the following action plans: encourage and incentivise the use of IFC compliant BIM tools on medium and large-scale projects, integrates the six zonal task groups, use the zonal task groups to monitor BIM adoption, and publish a report on BIM-based pilot projects. The following actions are instigated and continue till the end of the sixth year: management of information regarding firms with BIM capabilities (by BPP), continuous update on context-based online object library, and the development of a database for storage and retrieval of built facilities for facility management and emergency needs.

Finally, the sixth year continues with some deliverables from the fifth year as described. BIM-based pilot projects will be reviewed and published. While these activities are getting to an end, a full deployment of BIM level 2 is targeted at the end of the year, and enforcement of the limited mandate becomes paramount. Full compliance with BIM level 2 is for specified projects in size, cost and complexity.

The developed framework (Figure 7.2) relied on the research findings from both the quantitative (questionnaire survey) and the qualitative (interview) results. Part of the quantitative aspect utilises the five macro BIM adoption conceptual frameworks to inform the research on how the framework should be structured; also, helped in establishing BIM Maturity in Nigeria (objective four). The other aspect explores BIM awareness and adoption in Nigeria (objective three). The comparative case studies (section 2.8.1) informed the structure and presentation of this framework.

The reviewed literature presented the current challenges in the Nigerian construction industry and discussed BIM as a productive system potential in providing a solution to some difficulties (objective one). Moreover, the in-depth exploration and review of some case study countries where BIM usage is rapidly evolving as precedent informed this research on the various experiences and policies of BIM adoption (objective two).

The qualitative aspect of this research came up with more context-based benefits of BIM adoption (objective five) and finally revealed the effective ways to have BIM adopted in the Nigerian construction industry (objective six).

7.4 CONCLUSIONS AND FUTURE RESEARCH

This research aim was to develop an effective method in form of a framework for BIM adoption in the Nigerian construction industry as fully illustrated and explained in section 7.3. This was achieved through a review of literature on BIM and its impacts on the construction industry, exploring BIM development and adoption trends in countries where BIM is dynamic; exploring BIM awareness and adoption in the Nigerian construction industry. Moreover, establishing the Nigerian BIM Maturity and identifying the potential benefits of BIM adoption concerning the industry's current challenges.

Objective one was achieved through a stratified review of the literature (in generic and in the context-based). BIM efficacies were explored, and potential challenges to its adoption were identified.

Objective two was met through a comparative analysis of three case study countries. Three different BIM adoption strategies were identified from these countries, and this objective highlights major structural components and presentation of the research aim (strategic framework).

Both objective 1 and 2 informed the structure and content of objectives 3, 4 and 5.

Objective three was met through quantitative measurement, using a questionnaire as a tool for data collection. Low level of awareness and limited BIM adoption were identified.

Objective four was met quantitatively using Macro BIM adoption models, and data was collected through a questionnaire survey. Objective four guides the research on how the framework should be structured; also, helped in establishing BIM Maturity in Nigeria.

Objective five was met through qualitative content analysis of interview scripts. The objective five revealed current benefits derived by the BIM adopters in Nigeria.

Objective six was met while considering the structural components derived from the comparative analysis (objective two), macro BIM adoption study (quantitative approach) and the qualitative content analysis of the interviews conducted on the BIM adopters. A top-level strategy for BIM adoption is inductively and deductively generated.

The comparative analysis of the three case studies, presented in section 2.8.1, concluded that other BIM strategies do not fit the Nigerian industry. However, they possess some common attributes. The Australian trend is closer to that of the Nigerian construction market.

The current Nigerian situation and the adopters' conviction translate into having a combination of awareness, training, structured guidance, partial mandates, and incentives (as stated by Bilal Succar, 2019) to encourage BIM adoption, particularly considering the high level of corruption in the industry (Kori and Kiviniemi 2015).

The majority of the research interviewees believe of BIM mandate as one of the solutions to its resistance. However, a complete mandate is not found to be the one-time solution to the BIM resistance base on the history of the industry. The use of BIM level 0 (CAD tool) is now the norm in the Nigerian construction industry without any mandate, as such partial mandate (with incentives) is concluded as the most appropriate approach.

In summary, the study concludes that government and industry-driven through the government and industry support, and lead by the government and industry as the viable approach to realising a wider BIM adoption in the Nigerian construction industry. This conclusion is based on the industry’s unique requirements for achieving the set goal.

The implementation of BIM in the Nigerian construction industry has the potential to integrate the industry, control project cost, and improve the project quality and efficiency. On the other hand, the proposed framework has a potential risk of failure ('reject to adopt' by the prospective adopters) only if the required parameters are not put in place to provide the necessary variables as prescribed by the framework. Therefore, the risks associated with this framework are late implementation (which needs adjustment with time) and failure of its full application.

SWOT refers to Strength, Weaknesses, Opportunities and Threats. The SWOT scrutiny is commonly utilised in vital administration when building the procedure of a given populace. It may be a kind of demonstrative instrument, often used at the exceptionally starting of the method of characterising future essential plans (Zima et al. 2020). The SWOT investigation could be a basic but capable device for measuring up capabilities and lacks, openings and the external dangers to the future of a developed strategy (Thompson et al. 2007). Thus, SWOT analysis is adopted to present the strengths, weaknesses, opportunities and threats of the developed BIM adoption framework (refer to Figure 7.3).

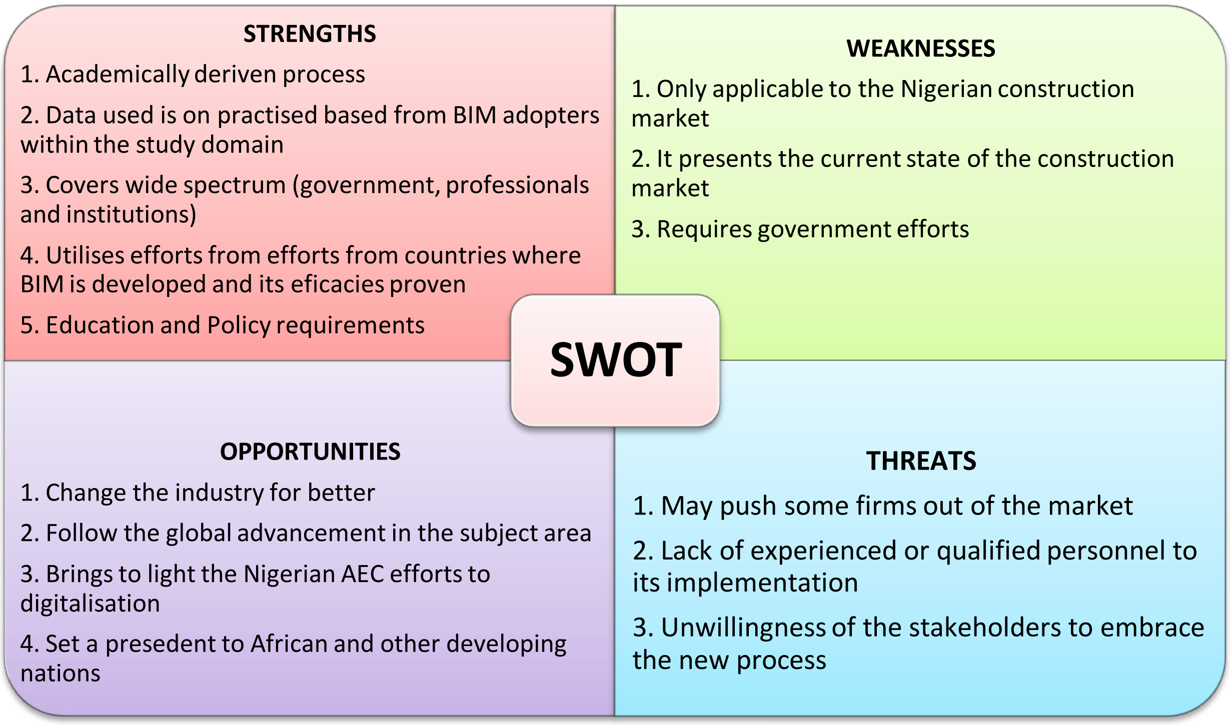


Figure 7.3: SWOT Analysis of the developed framework

There are some global benefits of this research, include the development of three frameworks for the case study countries, setting a precedent in developing a BIM adoption framework for early adopter countries and inclusion of Nigeria in the global BIM study areas.

7.5 RECOMMENDATIONS

The study recommends a thorough implementation of the strategy (framework) in its sequential pattern and in full by the government in collaboration with industry stakeholders. Full participation of the professional bodies is recommended especially in the area of CPD and broader awareness amongst the built professionals. Considering the dynamic nature of the industry, the fast changes in the BIM development, and adjustment with time; the sequence may likely change over time. As a result of potential accrued changes in the areas of Diffusion Dynamics and Policy Actions requirements, the framework may need to be adjusted with time. Therefore, it recommends a periodic macro BIM adoption study (as in section 5.3) ahead of the framework implementation.

7.6 FUTURE STUDIES

Further research is expected on how BIM can be embedded into built environment-related courses to fill the skill gap in the industry and create additional opportunities. Additionally, a study on the development of standardised local objects library is also important. The same study can be undertaken using the same method on other developing countries or early adopter countries.

7.7 RESEARCH CONTRIBUTION

The research promotes a new process of working and facilitates a way for government and industry stakeholders to initiate the paradigm shift for the better construction industry to avoid falling behind in a rapidly digitised world and economy. The research also contributes to the extraction and mapping of maturity models from three developed countries.

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APPENDICES

9.1 APPENDIX – 1: SUMMARY OF BIM STUDIES IN THE NIGERIAN CONTEXT

ISSUES S/ No	Publication	Methodology	BIM Barriers	Summary	Remark	Culture of the industry	Lack of awareness	Policies / legal issues	Lacks trained staff	Affordability/availability of software packages
1	EZEOKOLI, F., OKOYE, P. and NKELEME, E., 2016. Factors Affecting the Adaptability of Building Information Modelling (BIM) for Construction Projects in Anambra State Nigeria.	**Questionnaires** were administered, the generated data were analysed using **mean score, percentages and relative importance index.**	The industry here are early adopters; the barriers to adoption are: compatibility between software platforms; **poor level of knowledge and awareness;** structure/culture of the industry as well as availability of the appropriate technology.	It can be observed that, the practice of a lonely or isolated BIM is recorded of about 23% at moderate level. Not more than 32% are using CAD 3D package.	These findings are limited to a location (Anambra State of Nigeria); only structural engineers were involved out of engineering discipline in the survey; and only building construction was considered.	X			X	
2	KORI, S.A. and KIVINIEM, A. 2015. Toward adoption of BIM in the Nigerian AEC industry; context framing, data collecting and paradigm for interpretation. 9th BIM Academic Symposium & Job Task Analysis Review, NIBS-Washington DC, USA, 7-8 April 2015.	The research involves an online **questionnaire survey** targets Architectural firms in Lagos, Abuja, Kaduna and Kano; **Chi-square test of independence was used to validate the correlation** of 3 divided sized firms against BIM maturity model by cross tabulation.	**Lack of understanding of BIM process and policies issue**.	Large firms were the only firms achieving average at **model-based collaboration**, however, the small firms partake at **object-based modelling** while the medium firms were able to manage the **object based.**	This research is limited to **Architectural firms** and perhaps referring to some Architectural consultancy firms in **Lagos, Abuja, Kaduna and Kano.**		X	X		
3	ABUBAKAR, M., IBRAHIM, Y., KADO, D. and BALA, K., 2014. Contractors' Perception of the Factors Affecting Building Information Modelling (BIM) Adoption in the Nigerian Construction Industry. Computing in Civil and Building Engineering (2014). pp. 167-178.	Structured **questionnaires and semi-formal interviews** were the sources of primary data collection; subsequently analysed by Relative Importance Index (RII) for ranking.	*The top barriers to BIM adoption are: Social and Habitual Resistance to Change; Legal and Contractual Constraints; High Cost of Training; Lack of Enabling Environment (Government policies and legislations);* ***Lack of Trained Professionals to handle the tools;*** *Clients not requesting the use of BIM on projects.*	*"There is need for attention by researchers, government, and other stakeholders towards a country-wide implementation of BIM technologies and has set a scene for developing a framework for BIM adoption in the Nigerian construction industry."* **"further research should focus on developing a framework for the full adoption of BIM in the Nigerian construction industry"**	The study focused only on building construction firms; and the primary data were obtained from very few states **(Abuja and Lagos)** of the country and also centered on **contractors only**, therefore it cannot be generalized.		X		X	
4	ABUBAKAR, M., IBRAHIM, Y.M., and BALA, K., 2013. Readiness of Nigerian building design firms to adopt building information modelling (BIM) technologies. *The 5th International Conference for Construction Engineering and Project Management, ICCEPM 2013.*	A review of literature coupled with a structured **questionnaire** were used to collect data; stratified sampling method was used for the firms' selection within Kaduna and Abuja. Analysed by descriptive statistics such as Means and S.D., ANOVA, DUNCAN (for exploring extent of variation)	**Lack of awareness of the technology amongst professionals and clients; lack of availability of well-trained professionals**; lack of cooperation and commitment of professional societies.	The designers were observed to be appreciably ready for adopting BIM technologies in their practice with little variations in their respective levels of readiness.	This study has some limitations, such as: Only **building designers** were considered for the study; The target group (location) is **Kaduna & Abuja.**		X		X	

		multiple range test.								
5	UGOCHUKWU, S.C., AKABOGU, S.C., and OKOLIE, K.C., 2015. Status and perceptions of the application of building information modelling for improved building projects delivery in Nigeria. American Journal of Engineering Research (AJER), 4(11), pp. 176-182.	A structured questionnaire was administered to building professionals; using descriptive tool (mean score method) for the analysis.	The most significant barrier to BIM implementation is **Lack of awareness amongst stakeholders**; power failure & internet issues were also considered as serious barrier, amongst the tops include **lack of skilled staff on BIM** as well as lack of industrial standards. Collaborative procurement was rated high to promoting BIM adoption in Nigeria, on the other hand Traditional method (separated) was rated low to promoting the BIM adoption/implementation in Nigeria.	*Determination of level of awareness for BIM application, extent of participation in BIM projects, identify suitable procurement method to BIM application, the barriers and its benefits to building delivery in Nigeria. Results revealed lack of BIM knowledge among professionals (33%), use of BIM in projects is non-existent, the collaborative procurement method as best to supporting BIM use, lack of awareness as a major barrier to BIM application, while simultaneous access to project database by stakeholders as the highest ranked benefit of BIM application.*	The study target group is small only two states (**Anambra and Enugu states**) were considered; going by the procurement route mostly adopted by the public sector, consultants (designers) should have been amongst the respondents. No evaluation on the respondents' experience. For more clarity, response by the clients should have been evaluated separately from that of the contractors.		**X**		**X**	
6	EBILOMA, D.O., DAIBI-ORUENE, W.D. and BUMAA, F.N., 2017. APPLICATION OF MULTIPLE REGRESSIONS ON THE IMPACT OF BUILDING INFORMATION MODELLING ADOPTION DRIVERS ON SUSTAINABLE CONSTRUCTION IN NIGERIA.	Quantitative in nature; survey design was used (structured questionnaire survey); using random sampling method. Data analysed by Relative Importance Index (RII); subsequently used multiple regression analysis for test. In summary ANOVA was used.	Lack of professional workshops and training for stakeholders; lack of trained professionals; expensive software packages.	The finding revealed that, professional workshops and training stakeholders as well as providing well-trained professionals are the main/critical drivers to poster BIM adoption in Nigeria.	In summary education and training is the main issue to be handle before serious BIM adoption in the study area. The study covered only one state **(Akwa Ibom)** of the country.				**X**	**X**
7	DIM, N., EZEABASILI, A. and OKORO, B., 2015. Managing the Change Process Associated with Building Information Modelling (BIM) Implementation by the Public and Private Investors in the Nigerian Building Industry.	Case study as well as Literature review-based research with huge derivations from the developed nations (specifically, the UK)	Significantly **lack of awareness** with traditional way of doing things.	The stakeholders in the industry heard nothing of BIM before (2015) and therefore have no clue what BIM is all about. The professionals use some application software packages (AutoCAD and ArchiCAD) at design stage but subsequently uses printed drawings at construction stage with virtually no collaboration.	**Reviewed literatures and some case studies from the UK**	**X**	**X**			
8	ONUNGWA, I.O. and UDUMA-OLUGU, N., 2017. Building Information Modelling and Collaboration in the Nigerian Construction Industry. Journal of Construction Business and Management, 1(2), pp. 1-10	Structured questionnaire method was adopted; respondents (30 AEC) were selected through the simple random sampling method. The data were analysed using SPSS (mean and variable with highest impact); ANOVA was used to test variation.	The most significant barriers to adopting BIM are: **Lack of skilled personnel,** lack of internet connectivity and reluctance of the other stake holders and lack of **awareness of the technology.**	***There is need for a more sustained study in this are;*** Need to develop and incorporate BIM in curriculum of construction related courses.	The study was conducted within **Lagos and its environs, 2015 survey data were used for this study**.		**X**		**X**	

9	ONUNGWA, I.O., UDUMA-OLUGU, N. and IGWE, J.M., 2017. BUILDING INFORMATION MODELLING AS A CONSTRUCTION MANAGEMENT TOOL IN NIGERIA. WIT Transactions on The Built Environment, 169, pp. 25-33	Data generated through **questionnaire survey** of AEC firms selected via simple random sampling method. Data analyzed using descriptive statistics (mean, relative index and percentages).	Lack of **awareness;** lack of support by government as well as **trained personnel.**	Utilization of BIM as an active tool in construction management in Nigeria is at preliminary stage. **In Nigeria, the process in which buildings are constructed are still unchanged.**	The study focused predominantly the **South West of Nigeria specifically Lagos (75%)** with just 6.3% from South region of the country. **2015 field survey data were used for this study.**		**X**	**X**	**X**	
10	WANG, C., ADETOLA, S. M. and ABDUL-RAHMAN, H., 2015. Assessment of BIM implementation among MEP firms in Nigeria. International Journal of Advances in Applied Sciences, 4(3), pp. 73-81	Structured **questionnaire survey** was used for data collection. *The data were analyzed using descriptive statistics, one-way ANOVA test for statistically significant difference, Chi-Square test, and Cross Tab analysis.*	Lack of **awareness** of the technology, lack of **technical expertise** on its tools' utilization, high cost of **training staff** and software and hardware shift.	This study was done on MEP firms only. They were found to have relatively high level of awareness on the BIM technology	The findings revealed relatively **high level of awareness at the same time lack of awareness as a barrier to** BIM adoption.		**X**		**X**	**X**
11	TIMOTHY, O. O., KEHINDE, O., FAGBEMI, K. and SADIKU, A., 2016. "Exploring New Directions for the Transformation of the Built Environment in Nigeria: The Role of Building Information Modelling" Developing Country Studies ISSN 2224-0525 (Online) Vol.6, No.6, 177-182.	A theoretical framing of research questions together with **questionnaire and interviews were carried out for primary data; frequency/percentages** was used to ascertain level of each variable.	Dispositional attitude between the team members; **lacking trained personnel on BIM.**	The industry is fragmented, record blames between team members, everyone blaming the other of not using BIM tools: this portray the knowledge lacking on BIM benefits & implementation process.	The findings were derived from Architectural Firms **only** and targeted **Akure only.**	**X**			**X**	

9.2 APPENDIX – 2: QUESTIONNAIRE FOR EXPLORATORY STUDY

DIFFUSION OF INNOVATIONS: THE STATUS OF BUILDING INFORMATION MODELLING UPTAKE IN NIGERIA

* Required

1. **Name (Optional - for data sorting only)**

2. **What is your main discipline?** *Mark only one oval.*

   Architect
   Builder
   Contractor
   Engineer
   Quantity Surveyor
   Client

3. **How many staff do you have in your firm or organization? *** *Mark only one oval.*

   1 – 5 personnel
   6 – 10 personnel
   >10 personnel

4. **What is your academic qualification? *** *Mark only one oval.*

   OND/HND
   B.Sc./B. Tech./B. Eng.
   M.Sc.
   PhD

5. **For how long have you been in the industry? *** *Mark only one oval.*

   Less than 5 years
   5 - 10 years
   10 - 15 years
   More than 15 years

Building Information Modelling Awareness and Abilities

6. **What is the CAD type do you mostly used? *** *Mark only one oval.*

   No CAD
   2D CAD only

2D and 3D CAD
3D CAD only

7.

What do you benefit from using 3D CAD? where applicable * *Mark only one oval.*

Visualization
Information sharing
Database for components' attributes
Generating bills and shedule
Simulations / Performance analysis

Not Applicable (NA)

8.

When producing CAD drawings, which of the below tools do you mainly use? * *Mark only one oval.*

Autodesk AutoCAD 2D
Autodesk AutoCAD 3D
Revit Arch, Struct, MEP
Bentley Arch, Struct, Mech, Elect
Synchro Project Constructor
Nemetschek Vectorworks
Graphisoft ArchiCAD
Google Sketchup
Bentley Microstation
Bentley Building Suite
TEKLA

9.

Are you aware of Building Information Modelling (BIM) and do you use it? *Mark only one oval.*

Neither aware nor using BIM
Just aware of BIM
Aware and currently using BIM

10.

How confident are you in your knowledge and skills in BIM? * *Mark only one oval.*

Not confident
In between
Confident

11.

How do you mostly share design/construction information with other stakeholders? * *Mark only one oval.*

Using the same tool (i.e. AutoCAD) via email
Using the same tool (i.e. AutoCAD) via database
Using the same tool (i.e. AutoCAD) via SD
Using different tool (i.e. pdf) via email

Using different tool (i.e. pdf) via SD

12.

What do you consider as barriers to BIM adoption? * *Check all that apply.*

- Lack of Expertise
- Lack of Standardised tools and protocol
- Cost
- Our projects are too small for that
- Lack of collaboration by other stakeholders
- Lack of clients' interest Government policies

13.

Which procurement method do you mostly engaged in within the last 5years? * *Mark only one oval.*

- Design and Build
- Traditional

Powered by Google Forms

9.3 APPENDIX – 3: INTERVIEW GUIDE FOR EXPLORATORY STUDY

ROBERT GORDON UNIVERSITY • ABERDEEN

The Scott Sutherland School of Architecture and Built Environment, Robert Gordon University
The Sir Ian Wood Building, Riverside East, Garthdee Road
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Supervisor's email: t.kouider@rgu.ac.uk

……………………………………………………………………………………………………

EXPLORATORY STUDY: INTERVIEW GUIDE

1) Knowledge and understanding of Building Information Modelling (BIM)
2) The use of software (BIM tools) for design and other activities by consultants
3) The use of software (BIM tools) by constructors (contractors)
4) The use of software (BIM tools) by the clients/clients' representative
5) Participation in a project where BIM was used
6) Any planned for policy by government to adopting
7) Legislative provision to supporting/funding new innovation in the building industry
8) Policy for enforcement
9) Any digitalization in the system or plan to going it
10) How ready the government is to adopting new innovation
11) The prime issues and the way out

Yours sincerely,
Mansur Hamma-adama
Mansur Hamma-adama *B.Eng., MSc.*
m.hamma-adama@rgu.ac.uk

9.4 APPENDIX – 4: QUESTIONNAIRE FOR EXPLORATORY STUDY (EXTENDED)

PRELIMINARY STUDY TO DETERMINE LEVEL OF COMPUTER

TRAINING ACQUIRED BY STUDENTS OF BUILT ENVIRONMENT AND
ENGINEERING FROM NIGERIAN UNIVERSITIES

* Required

1. **Name (Optional - for data sorting only)**

____

SECTION A: Profile of Respondent

2. **Which department do you service? *** *Mark only one oval.*

- Engineering
- Architecture
- Building
- Quantity Surveying
- Other:

3. **Which of the following _______________________ best describes your cadre? *** *Mark only one oval.*

- Lecturer
- Technician
- Technologist

4. **What is your academic qualification? *** *Mark only one oval.*

- OND/HND
- B.Sc./B.Tech
- M.Sc.
- PhD
- Other: _______________________

5. **For how long have you been in the academia? *** *Mark only one oval.*

- Less than 5 years
- 5-10 years
- 10-15 years
- More than 15 years

SECTION B: Available Facilities

6.

Do you have computer laboratory? * *Mark only one oval.*

- Yes
- No *Stop filling out this form.*

7.
How many computers are in the laboratory? * *Mark only one oval.*

- < 10
- 10 – 20
- 21 – 30
- 31 – 40
- > 40

8.
What are the software available on the computers? * *Check all that apply.*

- AutoCAD 2D
- AutoCAD 3D
- TEKLA
- Revit Arch, Struct, MEP
- Bentley Arch, Struct, Mech, Elect
- Synchro Project Constructor
- Other: ____________

SECTION C: Level of Training

9.
What are the training do you offer to your students? * *Check all that apply.*

- We have a computer laboratory but offer no training
- AutoCAD 2D
- AutoCAD 3D
- TEKLA
- Revit Arch, Struct, MEP
- Bentley Arch, Struct, Mech, Elect
- Synchro Project Constructor
- Other: ____________

10.
What is the proficiency training level do you offer them? * *Check all that apply.*

- Not Applicable (NA)
- Fundamental awareness (Basics)
- Novice (Limited experience)
- Intermediate (Practical application)

Advance (Applied theory)

Expert (Recognized authority)

11.

What is the proficiency level do they (students) generally graduated with? * *Check all that apply.*

- [ ] Not Applicable (NA)
- [ ] Fundamental awareness (Basics)
- [ ] Novice (Limited experience)
- [ ] Intermediate (Practical application)
- [ ] Advance (Applied theory)
- [ ] Expert (Recognized authority)

9.5 APPENDIX – 5: EXPLORATORY STUDY: TRANSCRIBED INTERVIEWS

EXPLORATORY STUDY: INTERVIEWS TRANSCRIPTION

INTERVIEW 01 (CONTRACTOR – PROJECT MANAGER) - CPM

➢ **Do you know anything related to Building Information Modelling (BIM)?**

✓ Am not aware of anything Building Information Modelling (BIM)

➢ **Have you ever used 3dimensional AutoCAD?**

✓ No! 2dimensional (2D) AutoCAD

➢ **Do you have any in-house policy to adopting something like AutoCAD 3D etc.?**

✓ No, the one we are using is coming from consultants even, the consultants we are working with are using that 2dimensional AutoCAD.

➢ **So, you normally adopt what you are using from what the consultants are using?**

✓ Yes

➢ **Is like most of the contracts you are engaged in is traditional form of**

contract [designer separated from constructor (contractor)]?

✓ Yes

- **Are you aware or know any policy from the government related to all these kind of AutoCAD?**

✓ No

- **How do you think the industry is ready to adopting all these kind of new software and new way of working?**

✓ I think that one must be coming from the Universities (schools), from the place where the Engineers take that education (get trained). …from that place the start to use the AutoCAD 2dimensional, and I think if there is new thing, they must start from there.

- **So you expect the new innovation to start from schools (institutions)? And then followed by who?**

✓ Must start from there, followed by the consultants; then contractors, if it's available everywhere the contractor will start to use even. If something is available in the market and you see all the people will start to use it and that one is good for the job and they make the job easy and with good quality.

- **Do you think there is any way of digitalization, something like connecting your work with drawings?**

✓ There is no any link between our project progress and the design/drawings, so far none.

COMMENT

The best way to adopting this system is marketing, and the marketing must start from school. Because whatever training I get from school will be what to be using (i.e. AutoCAD) until I get training with this BIM; is marketing and the marketing will start from there (school); secondly from marketing, they must do link with the construction company or the consultants' office to do change, without that one, the consultant will not make any change. …and the companies I think few of them will do change, the remaining they will stay using AutoCAD or the other system.

INTERVIEW 02 (CLIENT – ENGINEER) - CLE

- **What do you understand by Building Information Modelling (BIM)?**

✓ My knowledge on Building Information Modelling (BIM) is pretty below limited, is an area that I will say I heard of it virtually today through the research student and it appears quite exciting to me. So I can't say am knowledgeable to good extend on that, but is an interesting area that I love to know more about.

- **Have you ever use Building Information Modelling tool? Something like AutoCAD 3D, Civil CAD etc. May be participated in project related to that.**

✓ …yes, AutoCAD yes, Civil CAD yes, but know it, to have harmonized it into a BIM I will say no, but as an isolated software for design, yes I have used it severally for infrastructural design works in the office.

➢ **Is there any in-house policy, perhaps government policy in relation to using software?**

✓ For a policy regarding use of software, explicitly stated no! But department of engineering services and FCDA as a hall encourages development of workers, like AutoCAD, Civil CAD and the like, they have been sending a lot of people for training in that area and I do know that our infrastructural design are done using some of those software. So, there is interest, but to expressly say there is policy on ground as regards that, no!

➢ **Is there any plan towards policy by the government, may be on digital procurement?**

✓ For a policy explicitly stating that, am not aware of it. But I do know there is a strong interest from the government, typical example is during preparation of 2018 budget, the authority explicitly encouraged development of e-library, use of software for design and to equip such centers to enable engineers have access to software that will do that. Well there is strong interest from the government, but in terms of whether there is policy in the opened, I doubt it, not for now as far as FCDA and as far as I know.

➢ **Do you get any support (legislative) in that respect or any policy for enforcement?**

✓ No legislative support and no any policy enforcement in relation to use of software. Since there is no policy, then the enforcement cannot come in.

➢ **How ready do you think the government is to adopting such kind of innovations?**

✓ I think the government is more than ready and willing to do that. It appears in my perspective that the knowledge for somebody who is knowledgeable in that area to explain it so explicitly, so clearly the way you did now is not there. So it becomes really difficult to convince the authority if you don't have somebody who knows it very well to articulate the position to state cut clearly the benefits of BIM before the authority buys it in. That appears to be the major problem; there is no knowledge, no expertise along that area at all.

➢ **Is there any digitalization may be in terms of recording process and monitoring activities on site?**

✓ I think we have achieved quite much in that area. Construction started in Abuja in 1980, most of our drawings were done then manually and I do know a unit was created clearly with a mandate to digitalise all our drawings and information and have it in format that are electronically driven, I think we have gone very far on that. Our progress reports, our assessment we have gone very far. What we are lacking is to transit from where we are right now into this BIM be able to do things more electronically than manual, that gap is still there, that transition is still there.

➢ **Do you digitally monitor progress of work on site while here in the office?**

✓ We don't have way of monitory progress on site while in the office. However, the current director of engineering is of that opinion to digitize our activities which would be updated may be on a weekly basis so that every single site on your tablet; so that he has information on all the over 5,100 projects we have. He can be able to access it being updated, that has not yet been done, may be because of finances but it’s an area where he is deeply interested in, I think with this line of motivation we would put pressure along that line.

COMMENT

I would say, for this year, this is the best I have heard that motivated me along the lines of doing things that will improve work in the FCT, development of infrastructure in the FCT. I think BIM is when a proposal is articulated well and presented to the department of engineering I am sure we would work towards that line to make things much easier for us, we appreciate this.

INTERVIEW 03 (CLIENT – ARCHITECT) - CLA

➢ Do you know anything related to Building Information Modelling (BIM)?

✓ I only have general point of view, primarily from any work as an Architect, then from my work here as a member of pilot team that was developing the e-government system for the FCT as a hall.

➢ So what is your understanding of BIM?

✓ BIM for me is the use of... it is a very rudimentary definition, like I told you, is not very wide spread here, and we are only at the ‘ferry-ferry’ and we do know it’s an aspect of applying ICT applications toward making out built environment processes in terms of planning much better and much efficient.

➢ Have you ever participated on project where BIM is been used?

✓ Like I said my knowledge is restricted to a general sense, we don’t have that here, we are suppose to be part of a pilot team to popularise such systems starting with infrastructural development, ICT systems and the likes. But we are still at the stage of awareness raising and let me just add that, I am a member of the education board of Nigerian Institute of Architects even at that level, it’s still quite rudimentary. Am also a member of common wealth Association of Architects education work group where I think some discussion is at more advance level: For us here, we are at ‘*ferry-ferry*’ like I said, knowledge of it is on the base of general interest and some of the things I am doing.

For instance like I told you we are part of the team that was introducing e-procurement here, we are part of the team that was to make e-governance a major thing here. And we are supposed to be change agents as it were. Change agents here is a big thing, you need an enabling environment. Example, this building suppose to be smart, all the structured cabling has been done, and even though we have Architects and Engineers here, most of the software we use are not enterprise version, they are stand alone, it’s not integrated and most of the departments have to have their own small cyber systems just to serve.... We have a central cyber system which is not functioning very well and its even a territory wide and part of a system where we try to integrate this building and the central secretariat. In the central secretariat, there is an ICT backbone as far back as 2007. So, all we need to do is to integrate here and there and then the applications we wanted to start with at that time are basic office integrate document management. And, that kind of thing, so, some of the more specific systems that we are talking about were suppose to come at a later time after these have gone through some trial period and have some trouble shooting etc. Even some of these ones people are not aware.

You will be surprised that the e-procurement for example it was UNDP supported! The cyber on which the application was deployed, initially we wanted to locate them in Copenhagen (Denmark) where we would have free trouble shooting and management services. But the system here at that time felt to be a bit insulting, how can we be doing everything here, then we are locating the cyber in Copenhagen. So, unfortunately when the cyber came, they had problem, it was at the same time we were told to use galaxy, have a remote location in galaxy but we never got round to doing it.

- **So, do you have any government or in-house policy regarding all these?**

✓ I will tell you something, everything am telling you comes under broad based reform program, when Nigeria came at the beginning of 1999, when we came back to the democratic governance. A major outcome were supposed to be reform; reform in terms of anticorruption, reform in terms of public sector governance that is where these things am telling you about were actually located.

Another public sector governance, we had capacity building, we had institutional reform, we had e-governance and then we had very broad based capacity governing program that was supposed to incorporate everything; so, am telling that under the e-governance program we were able to initiate or not initiate. The fibre active backbone that was part of the program and some initial application that will be deployed to that backbone to be tried out as a pilot and then develop further on subsequently. But there is a major problem of power; if you ask me, I think power was one of the major reasons that has stolen the development; if you ask me there is policy, yes there is policy but key into the policy has been one thing.

- **Do you have any legislative backup towards that, supporting this kind transformation?**

✓ I will not tell you out rightly that am aware of any kind of legislative backup, but I can say with every sense of confidence that, the governments from 1999 came on board and part of their output was reform, reform particularly in the area of public sector governance and things like e-government. I recruit and a lot of these applications were supposed to come under that and then of course at the end of the day BIM as well.

- **But is there any funding towards that?**

✓ The funding aspect I may not be very competent to comment on that; I do know that federal ministry of science and technology is doing something in that regard, and then we have some Agencies that has been assisting, like NITDA and at a point even be for public service reform was deeply involved in some of these things. But essentially from my point of view a lot of funding has come from our technical partners in form of support in the system; the World Bank and UNDP, and I do know that the World Bank was very big in funding one e-government program with World Bank and support from UNDP.

- **Do you have any legislative backup to enforcement of such, perhaps the contractors have to abide by such as e–design etc.?**

✓ Let me tell from my own personal experience, when we launch the e-procurement program, it was essentially the then Minister, Malam Nasiru El-Rufai, he was even ahead of the government. We had our e-procurement program long before Bureau of Public Procurement (BPP) had an e-procurement program and till now I cannot tell you any degree of certainty that the BPP has the functional e-procurement program; but I have my documents and everything we have done on this program. Now when we wanted to launch a pilot for e-procurement, for example, one of the requirements entail having contractors to be registered in our electronic data base and that is where we were stocked because most of them were not compliant, most of them were not compliant.

- **Is there no legislation on that regard for you to enforce that on them (contractors)?**

- ✓ For now, am not aware there is any legislation, because the e-procurement for now is just an option. FCT has gone further than any other agency and if we are not doing it here, full blast. I don't think others could because FCT was the pilot agency in the entire country because we were the ones that were most likely to succeed, then other Agencies were to key in and learn from us. And am telling you now that we had issues even with the people we are supposed to be serving and the ever issue of energy (power) that will always remain the big problem if we are going to embark on any endeavor that has a futuristic interns even if it's for the benefit of the generality of the people.

- ➢ **How do you thing government is ready to adopting these kind of innovations?**

- ✓ Am a government person but unfortunately I have to speak to you from personal point of view, we need a champion, we need a champion, everything we achieved here it was because of Nasiru ElRufai, he was personally interested, he was personally involved. And even a lot of the donor agencies knew him as a person, they trusted him and they supported him all the way as soon as he left, most of the programs had a downward slide. It may interest you to know that if you interact with them outside this country beside some of this our e – initiatives amongst the failures that some of them embark upon beside them. So, how ready government is as a body is going to be difficult not because we are not interested, my personal opinion is that our level of ICT compliance as a nation sometimes is over rated, I think it's sometimes over rated. So it will take a lot of awareness raising and even the educational establishment (institutions) need to do a lot of work from basic to advance and expert level: particularly, at the basic levels.

COMMENT

What I have to say is, I want to encourage you we need such initiatives and any time I see people like you, I know that there is some hope especially if you decide to come back home at the end of the day. I want to tell you that, do not be discouraged, I wish we had gone to my other office where I was coordinating the world bank program on…, is full of document like this on the e–government program and all the applications we had urge to deploy. And, anytime I think we have a friendly government that will repackage them and send them, so that at least within FCT when people like you come, there will be something that you can build on, there is somewhere for you to get a foot holes to look forward but not just BIM but any other innovative program.

INTERVIEW 04 (CONSULTANT – ARCHITECT) - COA

- ➢ **Do you know something about Building Information Modelling?**

- ✓ To be honest, this is the first time am hearing about Building Information Modelling right? But during, at the cause of my profession I heard about Building Information but not modelling it, I have never heard of it.

- ✓ Now I understand what you are talking about, now at the level where we are in the process of Architecture; for example, from the client briefing, most of what we do is basically in analogue system. You take a briefs from clients, then you go back to the office and then analyses it send it back to him for confirmation and then from there you now start coming to developing your design analysis and everything. And, then you now come up with a sketch; all these are physically done, not on the system, but basically on paper. Was just recently because we have advent of computers and some other aids that help in the process of design that you can now say okay let me transfer all the ideas that I have into the system. Now where we have what you are saying, the technicality of integrating other professionals is also basically not in place, not online integration. For example, I do a design in AutoCAD, then from AutoCAD I now send a copy probably by same software, and send it structural engineer via email or copy in a flash drive for him, he now takes it start his own design process. The structural engineer I know they have their own software that they use to take care of your design on AutoCAD right? Take it to their software and from there they start to develop their own design.

- **Are you aware of a software that can do all that of the architect, engineers etc.**

✓ Yes, AutoCAD can do that (what you are saying) also, but the level, our use of AutoCAD is not up to that. Because in AutoCAD you can actually attach attributes to a line, this is what and what, and this is what that line represents; but you are the one that can input that; in the course of working one can create a log for that line but all these are done manually.

- **Are you aware of a software that do come with such properties?**

✓ Yes I am aware of that, but we don't really have that common here, is not common but I know software like Revit does that to some extend and then like 3D Home views, because I have use… I went on a training on a 3D homes software it does that and remember some years back; there was a software that use-to-use 3D homes. You do the entire house in 3D on that software and it will give you all the information about that house, so within that context, yes I will say we have some limited knowledge on that.

- **Do you use the same software or platform with other professionals (i.e. engineers)?**

✓ No! We don't do that.

- **Have you ever participated in a project where BIM is been used?**

✓ Well, when I was in Lagos, because the firm I worked in Lagos was fully developed, that's where we got the Revit software that was back then (2002 - 2003). The firm has its own in-house engineers: Mechanical engineers, Structural engineers and everything; we come together within the office right; and do all the design within the same software that we have. Do that in-house not with any other consulting firm, the only other consulting firm is just to send them the document and they will now respond.

Yes, but I will only talk about my firm process… from brief till final design…

- **Do you know any legislative backup toward may be digital Architecture?**

✓ Legislatively, there is none! That is why am even looking at the institute basically entirely (the institute of Architecture) I still find out a little bit of odds in there, the way they are operating. These are some of the things that the institute should project; come up with and say okay, bring up a policy that will back it up; say from now on all architects, this is the guideline. We are talking but generally in the construction industry am aware there is a legislation on building codes, and the building codes also stipulate the guideline you take but not necessarily within the context of design and construction process.

✓ Since there is no legislation in that regards, then no legislative backup to enforcing this process.

- **So, how do you think the industry is ready to adopting this kind innovation?**

✓ It's quite a good initiative if at all its presented to the professionals; the first of all, it has to be presented and accepted by the professions within the industry before it goes down to the process of being legislated upon by the government. Because, if the key players are not really in turn with what is happening, by the way one need to understand that not everybody within the profession is also digitally compliant.

9.6 APPENDIX – 6: PUBLISHED RESULTS FROM EXPLORATORY STUDIES

STATE OF BUILDING INFORMATION MODELLING (BIM) ADOPTION IN NIGERIA

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Construction Industry has had its biggest breakthrough since the development of Building Information Modelling (BIM). The industry has been changing over time; United States has been at the forefront of adoption and implementation of BIM while Australia, United Kingdom and some other developed nations are moving in full force concurrently. At the same time, developing countries are battling with BIM uptake. The BIM awareness and adoption in Nigerian Architecture Engineering and Construction (AEC) is significantly low; research to adopting this innovation has received very little attention. This piece of work (as part of preliminary investigation of a PhD work) is aimed at exploring the state of BIM within decision makers in Nigerian AEC. Semi-structured interviews were conducted with stakeholders in the industry (Contractor, Consultant and Clients); the transcribed interviews were analysed using qualitative content analysis. The information revealed that, the key players are generally not familiar with the term "Building Information Modelling" or "BIM" although mostly aware of some of its tools (i.e. AutoCAD, Revit etc.). Only a few uses some BIM tools at organisational level 'lonely BIM' and operating model based 'BIM stage 1.' Moreover, no legislative provision on BIM adopting or regulation. Nevertheless, the government is open for new concepts in promoting and advancing the industry only when they are convincing enough. Lack of experts on BIM is a major barrier to its adoption at all levels. Recommendations are made based on the findings based of the exploration for the industry to compete with its global counterpart.

Keywords: BIM, CAD, innovation, adoption, construction industry

INTRODUCTION

Engineering business is going digital and integrated; there still remain significant move and development to achieving it globally. Building Information Modelling (BIM) is the most recent paradigm shift in construction industry and the promising concept determine to shape the industry's fragmentation (Zhao *et al.,* 2016). BIM is defined as a set of interacting policies and processes being enabled by technologies in generating a methodology to procure building works from inception to completion down to the entire lifecycle of a building in a digital format (Succar, 2009).

There are numerous application of BIM, to mention but a few with: design coordination, energy performance simulation, scheduling and quantity take-off, clash detection and 3D visualisation (Cao *et al.,* 2014, Eastman *et al.,* 2011, Monteiro *et al.,* 2014). There are several arguments regarding BIM benefits over the years. Autodesk (2008) claimed a time saving up to 91% on checking and coordination, 50% on developing a design while using Revit® Architecture software compared with the conventional Computer Aided Design (CAD). However, countries have been adopting it with individual experiences (in

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Diffusion of Innovations: The Status of Building Information Modelling Uptake in Nigeria

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Authors' contributions

This work was carried out in collaboration between all authors. Author MH designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Author HS revised the first draft. Author TK supervised the entire study. All authors read and approved the final manuscript.

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ABSTRACT

Aim: This study evaluated Building Information Modelling (BIM) awareness and adoption in Nigeria through the line of enquiry known as the 'diffusion of innovations' and its possible uptake.
Study Design: The study is quantitative in nature and the primary data fetched through questionnaire survey within Nigerian construction industry.
Place and Duration of the Study: Conducted within North-west, North-central and Lagos, Nigeria for a period of 4 months.
Methodology: A quantitative approach was adopted to x-ray the Nigerian construction industry; a structured questionnaire was used across the Architecture, Engineering and Construction (AEC). The generated data were analysed through descriptive statistics (in percentages) and presented in charts and graphs.
Results: The result revealed that 59.5% are aware of BIM technology; 22.8% are aware and currently using BIM and the remaining 17.7% neither aware nor using BIM; consequently, the industry was evaluated just within the *Late Majority* in terms of awareness and just entered the *Early Majority* in terms of BIM technology adoption.

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RESEARCH ARTICLE

Building Information Modelling Uptake: Tool Training in Nigeria

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Abstract:

Computer Aided Design software and their kind are generally considered as Building Information Modelling (BIM) tools; moreover the sophistication level of one determines its maturity level. Education and research are the background to innovation while training is a window to continuity in skills transfer. The BIM uptake in the developing countries is significantly lagging behind; amongst various reasons is the lack of trained professionals. Experts are evolving from the industry professionals who are first trained in the university. This study determined the capacity of Nigerian universities in providing BIM tools training for BIM adoption in Architecture, Engineering and Construction (AEC). The study is quantitative in nature, with the primary data collected through a structured questionnaire survey within the built environment and engineering schools of Nigerian universities. The collected data were analysed using descriptive statistics. The institutions are physically ready with relatively sufficient hardware, however technically not ready due to insufficiency of up to date software. There is a significant correlation between software availability and proficiency level of training, while no correlation between academic qualification and the training proficiency. More than 70% of the students are graduating on 'file based collaboration' – 2D and 3D CAD knowledge with proficiency level between limited and practical application. However, the collaborative software training received proficiency level of basic to practical application; a 13% trained on collaboration software is very little to providing experts for the industry. This reveals a clear setback in the tools training to carter for the BIM uptake in the country.

9.7 APPENDIX – 7: PUBLISHED RESULTS FROM LITERATURES

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A Review on Building Information Modelling in Nigeria and Its Potentials

Mansur Hamma-Adama, Tahar Kouider

Abstract—Construction Industry has been evolving since the development of Building Information Modelling (BIM). This technological process is unstoppable; it is out to the market with remarkable case studies of solving the long industry's history of fragmentation. This industry has been changing over time; United States has recorded the most significant development in construction digitalization, Australia, United Kingdom and some other developed nations are also amongst promoters of BIM process and its development. Recently, a developing country like China and Malaysia are keying into the industry's digital shift, while very little move is seen in South Africa whose development is considered higher and perhaps leader in the digital transition amongst the African countries. To authors' best knowledge, Nigerian construction industry has never engaged in BIM discussions hence has no attention at national level. Consequently, Nigeria has no "Noteworthy BIM publications." Decision makers and key stakeholders need to be informed on the current trend of the industry's development (BIM in specific) and the opportunities of adopting this digitalization trend in relation to the identified challenges. BIM concept can be traced mostly in Architectural practices than engineering practices in Nigeria. A superficial BIM practice is found to be at organisational level only and operating a model based - "BIM stage 1." Research to adopting this innovation has received very little attention. This piece of work is literature review based, aimed at exploring BIM in Nigeria and its prospects. The exploration reveals limitations in the literature availability as to extensive research in the development of BIM in the country. Numerous challenges were noticed including building collapse, inefficiencies, cost overrun and late project delivery. BIM has potentials to overcome the above challenges and even beyond. Low level of BIM adoption with reasonable level of awareness is noticed. However, lack of policy and guideline as well as serious lack of experts in the field are amongst the major barriers to BIM adoption. The industry needs to embrace BIM to possibly compete with its global counterpart.

Keywords—Adoption, BIM, CAD, construction industry, Nigeria, opportunities

I. Introduction

ARCHITECTURE Engineering and Construction (AEC) business is developing as a result of digital transition. This development became obvious since development of BIM concept. However, this is yet to be achieved globally due to conventional nature of the industry. BIM is the most recent development of the construction industry's process and a promising concept determine to shape the industry's fragmented culture [1]. BIM is described as a set of interacting policies and processes that are being enabled by technologies in generating a methodology to procure building works [2], purely from inception (or renovation) through the construction process to completion and to the entire lifecycle of a building. Fig. 1 presents a representation of BIM (schematic).

There are numerous applications of BIM, to mention but a few with: design coordination, energy performance simulation, scheduling and quantity take-off, clash detection and 3D visualization [4], [5]. Countries have been adopting BIM at different level and with different purpose, having different experiences (in benefits), depending on adoption level and possibly their challenges earlier to the adoption. For example, McGraw Hill Construction [6] study discloses some substantial benefits of adopting BIM by Australia and New Zealand; these include the reduction in rework, business reputation, effective management of construction time and cost as well as reduction in errors and omissions. The rationale behind BIM adoption varies from country to country; however, there are common goals amongst most of the countries. These include, improving the industry's productivity and unifying its standardizations by changing its way of working [7], [8].

BIM has now gone beyond a concept for building design and construction; it is fully into the infrastructural development process. Bentley has been developing highly sophisticated BIM tools for engineering of infrastructural design and construction processes and it is generating acceptance throughout the construction and facility management sector. The same can be noticed with Autodesk in the recent years. Fig. 2 presents an outlook of infrastructural engineering design in a BIM environment [9].

Developed countries' BIM awareness has gone near universal and its adoption and implementation is currently dynamic, though there is generated argument on its clarity in adoption level or stage [10]. However, there remains a long way to go in most of the developing countries especially Nigeria. Regardless of several years of discussions and researches in the area of BIM concept and its adoption, Nigerian construction industry has not been seen in the BIM discussion. Till 2013, when a first study surfaced, this study was mainly on assessment of readiness of the first line adopters of BIM in the industry (consultants - designers). The assessment was due to lack of clarity on whether the industry is ready (technologically) to adopting the concept; but not the other two fields (process and policy) – this is a sign of starting point or '*readiness ramp*' [10]. Furthermore, the starting point was an exclusive searching for a significant match towards the concept adoption.

The previous research concentrated mostly in trying to assess BIM (within a limited profession or location) or assess

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Comparative Analysis of BIM Adoption Efforts by Developed Countries as Precedent for New Adopter Countries

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Authors' contributions

This work was carried out in collaboration between both authors. Author MH designed the study, reviewed the literature and produced the first draft of the manuscript. Author TK structured the writing, proofread and approved the final manuscript before submission.

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ABSTRACT

Building Information Modelling (BIM) adoption is generally assessed through one of these two main approaches: Statistical evaluation of survey from stakeholders operating within a country or market and the use of macro BIM-adoption models and metrics. The recent paper "macro-BIM adoption: Comparative market analysis" sets a pace to continues development of comparative market studies. However, precedent is important for continues learning and adoption to contextualise this evolving field. This study aimed to set a unique precedent through comparative analysis of BIM adoption trends in the USA, UK and Australia to set a pace for beginners or early BIM adopting countries to learn from. This study is literature based analysed using content analysis. The study reveals the following:

- ✓ For a vibrant and even BIM adoption, government is involved;
- ✓ Government mandate facilitates wide BIM adoption and integrates a country's industry to the world;

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9.8 APPENDIX – 8: PUBLISHED RESULTS FROM THE INVESTIGATIVE STUDY

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What are the Barriers and Drivers toward BIM Adoption in Nigeria?

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Abstract

The 'digitalization and collaboration' or Building Information Modelling (BIM) in the construction industry has been gaining momentum in the recent academic engagements. Despite its existence in many industries (i.e. publishing, retailing, financial and travel services) for over a decade, the construction industry is yet to catch up with them. This is due to several challenges whose existence are more dynamic and perhaps generic than static to various countries. The challenges are mostly defined, but their impacts are frequently varied with boundaries; and the same applied to drivers toward a successful BIM adoption. This study aims to establish barriers and drivers to adopting BIM across Nigerian construction industry professions for synchronization and collective engagements. Primary data was fetched from professional stakeholders (Architects, Engineers, Builders, Quantity Surveyors, Project Managers and Planners) using online structured questionnaire. A total of 68 valid responses were analyzed using descriptive statistics. The study reveals a significant improvement in awareness level with much better adoption rate; however, the utilization level remain very limited due to lack of clarity, knowledge and guide. Lack of expertise within organizations and within project team as well as lack of standardization and protocols (in descending order) were found as significant barriers to BIM adoption. On the other hand, availability of trained professionals to handle BIM tools, proof of cost savings by its adoption and the BIM software affordability (in descending order) were found as the significant drivers to achieving a quick and effective BIM adoption. Recommendations were made based on the study findings.

Peer-review under responsibility of the scientific committee of the Creative Construction Conference 2019.

Keywords: adoption; barriers; BIM; construction; drivers; Nigeria

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1. Introduction

Building Information Modelling (BIM) is the process of creating a digital model of a building or infrastructure facility. The fundamental idea behind BIM is to create and share the right information at the right time throughout the design, construction and operation of a building or facility, in order to improve efficiency and decision making (CIOB). This new paradigm shift in the construction industry is gaining high recognition both in the academic discuss (research) and the industry (application). However, its wide (universal) adoption is facing ordinary challenges but yet persistent within the industry and across the world. These challenges are more the same rather than different; although their significance and uniqueness vary with country. On the other hand, the drivers that facilitate its adoption have similar trend with the barriers.

Macro-BIM Adoption Study: Establishing Nigeria's BIM Maturity

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Abstract. Construction Industry in Nigeria has since required a disruptive technology to change its construction business and improve its capabilities and productivity. As an on-going research (PhD work) to developing a strategy for an effective Building Information Modelling (BIM) adoption in Nigeria, a macro-BIM adoption study was carried out to establish BIM maturity within the Nigerian construction market. Online questionnaire was used as tool for data collection from the professional stakeholders in the industry. In the process to formulate a National BIM Roadmap, five conceptual macro-BIM maturity models were utilized. The models' findings act as a guide in developing a national BIM adoption policy. The five applied models helped classify the macro maturity components and the key policies' deliverables that must be addressed within both the initiation and consultation phases of proposing the Nigerian BIM roadmap. The results established positive progress in awareness and adoption level compared to the 2017 survey. Recommendations are made based on the study findings as to advance into policy development.

Keywords: Building Information Modelling · Macro-BIM · Adoption · Nigeria · Construction industry

1 Introduction

BIM is gradually becoming a norm in the built asset procurement, but its adoption around the world varies significantly. Effort by government is playing a significant role in facilitating BIM adoption around the world. For example, UK, USA, Finland, Russia, Denmark, Singapore etc. are some case study countries where government involvement played a significant role on BIM adoption [1, 2]. Moreover, more countries are keying into this strategy, to mention but a few, such as Canada, Germany, Japan, Ireland, Qatar and Spain. Some of these countries used the developed macro-BIM adoption models to streamline or develop BIM adoption roadmap and guidance for the development of their BIM adoption policy, and such countries include Ireland and Brazil [2, 3]. Other countries which are currently utilizing the macro-BIM adoption models include Spain, Canada, Russia, Brazil, Hong Kong etc.

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Analysis of Barriers and Drivers for BIM Adoption

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Abstract:

Research on 'digitalization and collaboration' in the construction industry has been gaining momentum in the recent academic engagements. Despite its existence in many industries (i.e. financial services, retailing, publishing and travelling) for over ten years, it is yet to catch up by the construction market; this is due to several challenges whose existence are more dynamic and contextual than generic to various countries. The problems are defined in many studies across borders, but their impacts varied with countries. This case is equally the same to drivers toward the adoption of BIM. This study analyses barriers and drivers to BIM adoption in the Nigerian construction industry from adopters and non-adopters perspectives as to allow an informed decision in developing a strategy for macro BIM adoption. Primary data fetched from professional stakeholders through an online questionnaire survey were analysed using SPSS software and Microsoft Excel. This investigation reveals the most significant barriers against BIM adoption as Lack of expertise, Lack of standardization and protocols to mention but a few. And, most influential drivers from both adopters and non-adopters as Availability of trained professionals to handle the tools, Proof of cost savings by its adoption, BIM Software affordability, and awareness of the technology among the industry stakeholders. The adopters and non-adopters groups have nearly equal Percentage Disagreement (PD) and Percentage Agreement (PA) for both the barriers and drivers to BIM adoption. Thus, this suggests that the adopters are still at the early stage of BIM adoption, so have nearly the same perceptions with the non-adopters. The study recommends proper consideration of the established barriers and drivers while developing any strategy for effective BIM adoption. Further face-to-face (interview) study is necessary to explore more and in-depth challenges to adoption of BIM in the industry; and as the industry is getting more aware of the BIM, periodic evaluation of the critical barriers and drivers is vital.

Keywords: BIM adoption; BIM barriers; BIM drivers; construction industry; Nigeria.

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9.9 APPENDIX – 9: QUESTIONNAIRE SURVEY (INVESTIGATIVE STUDY)

Nigerian Building Information Modelling (BIM) Macro Adoption Study

Establishing Nigeria's BIM Maturity

* Required

1. **Email address ***

   ____

2. **What is your sex? *** *Mark only one oval.*

   - Male
   - Female

3. **What is your academic qualification? *** *Mark only one oval.*

   - OND or HND
   - B.Sc./B. Tech./B. Eng.
   - MSc
   - PhD

4. **What is your profession? *** *Mark only one oval.*

   - Architecture
   - Building Engineering
   - Civil/Structural Engineering
   - Electrical Engineering
   - Mechanical Engineering
   - Construction/Project Management
   - Quantity Surveying
   - Other: ______________________________

5. **Which of the following best described your specialisation? *** *Mark only one oval.*

   - Contractor/Construction
   - Designer or Consultant
   - Client
   - Development Authority

6.

What is the size of your technical personnel? * *Mark only one oval.*

- < 10 personnel (Micro)
- 10 - 50 personnel (Small)
- 50 - 200 personnel (Medium)
- > 200 personnel (Large)

7.

Who do you mostly work for? * *Mark only one oval.*

- Government (public sector)
- Private (individuals or cooporate bodies)
- Both (Public and Private)

8.

Where in Nigeria do you practice? * *Mark only one oval.*

- North-Cenral
- North-East
- North-West
- South-East
- South-South
- South-West

9.

How long have you been in the practice? * *Mark only one oval.*

- < 5 years
- 5 - 10 years
- 11 - 15 years
- > 15 years

Building Information Modelling (BIM) Awareness

BIM is the process of creating a digital model of a building or infrastructure facility. The fundamental idea behind BIM is to create and share the right information at the right time throughout the design, construction and operation of a building or facility, in order to improve efficiency and decision making (CIOB.)

10.

Are you aware of Building Information Modelling (BIM) * *Mark only one oval.*

- Yes
- No *After the last question in this section, stop filling out this form.*

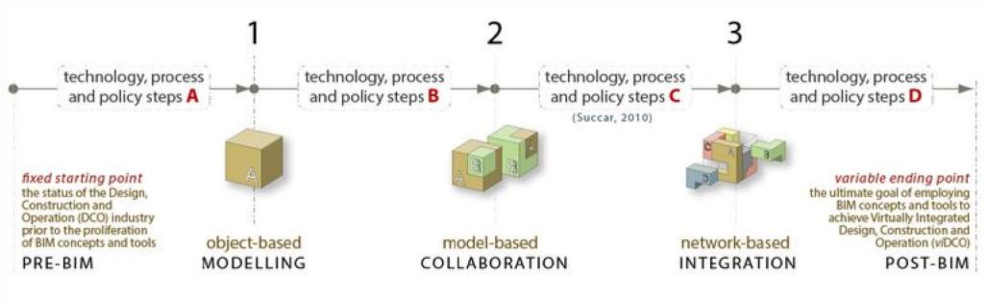
11.

Have you ever used BIM in any of your project? * *Mark only one oval.*

- Yes
-

No After the last question in this section, skip to question 12.

12.
If yes, to what extent?



Mark only one oval.

- Modelling only (BIM stage 1): We are using 3D (software) to generate geometric model (e.g. for details and visualisation)
- Collaboration (BIM stage 2): We are using and exchanging model with other stakeholders via the same tool (software format)
- Integration (BIM stage 3): We are using network based integration (network based solution for exchange)

BIM Maturity in Nigerian Construction Industry

13.
What do you consider as the major drivers to adopting BIM? (ranking from 1 - low to 5 - high) * *Mark only one oval per row.*

	1	2	3	4	5
Availability of trained professionals to handle the tools BIM					
Software affordability					
Enabling environment within the industry					
Clients' interest in the use of BIM in their projects					
Awareness of the technology among industry stakeholders					
Cooperation and commitment of professional societies to its implementation					
Proof of cost savings by its adoption					
Cultural change among industry stakeholders					
Government support through legislation					
Collaborative Procurement methods					

14.
What do you consider as the major barriers to using BIM? (ranking from 1 - low to 5 - high) *
Mark only one oval per row.

	1	2	3	4	5
Lack of expertise within the organisations					
Lack of expertise within the project team					
Lack of standardisation and protocols					
Lack of collaboration among stakeholders High Investment Cost					
Legal issues around ownership, IP & PI insurance					
Lack of client demand					

Lack of infrastructure
Lack of government policy
Industry's Cultural resistance
Lack of additional project finance to support BIM
Resistance at operational level
Reluctance of team members to share information
Return on Investment (ROI) issue

15.

In your opinion, what is the industry's BIM capability based on the following BIM stages and fields (ranking from 0 - nothing achieved to 4 - highest achieved) *

Cumulative Capability Increase →	TECHNOLOGY	PROCESS	POLICY
INTEGRATION	**3TE**: Integration Technologies Rate of adoption of *network-based* interchange solutions (e.g. model servers); rate of proliferation of real-time network-based integration across disparate systems	**3PR**: Integration Processes Rate of adoption of *integrated supply-chain* processes across the whole supply chain; rate of proliferation of interdisciplinary workflows across all project life cycle phases	**3PO**: Integration Policies Rate of adoption of *integrated supply-chain* standards, protocols and contractual agreements; rate of proliferation of interdisciplinary educational programmes
COLLABORATION	**2TE**: Collaboration Technologies Rate of *inter-organizational* adoption of model-sharing software and middleware tools (e.g. Navisworks, Vico and Ecodomus)	**2PR**: Collaboration Processes Rate of *inter-organizational* adoption of project BIM roles (e.g. Information Manager); rate of proliferation of multidisciplinary model-based workflows; rate of proliferation of new collaboration-centric business models	**2PO**: Collaboration Policies Rate of *inter-organizational* adoption of modelling standards and collaboration protocols; rate of proliferation of collaboration-centric contractual agreements and educational programmes
MODELLING	**1TE**: Modelling Technologies Rate of *intra-organizational* adoption of BIM software tools (e.g. Revit and Tekla) and their underlying hardware and network requirements	**1PR**: Modelling Processes Rate of *intra-organizational* BIM roles (e.g. model manager, and BIM trainer) and model-based workflows	**1PO**: Modelling Policies Rate of *intra-organizational* adoption of modelling standards (e.g. naming standards, shared parameters, level of details, and property sets) and file exchange protocols

Mark only one oval per row.

	0	1	2	3	4
Modelling Technologies					
Modelling processes					
Modelling policies					
Collaboration technologies					
Collaboration processes					
Collaboration policies					
Integration technologies					
Integration processes					
Integration policies					

16.

Can you measure the following BIM maturity components as to their respective availability in Nigeria (ranking from 0 - low maturity to 4 - high maturity) *

Macro-maturity matrix at *granularity level 1*.

		a	b	c	d	e
		Low maturity	Medium–low maturity	Medium maturity	Medium–high maturity	High-maturity
I	Objectives, stages and milestones	There are no market-scale BIM objectives or well-defined BIM implementation stages or milestones	There are well-defined macro-BIM objectives, implementation milestones and capability stages	BIM objectives, stages and milestones are centrally managed and formally monitored	BIM objectives and stages are integrated into policies, processes and technologies and manifest themselves within all other macro-maturity components	BIM objectives and stages are continuously refined to reflect advancements in technology, facilitate process innovation, and benefit from international best practices
II	Champions and drivers	There are no identifiable market-wide champions or BIM implementation drivers	There are one or more volunteer champions and/or informal BIM drivers operating across the market	There is a unified task group or committee driving BIM implementation/diffusion across the market	Driver(s) coordinate all macro-adoption activities, minimise activity overlaps, and address diffusion gaps	Driver(s) role is diminished, replaced by optimised systems, standards and protocols
III	Regulatory framework	There is no formal BIM-era regulatory framework	There is a formal regulatory framework addressing basic BIM-era rights and responsibilities of a number of stakeholders	The formal regulatory framework covers all BIM-era rights and responsibilities of all stakeholders	The regulatory framework is integrated into all requirements, roles, processes and deliverables	The regulatory framework is continuously refined to reflect technological advancements and optimised collaborative workflows
IV	Noteworthy publications	There are no – or a small number of – noteworthy BIM publications (NBPs) across the market	There are many NBPs with overlapping knowledge content; some NBPs are redundant or collectively include knowledge gaps	NBPs are developed and/or coordinated by a single entity thus minimising overlaps and knowledge gaps	NBPs are authoritative, interconnected and integrated across project life cycle phases and the whole construction supply chain	NBPs are continuously optimised to reflect international best practices
V	Learning and education	BIM learning topics are neither identified nor included within legacy education/training programmes; learning providers lack the ability to deliver BIM-infused education	BIM learning topics are identified and introduced into education/training programmes; BIM learning providers are available across a number of disciplines and specialties	BIM learning topics are mapped to current and emergent roles; BIM learning providers deliver accredited programmes across disciplines and specialties	BIM learning topics are integrated across educational tiers (tertiary, and vocational) and address the learning requirements of all industry stakeholders	BIM learning topics are infused (not separately identifiable) into education, training and professional development programmes
VI	Measurements and benchmarks	There are no market-wide metrics applied in measuring BIM diffusion, organisational capability or project performance	Formal metrics are used to benchmark project outcomes and assess the abilities of individuals, organisations and teams across the market	Standardised metrics are used to centrally benchmark project outcomes; certify the abilities of individuals, organisations and teams; and accredit learning programmes, software systems and project delivery mechanisms	Standardised metrics and benchmarks are integrated into project requirements, workflows and deliverables; consistently used in defining and procuring services; and used to prequalify the abilities of individuals, organisations and teams	Standardised metrics are continuously revised to reflect evolving accreditation requirements and international best practices
VII	Standardised parts and deliverables	There no market-specific *object libraries* (e.g., doors and windows); service delivery *model uses* (e.g., clash detection) and *operational data* requirements (e.g., COBie)	*Object libraries* are available yet follow varied modelling and classification norms; service delivery *model uses* and *operational data* requirements are informally defined and partially used	Standardised *object libraries* are available and used; service delivery *model uses* and *operational data* requirements are formally defined and used across all project lifecycle phases	Standardised *object libraries*, service delivery *model uses*, and *operational data* requirements are integrated into, procurement mechanisms, project workflows and lifecycle facility operations	Standardised *object libraries*, service delivery *model uses* and *operational data* requirements are continuously optimised and realigned to improve usage, accessibility, interoperability and connectivity
VIII	Technology infrastructure	Non-existent, inadequate or unaffordable technology infrastructure (software, hardware and networks) as to prohibit widespread BIM adoption	The technology infrastructure is of adequate quality and affordability to enable BIM implementation within organisations and diffusion across varied market sectors	The technology infrastructure is of high quality and affordability enabling the efficient exchange, storage and management of complex, federated models among dispersed project teams	The technology infrastructure is uniformly accessible and interoperable allowing real-time network-based integration across disparate systems and data networks	The technology infrastructure is intuitive and ubiquitously accessible allowing seamless interchange between all users, virtual systems and physical objects across the whole lifecycle

Mark only one oval per row.

	0	1	2	3	4
Objective, stage and milestones					
Champions and Drivers					
Regulatory Framework					
Noteworthy Publications					
Leaning & Education					
Measurements & Benchmarks					
Standardised parts & Deliverables					
Technology Infrastructure					

17.

What is your assessment of the current BIM directional pressure dynamics in Nigeria (who is pushing BIM adoption) *

DIFFUSION DYNAMIC	MACRO ACTOR, TRANSMITTER	PRESSURE MECHANISM	PRESSURE RECEPIENT, POTENTIAL ADOPTER	ISOMORPHIC PRESSURE TYPE
Top-Down	Government or regulatory body	Downwards	All stakeholders falling within the circle of influence of the authority exerting pressure	Coercive; normative
		Horizontal	Governments and authorities in other markets	mimetic
Middle-Out	Large organization or industry association	Downwards	Smaller organizations further down the supply chain; members of industry associations	Coercive; normative; mimetic
		Upwards	Governments and regulatory bodies within the market	Normative
		Horizontal	Other large organizations and industry bodies within or outside the market	Mimetic; normative
Bottom-Up	Small organization	Upwards	Larger organizations and industry bodies	Normative
		Horizontal	Other small organizations	Mimetic; normative

Mark only one oval.

- Top-down (e.g. government mandate and policies)
- Middle-out (e.g. driven by larger Design or Construction firms)
- Bottom-up (e.g. driven by smaller industry stakeholders from Designers and Contractors)

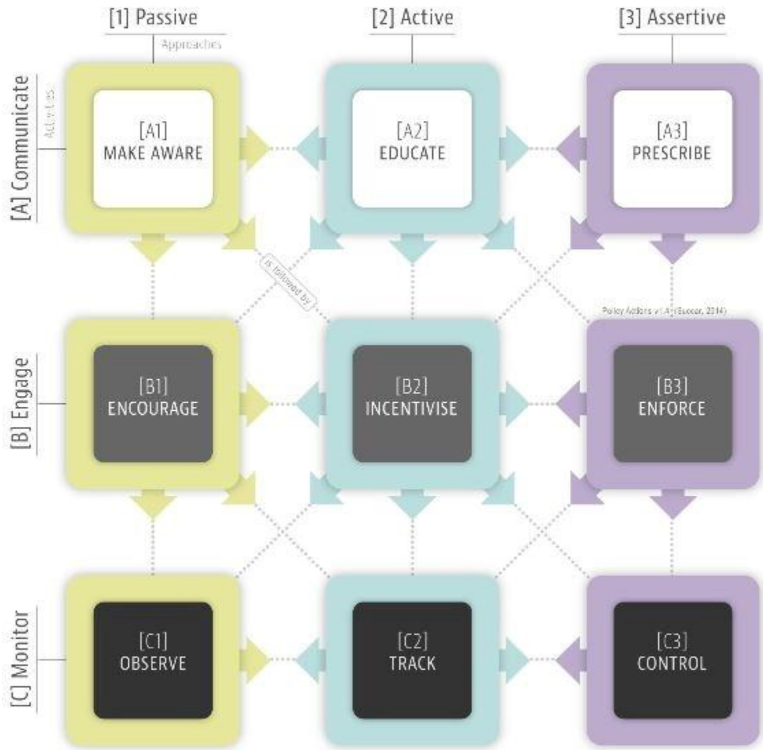
18.

Are there any regulations on BIM in Nigerian Construction Industry? * *Mark only one oval.*

- Yes
- No

19.

What do you think is the most effective policy approach to enforce BIM in Nigeria *



Mark only one oval per row.

	[1] Passive	[2] Active	[3] Assertive
[A] Communicate			
[B] Engage			
[C] Monitor			

20.

Rank the following players' contribution in facilitating diffusion of BIM within and across the industry in Nigeria (from 0 - no influence to 4 - high influence) *

POLICY FIELD	PROCESS FIELD	TECHNOLOGY FIELD
1 Authorities Governmental players undertaking an active role in mandating or encouraging the adoption of BIM tools and workflows *e.g. the BIM Task Group in the UK and BCA in Singapore*	**3 Construction organizations** Designers, contractors, owners, operators and other organizational players involved in deploying BIM tools and workflows, training their staff and delivering BIM-enabled outcomes	**5 Software developers** The large software houses responsible for developing and maintaining BIM software tools, network solutions and middleware *e.g. Autodesk, Nemetschek and Trimble*
2 Educational institutions The universities and not-for-profit technical institutions developing and delivering learning programs and materials	**4 Individuals** The individual practitioner, researcher, lecturer and student involved in learning, or actively implementing BIM tools and workflows	**6 Value-adding resellers** The companies bridging and maintaining the relationship between software/network solution developers and end users

POLICY-PROCESS OVERLAP	PROCESS-TECHNOLOGY OVERLAP	POLICY-TECHNOLOGY OVERLAP
7 Industry associations Associations dedicated to representing the interests of their individual and organizational members *e.g. AMCA in Australia*	**8 Communities of practice** The informal grouping of individuals with a shared interest in improving their own BIM performance *e.g. Revit user groups*	**9 Technology advocates** The associations involved in developing and promoting technology-centric solutions for industry challenges *e.g. buildingSMART*

Mark only one oval per row.

	0	1	2	3	4
Policy makers					
Educational institutions					
Construction organisations					
Individual practitioners					
Technology developers					
Technology service providers					
Professional associations					
Communities of practice					
Technology advocates					

9.10 APPENDIX – 10: CONSENT LETTER FOR INTERVIEW (INVESTIGATIVE STUDY)

ROBERT GORDON UNIVERSITY•ABERDEEN

20th December 2018

……………………………………………………………………………………………… …………………………

Dear Sir/Madam,

I am a research scholar based in Robert Gordon University, Aberdeen, United Kingdom. My research interest and specialty are **Building Information Modelling (BIM)/Innovation in Construction**. I am particularly interested in a strategy to the adoption of BIM in Architecture Engineering and Construction (AEC) Industry. Below is my appeal to your participation in the forthcoming interview proposed early 2019 in relation to the development of a framework for a strategic adoption of BIM in the Nigerian construction industry.

I sincerely appreciate your response to my *questionnaire survey* that aimed at studying the ***macro-BIM adoption*** in Nigeria as part of the process to pursuing my Ph.D. journey. Going through the survey responses, I realized your abilities in working with BIM concept or perhaps used BIM at one time. Thus, you fall within my interest group to further my investigation aimed at developing a *framework* or *roadmap* for a strategic adoption of BIM in the Nigerian AEC. The further study involves a *semi-structured interview* to expand on the previous questionnaire survey. I am therefore appealing for a little out of your time for the interview possibly at the end of January (between January 21st and February 8th 2019) if possible. The questions will be sent to you ahead of the interview time for approval. Information collected from the interview will be exclusively used for the purposes of my PhD work and I will maintain high levels of anonymity unless you advised for a disclosure and comply fully with the General Data Protection Regulations and the University code of ethics.

I would be glad to be contacted any time regarding the interview or procedures via the following: call +447774857145, WhatsApp +2348037667944 or email to 1011851@rgu.ac.uk . Many thanks for your time and assistance.

Yours sincerely,

Mansur Hamma-adama

Mansur Hamma-adama *B.Eng., MSc, PGCert.*
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9.11 APPENDIX – 11: GUIDE FOR SEMI-STRUCTURED INTERVIEW (INVESTIGATIVE STUDY)

ROBERT GORDON UNIVERSITY•ABERDEEN

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Date: 17th January 2019

BIM ADOPTION IN NIGERIA: INTERVIEW QUESTIONS

1) What is your background and role in the construction industry?
2) How and where did you know about Building Information Modelling (BIM)?
3) Based on your experience, can you describe what BIM is?
4) What BIM tools or systems have you used or have seen being used by colleagues/clients, etc.?
5) What is the best definition of BIM to your understanding?
6) How many years of experience do you have in the industry?
7) Considering your personal professional experience, what type of projects are you involved with the majority of the time?
8) Considering your personal professional experience, in which sector of construction are most of your projects?
9) What is your level of BIM utilization as an individual and as an organization?
10) What proportion of your projects benefited from the use of BIM and to what level?
11) How successful are these projects?
12) What are the potential benefits of using BIM concept and what did you benefitted so far?
13) What motivated you or your organization to adopt the BIM on your projects?
14) What do you think are the barriers against wide adoption of BIM in the Nigerian construction industry?
15) What challenges did you face before, during and after adopting BIM?
16) How did you manage these challenges?
17) What additional services have you been able to offer to clients as a result of using BIM?
18) What is your experience with BIM as a new concept?

19) Is there any guide, protocol and standard to adopt BIM in Nigeria?

20) Do you think a national guide (protocol / standard) is needed to adopt BIM? Or adopting other countries' guide will be appropriate?

21) What form of contract do you generally use?

22) Does the form of contract use adequate enough to deliver project where BIM is adopted?

23) What do you think if government plan to come up with policy on digitalisation in the AEC processes?

24) In the Nigerian government decides to mandate BIM as a standard way of working, how long (in years) do you think is realistically okay to prepare the industry for BIM implementation?

25) Any additional feedback on how this study can affect future direction of the Nigerian construction industry?

26) If Nigeria would develop alliances with other international BIM promotional teams, who have developed guidance and support resources that could well be appropriate for Nigerian AEC. Would you support such strategy?

27) Do you get BIM-trained personnel for employment or you get them specially trained?

28) What BIM tools do you use?

29) Are these tools available and affordable?

30) Is the technology infrastructure adequate to support BIM concept?

31) How would you think of government support on adopting BIM in terms of software, technology and infrastructure?

32) When building a model (at design stage) using BIM tools, do you have any challenge as to availability of objects or any building fabric within objects library as for Nigerian buildings?

33) Do you use/update from online objects library or you are limited to those available in the software? Any other limitation?

34) Do you have sufficient BIM-trained staff?

35) If BIM was used, please describe what method/ processes you used to specify roles/ responsibilities, requirements and deliverables?

36) How ready your firm is to fully adopt BIM? And how ready do you think the industry and the government are to adopting BIM as well?

37) What was your level of participation (ROLE) in your last project where BIM was utilised?

38) To manage BIM in Nigerian AEC, how do you think this process should be effectively managed?

39) Who do you think could play a better role in managing the BIM amongst the AEC stakeholders?

40) Who do you think could possibly take the responsibility of leading the BIM implementation?

41) Where do you see yourself in the future in terms of BIM adoption/ implementation?

42) What is your time frame to fully adopt BIM in your process?

43) Who takes responsibility (cost) of using BIM on your projects?

44) Who do you think should bear the cost of BIM process?

45) Do you have any comment that can help in setting out BIM adoption in Nigeria?

Yours sincerely,
Mansur Hamma-adama
Mansur Hamma-adama *B.Eng., MSc, PGCert.*
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9.12 APPENDIX – 12: REVISED QUESTIONS FOR THE INTERVIEWS (INVESTIGATIVE STUDY)

ROBERT GORDON UNIVERSITY • ABERDEEN

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BIM ADOPTION IN NIGERIA: INTERVIEW QUESTIONS

1) What is your background and role in the construction industry?

2) How and where did you know about Building Information Modelling (BIM)?

3) Based on your experience, can you describe what BIM is?

4) What BIM tools or systems have you used or have seen being used by colleagues/clients, etc.?

5) How many years of experience do you have in the industry?

6) Considering your personal professional experience, what type of projects are you involved with the majority of the time?

7) What is your level of BIM utilisation as an individual and as an organisation?

8) What proportion of your projects benefited from the use of BIM and to what level?

9) How successful are these projects?

10) What are the potential benefits of using BIM concept and what did you benefitted so far?

11) What motivated you or your organisation to adopt the BIM on your projects?

12) What do you think are the barriers against wide adoption of BIM in the Nigerian construction industry?

13) What challenges did you face before, during and after adopting BIM?

14) How did you manage these challenges?

15) What additional services have you been able to offer to clients because of using BIM?

16) What is your experience with BIM as a new concept?

17) Is there any guide, protocol and standard to adopt BIM in Nigeria? Do you think a national guide (protocol / standard) is needed to adopt BIM? Or adopting other countries' guide will be appropriate?

18) What form of contract do you generally use? Does the form of contract use adequate to deliver project where BIM is adopted?

19) What do you think if government plan to come up with policy on digitalisation in the AEC processes?

20) In the Nigerian government decides to mandate BIM as a standard way of working, how long (in years) do you think is realistically okay to prepare the industry for BIM implementation?

21) Any additional feedback on how this study can affect future direction of the Nigerian construction industry?

22) If Nigeria would develop alliances with other international BIM promotional teams, who have developed guidance and support resources that could well be appropriate for Nigerian AEC. Would you support such strategy?

23) Do you get BIM-trained personnel for employment or you get them specially trained?

24) Are the BIM tools available and affordable?

25) Is the technology infrastructure adequate to support BIM concept?

26) How would you think of government support on adopting BIM in terms of software, technology and infrastructure?

27) When building a model (at design stage) using BIM tools, do you have any challenge as to availability of objects or any building fabric within objects library as for Nigerian buildings?

28) What was your level of participation (ROLE), please describe what method/ processes you used to specify roles/ responsibilities, requirements and deliverables?

29) How ready your firm is to fully adopt BIM? And how ready do you think the industry and the government are to adopting BIM as well?

30) To manage BIM in Nigerian AEC, how do you think this process should be effectively managed?

31) Who do you think could play a better role in managing the BIM amongst the AEC stakeholders?

32) Who do you think could possibly take the responsibility of leading the BIM implementation?

33) Where do you see yourself in the future in terms of BIM adoption/ implementation?

34) What is your time frame to fully adopt BIM in your process?

35) Who takes responsibility (cost) of using BIM on your projects? Who do you think should bear the cost of BIM process?

36) Do you have any comment that can help in setting out BIM adoption in Nigeria?

Yours sincerely,
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9.13 APPENDIX – 13: MAIN INVESTIGATIVE STUDY DATA

9.13.1 DATA FROM MAIN QUESTIONNAIRE SURVEY

9.13.2 Demography of the Survey Respondents

The respondents' demography is shown in *Table 9.1*. Location of practice, years of practice, firm size, profession and speciality are information considered and are deemed necessary to defining the survey respondents.

Table 9.1: Demography of the Respondents (field survey, 2018.)

Variable	Characteristics	Freq.	Percentage (%)	Total
Location of practice	North-Central	18	48.6	
	North-East	2	5.4	
	North-West	8	21.6	
	South-East	2	5.4	
	South-South	3	8.1	
	South-West	4	10.8	37
Years practice	< 5 years	12	32.4	
	5 - 10 years	13	35.1	
	11 - 15 years	5	13.5	
	> 15 years	7	18.9	37
Number of employees	< 10 personnel (Micro)	21	56.8	
	10 - 50 personnel (Small)	12	32.4	
	50 - 200 personnel (Medium)	3	8.1	
	> 200 personnel (Large)	1	2.7	37
Profession	Architecture	14	37.8	
	Building Engineering	1	2.7	
	Civil/Structural Engineering	14	37.8	

	Construction Management	0	0.0	
	Electrical Engineering	0	0.0	
	Mechanical Engineering	1	2.7	
	Quantity Surveying	6	16.2	
	Other	1	2.7	37
Specialization	Contractor/Construction	8	21.6	
	Designer or Consultant	27	73.0	
	Client	1	2.7	
	Development Authority	1	2.7	37
Level of BIM utilization	Modelling only - BIM stage 1	20	54.1	
	Limited to Collaboration - BIM stage 2	12	32.4	
	Up to Integration - BIM stage 3	5	13.5	37

9.13.3 Macro BIM Adoption Mined Data (Data in Brief)

Table 9.2: Data for Diffusion Area Model

Respondents	Modelling Technologies	Modelling processes	Modelling policies	Collaboration technologies	Collaboration processes	Collaboration policies	Integration technologies	Integration processes	Integration policies
Res. 1	3.0	1.0	2.0	2.0	2.0	2.0	1.0	2.0	1.0
Res. 2	3.0	2.0	1.0	0.0	0.0	0.0	1.0	1.0	0.0
Res. 3	4.0	2.0	1.0	2.0	2.0	1.0	1.0	1.0	1.0
Res. 4	3.0	2.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0
Res. 5	2.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Res. 6	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.0
Res. 7	2.0	1.0	1.0	1.0	0.0	0.0	1.0	1.0	1.0
Res. 8	3.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	0.0
Res. 9	4.0	2.0	1.0	2.0	2.0	1.0	2.0	2.0	1.0
Res. 10	2.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Res. 11	2.0	1.0	0.0	1.0	1.0	0.0	0.0	0.0	0.0
Res. 12	2.0	1.0	0.0	1.0	1.0	0.0	0.0	0.0	0.0
Res. 13	3.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	1.0
Res. 14	2.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0
Res. 15	4.0	2.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0
Res. 16	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Res. 17	3.0	1.0	1.0	2.0	1.0	1.0	2.0	1.0	1.0
Res. 18	2.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Res. 19	1.0	2.0	2.0	2.0	1.0	2.0	1.0	1.0	1.0
Res. 20	4.0	2.0	2.0	2.0	2.0	2.0	1.0	1.0	0.0
Res. 21	4.0	2.0	2.0	2.0	2.0	1.0	2.0	2.0	1.0
Res. 22	2.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.0
Res. 23	4.0	2.0	1.0	2.0	1.0	1.0	1.0	1.0	0.0
Res. 24	3.0	2.0	2.0	1.0	1.0	1.0	2.0	2.0	1.0
Res. 25	2.0	1.0	1.0	1.0	1.0	1.0	0.0	0.0	0.0
Res. 26	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Res. 27	2.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Res. 28	3.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	1.0
Res. 29	1.0	1.0	0.0	1.0	1.0	0.0	1.0	1.0	0.0
Res. 30	3.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	1.0
Res. 31	0.0	0.0	0.0	1.0	1.0	0.0	1.0	0.0	0.0
Res. 32	2.0	1.0	2.0	2.0	1.0	2.0	2.0	2.0	1.0
Res. 33	2.0	1.0	0.0	1.0	1.0	0.0	0.0	0.0	0.0
Res. 34	1.0	1.0	0.0	1.0	1.0	0.0	0.0	0.0	0.0
Res. 35	2.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Res. 36	3.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	1.0
Res. 37	3.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Mean	2.4	1.3	1.0	1.2	1.0	0.8	0.9	0.9	0.5
Remark	Medium-High	Medium	Medium - Low	Medium	Medium - Low	Medium - Low	Medium	Medium - Low	Low /Low - Medium
Diffusion Capabilities (%)	**59%**	**32%**	**25%**	**30%**	**26%**	**21%**	**24%**	**23%**	**11%**

Table 9.3: Data for Macro Maturity Components Model

Respondents	Objective, stage and milestones	Champions and Drivers	Regulatory Framework	Noteworthy Publications	Leaning & Education	Measurements & Benchmarks	Standardised parts & Deliverables	Technology Infrastructure
Respondent 1	3.0	2.0	0.0	1.0	4.0	3.0	2.0	3.0
Respondent 2	2.0	1.0	1.0	0.0	1.0	1.0	3.0	2.0
Respondent 3	1.0	3.0	0.0	0.0	0.0	1.0	0.0	0.0
Respondent 4	0.0	1.0	0.0	0.0	1.0	0.0	1.0	1.0
Respondent 5	1.0	2.0	0.0	0.0	3.0	1.0	1.0	3.0
Respondent 6	1.0	2.0	0.0	1.0	0.0	1.0	2.0	1.0
Respondent 7	2.0	1.0	1.0	0.0	1.0	1.0	0.0	1.0
Respondent 8	1.0	2.0	2.0	2.0	4.0	4.0	4.0	4.0
Respondent 9	2.0	0.0	0.0	0.0	2.0	1.0	2.0	1.0
Respondent 10	2.0	1.0	0.0	0.0	1.0	1.0	1.0	2.0
Respondent 11	1.0	3.0	0.0	0.0	1.0	1.0	1.0	1.0
Respondent 12	1.0	2.0	0.0	0.0	1.0	1.0	1.0	2.0
Respondent 13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Respondent 14	0.0	1.0	0.0	0.0	0.0	0.0	0.0	1.0
Respondent 15	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Respondent 16	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0
Respondent 17	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0
Respondent 18	2.0	2.0	0.0	1.0	1.0	1.0	1.0	1.0
Respondent 19	4.0	3.0	1.0	0.0	3.0	3.0	3.0	3.0
Respondent 20	4.0	4.0	2.0	2.0	4.0	4.0	1.0	1.0
Respondent 21	4.0	3.0	2.0	1.0	2.0	2.0	2.0	2.0
Respondent 22	3.0	2.0	0.0	0.0	2.0	0.0	0.0	0.0
Respondent 23	1.0	2.0	0.0	2.0	0.0	1.0	2.0	1.0
Respondent 24	2.0	2.0	1.0	1.0	2.0	2.0	2.0	2.0
Respondent 25	2.0	1.0	0.0	0.0	2.0	1.0	1.0	1.0
Respondent 26	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0
Respondent 27	2.0	3.0	2.0	2.0	3.0	3.0	2.0	3.0
Respondent 28	1.0	1.0	0.0	0.0	1.0	1.0	1.0	1.0
Respondent 29	2.0	1.0	0.0	0.0	1.0	1.0	0.0	1.0
Respondent 30	1.0	2.0	1.0	0.0	2.0	2.0	3.0	3.0
Respondent 31	2.0	1.0	0.0	0.0	1.0	1.0	0.0	1.0
Respondent 32	0.0	0.0	0.0	0.0	1.0	1.0	1.0	0.0
Respondent 33	1.0	2.0	0.0	0.0	1.0	0.0	0.0	0.0
Respondent 34	1.0	1.0	0.0	0.0	1.0	1.0	1.0	1.0
Respondent 35	2.0	1.0	1.0	0.0	1.0	2.0	2.0	1.0
Respondent 36	4.0	3.0	2.0	2.0	2.0	2.0	4.0	4.0
Respondent 37	0.0	1.0	0.0	0.0	1.0	1.0	1.0	1.0
Mean	1.5	1.6	0.4	0.4	1.4	1.2	1.2	1.3
Remark	Medium - Low / Medium	Medium - Low / Medium	Low	Low	Medium - Low	Medium - Low	Medium - Low	Medium - Low
Percentage	38%	41%	11%	10%	34%	30%	30%	33%

Table 9.4: Data for Macro Diffusion Dynamics

Respondents	Top-down	Middle-out	Bottom-up
Respondent 1			Bottom-up
Respondent 2		Middle-out	
Respondent 3		Middle-out	
Respondent 4			Bottom-up
Respondent 5		Middle-out	
Respondent 6		Middle-out	
Respondent 7		Middle-out	
Respondent 8		Middle-out	
Respondent 9		Middle-out	
Respondent 10	Top-down		
Respondent 11		Middle-out	
Respondent 12			Bottom-up
Respondent 13			Bottom-up
Respondent 14			Bottom-up
Respondent 15			Bottom-up
Respondent 16			Bottom-up
Respondent 17			Bottom-up
Respondent 18		Middle-out	
Respondent 19			Bottom-up
Respondent 20			Bottom-up
Respondent 21		Middle-out	
Respondent 22			Bottom-up
Respondent 23			Bottom-up
Respondent 24		Middle-out	
Respondent 25			Bottom-up
Respondent 26			Bottom-up
Respondent 27			Bottom-up
Respondent 28		Middle-out	
Respondent 29		Middle-out	
Respondent 30			Bottom-up
Respondent 31	Top-down		
Respondent 32		Middle-out	
Respondent 33			Bottom-up
Respondent 34			Bottom-up
Respondent 35	Top-down		
Respondent 36			Bottom-up
Respondent 37			Bottom-up
Frequency	3	14	20
Response (%)	8%	38%	54%

Table 9.5: Data for Policy Action Model

RESPONDENTS	COMMUNICATE Action	ENGAGE Action	MONITOR Action
Respondent 1	[1] Passive	[2] Active	[1] Passive
Respondent 2	[2] Active	[1] Passive	[1] Passive
Respondent 3	[2] Active	[2] Active	[1] Passive
Respondent 4	[2] Active	[1] Passive	[2] Active
Respondent 5	[2] Active	[1] Passive	[1] Passive
Respondent 6	[1] Passive	[2] Active	[1] Passive
Respondent 7	[1] Passive	[2] Active	[2] Active
Respondent 8	[3] Assertive	[3] Assertive	[1] Passive
Respondent 9	[1] Passive	[2] Active	[2] Active
Respondent 10	[1] Passive	[1] Passive	[1] Passive
Respondent 11	[3] Assertive	[2] Active	[3] Assertive
Respondent 12	[2] Active	[2] Active	[2] Active
Respondent 13	[2] Active	[3] Assertive	[3] Assertive
Respondent 14	[2] Active	[2] Active	[3] Assertive
Respondent 15	[2] Active	[2] Active	[2] Active
Respondent 16	[3] Assertive	[2] Active	[3] Assertive
Respondent 17	[2] Active	[3] Assertive	[2] Active
Respondent 18	[2] Active	[2] Active	[2] Active
Respondent 19	[2] Active	[3] Assertive	[3] Assertive
Respondent 20	[2] Active	[3] Assertive	[2] Active
Respondent 21	[2] Active	[1] Passive	[3] Assertive
Respondent 22	[2] Active	[2] Active	[2] Active
Respondent 23	[2] Active	[3] Assertive	[2] Active
Respondent 24	[2] Active	[2] Active	[2] Active
Respondent 25	[2] Active	[2] Active	[3] Assertive
Respondent 26	[2] Active	[1] Passive	[2] Active
Respondent 27	[1] Passive	[2] Active	[2] Active
Respondent 28	[2] Active	[3] Assertive	[2] Active
Respondent 29	[3] Assertive	[3] Assertive	[2] Active
Respondent 30	[2] Active	[2] Active	[2] Active
Respondent 31	[2] Active	[1] Passive	[1] Passive
Respondent 32	[3] Assertive	[3] Assertive	[2] Active
Respondent 33	[2] Active	[3] Assertive	[2] Active
Respondent 34	[3] Assertive	[3] Assertive	[1] Passive
Respondent 35	[2] Active	[3] Assertive	[1] Passive
Respondent 36	[2] Active	[3] Assertive	[3] Assertive
Respondent 37	[2] Active	[2] Active	[3] Assertive
Passive (frequencies)	Passive: Make Aware - 6	Passive: Encourage - 7	Passive: Observe - 10
Active (Frequencies)	Active: Educate - 25	Active: Incentivise - 17	Active: Track - 18
Assertive (Frequencies)	Assertive: Prescribe - 6	Assertive: Enforce - 13	Assertive: Control - 9

Table 9.6: Data for Macro Diffusion Responsibilities

Respondents	Policy Makers	Educational Institutions	Construction organisations	Technology developers	Technology Service Providers	Industry Associations	Communities of practice	Technology Advocates
Respondent 1	0.0	1.0	2.0	2.0	3.0	3.0	1.0	1.0
Respondent 2	0.0	2.0	1.0	0.0	0.0	0.0	0.0	0.0
Respondent 3	2.0	3.0	2.0	2.0	2.0	3.0	2.0	2.0
Respondent 4	0.0	1.0	0.0	0.0	2.0	1.0	0.0	1.0
Respondent 5	0.0	2.0	1.0	1.0	2.0	1.0	1.0	0.0
Respondent 6	2.0	3.0	1.0	0.0	0.0	2.0	1.0	0.0
Respondent 7	0.0	0.0	1.0	0.0	0.0	0.0	0.0	1.0
Respondent 8	1.0	0.0	1.0	1.0	1.0	0.0	0.0	0.0
Respondent 9	0.0	1.0	1.0	3.0	3.0	1.0	1.0	2.0
Respondent 10	2.0	3.0	1.0	2.0	1.0	2.0	1.0	2.0
Respondent 11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Respondent 12	2.0	3.0	3.0	3.0	2.0	2.0	1.0	2.0
Respondent 13	2.0	3.0	3.0	2.0	2.0	2.0	3.0	2.0
Respondent 14	3.0	3.0	1.0	3.0	1.0	2.0	3.0	3.0
Respondent 15	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Respondent 16	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Respondent 17	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Respondent 18	2.0	2.0	2.0	1.0	1.0	2.0	2.0	2.0
Respondent 19	3.0	3.0	2.0	2.0	3.0	3.0	3.0	2.0
Respondent 20	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Respondent 21	0.0	3.0	3.0	3.0	1.0	1.0	0.0	1.0
Respondent 22	0.0	0.0	0.0	0.0	0.0	1.0	1.0	0.0
Respondent 23	2.0	0.0	1.0	0.0	0.0	1.0	0.0	1.0
Respondent 24	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Respondent 25	3.0	3.0	3.0	2.0	3.0	3.0	2.0	3.0
Respondent 26	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Respondent 27	3.0	3.0	2.0	2.0	2.0	2.0	3.0	2.0
Respondent 28	1.0	1.0	2.0	0.0	1.0	1.0	0.0	1.0
Respondent 29	3.0	3.0	3.0	2.0	2.0	3.0	2.0	2.0
Respondent 30	2.0	3.0	3.0	3.0	2.0	3.0	2.0	2.0
Respondent 31	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Respondent 32	2.0	3.0	3.0	3.0	3.0	2.0	3.0	2.0
Respondent 33	1.0	1.0	1.0	1.0	0.0	1.0	0.0	0.0
Respondent 34	2.0	1.0	1.0	1.0	1.0	2.0	1.0	2.0
Respondent 35	0.0	1.0	0.0	0.0	1.0	0.0	0.0	1.0
Respondent 36	3.0	3.0	3.0	3.0	2.0	2.0	2.0	2.0
Respondent 37	3.0	3.0	3.0	1.0	1.0	3.0	1.0	1.0
Mean	1.4	1.8	1.5	1.4	1.3	1.5	1.2	1.3
Remark	Medium - Low	Medium High	Medium - Low / Medium	Medium - Low	Medium - Low	Medium - Low / Medium	Medium - Low	Medium - Low
Diffusion Capabilities (%)	**34%**	**44%**	**39%**	**34%**	**33%**	**38%**	**29%**	**32%**

9.13.4 Barriers and Drivers for BIM Adoption

The most significant drivers and barriers to BIM adoption in Nigeria were considered important to facilitating BIM adoption in the country; *Table 9.7* and *Table 9.8* present the data for ranking drivers and barriers to BIM adoption respectively.

Table 9.7: Data for Ranking Drivers to BIM Adoption in Nigeria

Respondents	Are you aware of Building Information Modelling (BIM)	Have you ever used BIM in any of your project?	Availability of trained professionals to handle the tools	BIM Software affordability	Enabling environment within the industry	Clients' interest in the use of BIM in their projects	Awareness of the technology among industry stakeholders	Cooperation and commitment of professional societies to its implementation	Proof of cost savings by its adoption	Cultural change among industry stakeholders	Government support through legislation	Collaborative Procurement methods
Resp. 1	Yes	Yes	4	4	2	3	3	1	5	4	1	4
Resp. 2	Yes	No	2	2	3	1	2	2	4	2	3	3
Resp. 3	Yes	Yes	5	3	5	3	3	3	3	2	3	3
Resp. 4	Yes	No	4	4	1	1	4	3	1	2	2	3
Resp. 5	Yes	No	5	5	5	5	4	3	5	3	3	3
Resp. 6	Yes	No	5	3	4	5	5	5	3	4	5	4
Resp. 7	Yes	Yes	5	2	3	4	2	1	4	3	1	3
Resp. 8	Yes	No	4	3	4	5	5	4	4	3	4	2
Resp. 9	Yes	No	4	3	3	5	4	3	3	4	4	3
Resp. 10	Yes	No	4	3	3	5	4	3	3	4	4	3
Resp. 11	Yes	No	2	5	4	2	2	2	5	2	2	1
Resp. 12	Yes	No	5	4	4	3	3	3	2	2	2	3
Resp. 13	Yes	No	4	3	3	2	2	3	2	4	3	4
Resp. 14	Yes	Yes	5	5	4	5	3	5	5	3	4	4
Resp. 15	Yes	No	3	4	2	2	1	2	2	1	1	1
Resp. 16	Yes	Yes	2	3	3	2	3	2	3	2	2	2
Resp. 17	Yes	Yes	3	1	2	1	2	1	1	2	1	1
Resp. 18	Yes	No	5	4	5	5	4	4	5	3	4	4
Resp. 19	Yes	No	3	2	2	1	4	5	3	1	1	1

Resp. 20	Yes	Yes	2	1	2	1	2	2	3	2	1	2
Resp. 21	Yes	Yes	5	4	5	3	4	5	5	3	5	3
Resp. 22	Yes	No	2	1	2	1	1	2	3	1	2	1
Resp. 23	Yes	No	5	5	5	3	4	5	4	4	5	5
Resp. 24	Yes	Yes	4	4	3	3	3	3	5	3	3	3
Resp. 25	Yes	No	5	5	5	4	5	5	3	2	3	4
Resp. 26	Yes	No	3	2	2	3	3	2	3	3	2	2
Resp. 27	Yes	No	5	5	4	5	4	5	4	3	5	4
Resp. 28	Yes	No	4	5	4	5	4	3	5	2	3	4
Resp. 29	Yes	Yes	4	3	2	3	3	3	1	4	4	3
Resp. 30	Yes	No	5	5	3	1	5	5	5	2	5	3
Resp. 31	Yes	No	4	4	4	4	4	4	4	4	4	4
Resp. 32	Yes	No	4	4	2	2	3	4	4	3	2	2
Resp. 33	Yes	Yes	1	1	1	1	1	1	3	5	1	1
Resp. 34	Yes	Yes	4	5	3	3	5	4	5	3	3	3
Resp. 35	Yes	No	4	4	3	4	3	4	4	3	5	4
Resp. 36	Yes	Yes	5	3	4	5	5	4	4	5	4	4
Resp. 37	Yes	No	5	5	5	5	3	4	3	2	4	5
Resp. 38	Yes	Yes	1	1	2	4	3	2	3	1	1	4
Resp. 39	Yes	Yes	4	4	4	5	5	5	4	4	5	5
Resp. 40	Yes	No	5	5	5	5	5	3	4	4	3	3
Resp. 41	Yes	Yes	5	4	5	5	5	5	5	5	5	5
Resp. 42	Yes	No	2	2	2	1	3	2	4	2	1	1
Resp. 43	Yes	Yes	3	2	3	3	4	4	3	4	3	3
Resp. 44	Yes	Yes	2	2	3	3	4	4	5	4	3	3
Resp. 45	Yes	Yes	5	4	4	3	3	3	4	4	4	4
Resp. 46	Yes	Yes	5	4	4	3	3	3	3	2	2	2
Resp. 47	Yes	Yes	5	5	5	5	5	5	4	4	5	5
Resp. 48	Yes	Yes	5	1	4	5	3	3	4	4	1	1
Resp. 49	Yes	Yes	5	5	4	5	3	4	4	3	5	4
Resp. 50	Yes	Yes	4	4	4	5	4	4	5	4	3	4

Resp. 51	Yes	No	5	5	3	4	5	3	5	3	3	3
Resp. 52	Yes	Yes	4	5	4	5	5	5	5	5	4	5
Resp. 53	Yes	Yes	1	1	1	1	2	1	3	1	1	1
Resp. 54	Yes	Yes	4	4	4	5	4	4	4	4	4	4
Resp. 55	Yes	Yes	5	3	4	4	4	4	4	4	4	4
Resp. 56	Yes	No	4	5	3	4	4	5	5	3	4	5
Resp. 57	Yes	No	3	4	4	4	4	4	3	4	2	3
Resp. 58	Yes	Yes	4	4	4	4	4	5	4	4	5	5
Resp. 59	Yes	Yes	5	4	5	5	5	4	5	4	5	4
Resp. 60	Yes	Yes	1	3	1	2	2	3	1	2	1	1
Resp. 61	Yes	No	3	3	2	4	4	2	2	2	2	2
Resp. 62	Yes	Yes	5	4	4	5	5	4	3	3	3	4
Resp. 63	Yes	Yes	3	2	3	3	2	2	2	1	2	2
Resp. 64	Yes	Yes	4	4	4	4	3	4	4	3	4	4
Resp. 65	Yes	Yes	2	2	3	1	2	2	4	3	1	1
Resp. 66	Yes	No	1	1	2	1	2	2	2	1	1	1
Resp. 67	Yes	Yes	5	5	5	3	3	5	4	4	5	5
Resp. 68	Yes	Yes	4	5	4	5	4	5	3	4	4	4

Table 9.8: Data for Ranking Barriers to BIM Adoption in Nigeria

Resp.	Lack of expertise within the organisations	Lack of expertise within the project team	Lack of standardisation and protocols	Lack of collaboration among stakeholders	High Investment Cost	Legal issues around ownership, IP & PI insurance	Lack of client demand	Lack of infrastructure	Lack of government policy	Industry's Cultural resistance	Lack of additional project finance to support BIM	Resistance at operational level	Reluctance of team members to share information	Return on Investment (ROI) issue
Resp. 1	4	3	1	3	1	1	2	1	4	2	3	3	4	3
Resp. 2	2	3	2	3	2	3	3	3	2	2	3	3	2	3
Resp. 3	1	1	1	2	3	1	1	1	1	1	1	2	1	3
Resp. 4	3	3	3	4	2	3	3	2	3	3	3	4	4	3
Resp. 5	5	5	3	2	5	2	5	4	3	3	5	3	4	5
Resp. 6	5	4	4	4	3	4	4	2	4	3	4	3	3	3
Resp. 7	3	3	5	4	5	5	4	4	5	5	4	4	4	3
Resp. 8	3	3	3	4	4	4	5	4	5	3	3	2	4	1
Resp. 9	4	5	4	4	3	3	5	3	4	3	3	1	3	2
Resp. 10	4	5	4	4	3	3	5	3	4	3	3	1	3	2
Resp. 11	5	5	3	4	5	1	5	5	5	1	5	5	5	5
Resp. 12	5	4	4	4	3	5	5	5	5	4	4	3	5	3
Resp. 13	4	3	3	3	2	3	2	4	3	3	3	2	3	3
Resp. 14	5	4	4	4	5	3	5	3	3	3	5	3	4	2
Resp. 15	3	3	3	2	3	2	1	1	2	2	1	2	2	2
Resp. 16	4	4	2	2	2	2	5	4	1	2	4	3	4	3
Resp. 17	3	1	1	2	1	1	1	1	2	3	2	2	1	1
Resp. 18	4	4	4	3	3	3	3	3	4	4	3	3	4	3
Resp. 19	4	4	2	1	1	1	1	1	1	1	3	1	2	1
Resp. 20	1	2	3	2	2	2	3	3	3	2	3	2	2	1
Resp. 21	5	5	5	3	2	2	2	5	5	3	5	5	5	4
Resp. 22	4	2	3	2	1	2	3	3	2	2	2	2	2	2
Resp. 23	5	5	4	4	5	5	3	4	4	5	5	1	5	4
Resp. 24	3	3	5	5	3	3	4	3	3	3	3	3	5	3
Resp. 25	4	4	2	3	2	2	1	1	1	2	3	3	3	3

Resp. 26	4	4	3	4	3	3	4	4	4	2	3	3	3	2
Resp. 27	5	5	5	5	4	4	5	5	5	4	4	4	4	4
Resp. 28	5	5	4	4	3	2	2	1	2	3	2	2	3	3
Resp. 29	5	4	3	2	4	2	4	3	4	4	3	3	3	2
Resp. 30	5	5	3	1	3	3	1	5	5	5	3	4	5	3
Resp. 31	4	4	3	3	4	2	3	2	4	3	2	2	3	3
Resp. 32	4	3	4	4	4	4	4	4	4	4	4	4	4	4
Resp. 33	5	5	5	5	3	1	5	5	5	5	5	4	4	4
Resp. 34	3	4	4	4	5	5	2	4	3	4	5	3	3	2
Resp. 35	4	4	4	4	5	3	4	3	4	4	3	3	4	4
Resp. 36	5	5	3	3	4	2	3	2	4	4	3	3	3	4
Resp. 37	5	5	5	5	5	5	5	5	5	5	5	2	4	5
Resp. 38	5	5	5	3	2	1	3	4	1	5	1	1	1	2
Resp. 39	1	1	5	5	5	5	5	5	5	5	5	5	4	5
Resp. 40	4	4	5	5	5	3	3	5	4	4	4	3	4	2
Resp. 41	5	5	5	5	4	5	4	4	5	5	4	5	5	5
Resp. 42	2	1	1	1	2	2	2	2	1	2	2	2	2	3
Resp. 43	4	4	5	4	3	3	4	4	4	5	2	4	4	2
Resp. 44	4	4	4	4	5	3	4	4	5	3	4	5	3	5
Resp. 45	5	4	4	3	4	3	1	1	1	4	4	4	3	1
Resp. 46	5	3	5	3	5	3	2	2	2	2	5	3	3	3
Resp. 47	5	2	3	3	5	5	4	5	5	4	5	4	4	5
Resp. 48	3	3	3	3	5	5	5	5	5	4	5	3	5	5
Resp. 49	4	4	3	2	5	2	4	3	4	4	2	3	4	3
Resp. 50	4	4	4	3	3	3	5	4	3	3	5	3	3	4
Resp. 51	5	5	4	3	3	3	4	3	3	3	3	3	4	3
Resp. 52	2	5	4	5	3	5	5	4	2	4	4	5	4	3
Resp. 53	1	1	1	1	1	1	2	1	1	2	1	2	1	1
Resp. 54	4	5	5	5	3	4	4	4	4	4	3	3	3	3
Resp. 55	4	4	4	4	2	2	3	3	4	4	3	3	4	3
Resp. 56	3	4	3	4	5	4	3	4	4	4	5	4	4	4

Resp. 57	4	4	3	4	3	3	4	4	2	3	4	3	3	4
Resp. 58	3	3	5	5	3	3	5	4	5	4	4	3	3	3
Resp. 59	5	4	5	3	4	3	5	4	4	4	5	4	4	4
Resp. 60	1	2	3	1	1	2	2	1	1	3	1	1	2	1
Resp. 61	3	3	3	3	2	2	3	2	2	1	1	1	1	2
Resp. 62	3	3	4	2	3	2	2	2	2	3	4	3	2	3
Resp. 63	3	2	3	2	1	1	2	1	2	1	1	1	2	2
Resp. 64	4	4	4	4	2	4	3	4	4	3	3	4	4	3
Resp. 65	2	1	1	2	2	2	1	1	2	2	2	3	2	2
Resp. 66	2	2	1	1	1	1	1	1	1	2	1	1	2	1
Resp. 67	5	5	5	5	4	4	5	5	5	4	4	4	4	4
Resp. 68	4	2	5	4	4	4	5	3	5	5	4	4	3	2

9.13.5 DATA FROM THE MAIN INTERVIEWS (INVESTIGATIVE STUDY)

9.13.6 Understanding of BIM in Nigeria

ENG./CONS/01

…is a digitalized process that will enhance productivities of all construction professionals

ARC/CONS/02

…is a process that utilizes model as an information generation process whereby when you are designing, you are creating data and information and that information is then utilized for better project planning and management and even the facility management, after the project has been delivered

ENG./CONS/03

…is a modelling system that allows 3D model-based system that allows every professional within the industry to work on the same model

QS/CONS-CONT./04

…is a process that enable a collaborative Real-Time interaction between construction professionals on a project.

…is a process that enable an efficient communication, a Real-Time communication between construction project stakeholders.

ARC/CONS/05

…is the process, definitely that includes the way to generate information, process of generating information for the entire building structure throughout Project Life Cycle from inception to demolition and even beyond

…integrate everyone into one, one full house rather than making everyone stay in silos

…is a process to enhance the building industry

ARC/CONS/06

…is a process of developing information for building construction model not just having a model; the model is there but the attribute information been added to the model. The parameter information that are used to control the elements of the model determine what is what and their relationship between each other, and what can be changed when they can be changed, that's what makes it BIM

…is the process of giving usable construction information within model.

QS/CONS/07

…is a process that involve help during the construction, there at pre-contract and in the construction phase and allow join your information with any in the industry.

Is just a representation of all the characteristics of building in digital form for easy visualisation and coordination of building of drawing in 3D format.

BUILD/CONS/08

…it has to be a comprehensive digital model that possesses answers to every construction information.

…is a model that is repository of construction information, that every construction professional can come in there and tap from it through what I called BIM manager.

BIM is digital model of a building that contains all the information you need about that particular building so that at every point in time you can go in there, go into the model and pull out the information you need.

BUILD/CONS-CONT./09

…is like innovation in construction industry, a platform to anchor all the software… to bring all the idea in one place.

…is the menus of innovative in the construction industry from the decade of a traditional process which BIM is willing to unleash the potentials in the construction industry.

ARC/CONS/10

…is an innovative process in the construction project delivery whereby intelligent 3D based models are used to generate information that aid in the design construction and operation of buildings.

…the Information Management process that aids in the design, construction and operation of Buildings and facilities.

ARC/CONS/11

…is ICT design and construction coordination that is enabled by the ICT advancement.

…a process that is been enabled by IT to coordinate, communicate and collaborate information within the construction stakeholders.

…is 3D enable process that brings about effective and efficient communication between stakeholders in the construction industry.

9.13.7 BIM Awareness in Nigeria

ENG./CONS/01

I think with time and with the right information and awareness, in no time I think, I believe the Nigerians and the Nigerian construction industry will tend to start using BIM.

ARC/CONS/02

I think more efforts should actually go into awareness to people that are involved in the industry, the bottom-up awareness.

QS/CONS-CONT./04

…the solutions to BIM challenges in Nigeria and all over Africa is education. A lot of people need to be aware, there is large misconception of ideas. If you are approached average Nigerian construction professional and ask him what BIM is, they see it as a tool, as a software, and one item. So education, research, advocacy and a lot of others will go a long way to ensuring that we have actually become BIM compliant.

ARC/CONS/05

Lets people be aware of the BIM, awareness is everything, I can't do what I have not heard of. …my suggestion is preach, preach and preach; because for everything we do as long as people are not aware, where are all those working in vain; we have to let people know that this is what is out there right now. If we were able to enlightened people the more on benefits of this process, I believe the adoption will skyrocket.

QS/CONS/07

…so with the little seminars we have done, more people are coming up.

BUILD/CONS-CONT./09

…through professional networking. …the awareness should be more so that the government can look at it.

ARC/CONS/11

Yeah in the first place as I said persuasion and were able to as I said earlier we are able to show a lot of examples of projects that have used BIM and really got to do well I've said it already.

9.13.8 Readiness to Adopting BIM

ENG./CONS/01

Our company is ready to adopt BIM at any time, we are ready for it. The problem now is the country, for the country to adopt it is the challenge.

ARC/CONS/02

I will say we are quite BIM ready but the industry at large is not so BIM ready because they are still that level of ignorance pertaining BIM in Nigeria.

ENG./CONS/03

In all fairness, I don’t believe that the industry is ready to adopt BIM.

I don’t believe that government in terms of policy is anyway near adopting it.

Even for us, I think we fell on BIM because we bought the CD and I have heard of BIM. So, because we bought the AEC package and that has all of that system available within it. So in all fairness we didn't go out looking for BIM, it fell into our lap.

QS/CONS-CONT./04

…my firm is about 60% ready, I cannot give a higher number because a lot of the other workforce in our firm are not yet BIM compliant, so my firm as a firm is to some extent ready. But, the government and the industry are quite behind as regards to preparation for BIM adoption.

ARC/CONS/05

I will speak for my firm, we are ready, of course we are ready. The industry well, they still need more enlightenment.

So the industry is still… everyone is still at infant stage.

ARC/CONS/06

Infrastructure wise, machinery wise I am not ready. Knowledge wise, the industry is coming up, infrastructure and technology wise the industry still have a lot of challenges.

QS/CONS/07

my company is at 70% ready, but in government and the construction industry, they are those that don't seem changed, because they are afraid of adopting it and then let me say change.

BUILD/CONS/08

…for our firm, we are ready.

…the problem I see with the government is that most of the people at the decision-making, managerial level they don't know anything about it and they believe in the conventional method.

Yeah for the industry they are ready; there is competition everywhere you know.

BUILD/CONS-CONT./09

Well the industry for now, we are ready because we have a lot of challenges in Nigeria in project system you understand; and since the concept of BIM is ease out the project management, definitely we are ready to have the BIM adoption. The government parse is just… they are not fully incorporated to BIM

ARC/CONS/10

Currently, my firm still operates in 2D non-collaborative process. However, as a small firm with individuals who are open to new ideas, it may not take long to transition to 3D BIM once everyone sees the benefits.

The industry and government may not be ready to adopt BIM due to the bottleneck of bureaucracy.

ARC/CONS/11

We are already into BIM

…the government so far… we have been seeing them… obviously because they are still not even aware.

…there is issue of readiness as start to be, but we are really building a pride that we are the first that bring about BIM based public project. Because when we went to BPP (Bureau of Public Procurement), they have to admit that we are the first really coming with this as issue.

9.13.8.1 BIM Tools Available and those in-use

ENG./CONS/01

…the architects now, they use Revit Architecture. I have to use Revit structure with BIM compliance structural analysis software… …Civi3D is one of the BIM tools that we use vastly… …we have Tekla structural design that's for structural part… …we have InfraWorks. ENG./CONS/01

ARC/CONS/02

I use Revit Architecture. Of course, I have seen people that use MEP, Revit Structure, Navisworks, Management and BIM 360 for data management like common data environment during design. In Nigeria, it is mostly Autodesk tools like I mentioned. ARC/CONS/02

ENG./CONS/03

Autodesk package AEC package so we have them, I think there is BIM modelling system wouldn't… …that AEC package. ENG./CONS/03

QS/CONS-CONT./04

…major BIM too that I am use to is Autodesk Navisworks. …seen Autodesk Revit been used, I have seen BlueBIM been used, I have seen Synchro, I have seen Vico. QS/CONS-CONT./04

ARC/CONS/05

Revit by Autodesk, we have used… currently just on a very light note we use BIM360 just for testing… …and some other things not really adopted that fully. …and then Navisworks. ARC/CONS/05

ARC/CONS/06

I use Revit… …used ArchiCAD. ARC/CONS/06

QS/CONS/07

Revit, Navisworks and blueBIM. QS/CONS/07

BUILD/CONS/08

I could use ArchiCAD… Revit Architecture, Robot Structure, or Revit MEP, we also have ECOTech. BUILD/CONS/08

BUILD/CONS-CONT./09

Tekla, PlaGrid and Autodesk Revit. BUILD/CONS-CONT./09

ARC/CONS/10

ArchiCAD and Revit Architecture. ARC/CONS/10

ARC/CONS/11

Revit architecture, Revit structure, Dynamo and many more in the Autodesk and Solibri tools. ARC/CONS/11

9.13.8.2 Level of BIM Usage (Implementation)

ENG./CONS/01

… in designs, we use BIM tools 80% of it. Modelling and visualisations in most cases, that's all. Because the integration part of it, we don't have people that are ready to integrate with it.

I witnessed is less than 30% usage in construction.

…especially BIM we use in design process in most cases and the roles were itemised by corporal document to state the rule of any working thing on it, not in construction.

ARC/CONS/02

…the collaboration is still low. …most of the projects are modelled but the true benefits of BIM like collaboration and all that is still very low.

ENG./CONS/03

…is the first time we as organisation want to use BIM, because we are driving the design. Zero (implementation). Because we only got one project (currently on); okay fine, I do some management of that but technical management of that is my head of engineering that does that.

QS/CONS-CONT./04

we have not really had much of our projects to test run it with it, but I can boldly talk of one and that's we implemented BIM on one project and to, the level of BIM was 5D we were able achieve at least some sort of collaborations up to the 5th dimension of BIM.

ARC/CONS/05

…we have been trying to move most of our project from CAD base to BIM base although it is still on or base on level 1.

ARC/CONS/06

I have done 2D, 3D models for almost all the projects I have done.

…that would be like less than 10%.

QS/CONS/07

…about 40% that is the proportion.

BUILD/CONS/08

… in a scale of 5 maybe $\frac{2}{5}$.

BUILD/CONS-CONT./09

…on the area of lecturing and mentoring people on BIM, I can tell you excellent, I have really dealt with. To a project level, no, no, no. … It has never gone to the site.

ARC/CONS/10

At organisational level it's already 0. …but if it's from an individual a lot of my personal projects. I operate as individual so actually there's no collaborative working for now. My level of participation is in design.

…few personal projects executed BIM has been applied in a certain extent.

…for the construction phase was actually Information Management were strictly paper based.

ARC/CONS/11

I can say 100% of our projects are so far using BIM.

9.13.8.3 Availability of BIM-trained personnel

ENG./CONS/01

…these are the two major challenges; from the client and from a skill acquisition for the staff of company that want to adopt BIM.

No, we don't have (trained personnel), you have to train them; they need to be trained.

ENG./CONS/03

…we are training them by ourselves because we are taking time to understand the system and then train ourselves.

QS/CONS-CONT./04

Presently in the country, we have very few people that we regard as BIM trained personnel.

ARC/CONS/05

You have to train your own staff, yes, most times it is actually even individuals that actually train themselves and then come out for the employment.

QS/CONS/07

…we don't get BIM trained personnel, no! But I get people trained on BIM.

BUILD/CONS/08

We train them; we train them in our organisation …

BUILD/CONS-CONT./09

No (BIM trained personnel). In Nigeria for now, no!

ARC/CONS/10

Is an insignificant number they (BIM trained personnel) are not readily available.

9.13.8.4 Availability of Technology Infrastructure to Support BIM

ENG./CONS/01

Is not adequate (technology infrastructure), no! We don't have, is not adequate.

ARC/CONS/02

…the second barrier is also the cost of the tools and the infrastructure required. So, things like data infrastructure in Nigeria is still very expensive. People are still buying data in bandwidth and all that – yes internet; so is quite discouraging, if everything is based on cloud and internet is expensive it will increase and that infrastructure alone is a lot of barrier to implementing digital construction.

QS/CONS-CONT./04

…is the lack of infrastructure and when I mean infrastructure meaning we are referring to the internet system, …we don't have the basic infrastructure needed and that is not only in the construction industry is across board. A lot of the industries are having issues with technology because there's no basic infrastructure to support technology across board.

ARC/CONS/05

I still feel we need more infrastructure development for us to this to support BIM.

ARC/CONS/06

…it brings actually a challenge when it comes to talking about the technology infrastructure for BIM; so, the power infrastructure is a huge challenge, the communication infrastructure is still a work in progress.

9.13.9 Motivators and Drivers Toward BIM Adoption in Nigeria

ENG./CONS/01

Yes, because of the benefits, that we have seen that it will give us, relating it to what normal way of doing things

ARC/CONS/02

…is mostly information, there a lot of information you can't get from CAD that you are able to get from BIM and such things are able to help you plan your project like 4 D and cost your project from the same data and model of course these are benefits that someone wants to adopt BIM.

ENG./CONS/03

As an engineering firm, you can't remain stagnant and in looking at where the world is moving in terms of technology and Innovation when we fell on these, we actually believe and agree with it

…in my 30 years of working I have seen sometimes interface is the bigger problem than design problem so if this assist in eliminating a lot of interface issues

QS/CONS-CONT./04

What motivated us was the success stories. We heard from a lot of countries not our country we were able to study the success story of about 2 projects in the UK and then we sat down and evaluate that this could definitely be the something that would help our local construction too and

ARC/CONS/05

that tendency to always do better than your peers you always want to know what is the next big thing ahead

…for us to be able to get better building, cost-effective buildings and on time part of that is part of the things that motivated we seeking toward adopting BIM.

ARC/CONS/06

I will just say basically is the ease of… you know when you have something that empowers you to coup with your problems you definitely go for the fact that it empowers you

…faster, better and much more efficiently, so BIM allows me to coup much more efficiently with these problems

…efficiency of having BIM do most of the work that would take a lot of manual effort to do that; just that is enough reason

QS/CONS/07

I know BIM is the future, as in that is what the future is talking about, so we should actually adopt it so that one should remain in the construction industry.

BUILD/CONS-CONT./09

I always like to be on the edge of the technology

CIOB has really showcased this to us and made us to believe in it and when practicing it, I hook up to it that this is the right direction.

ARC/CONS/10

I personally... I'm the kind of person that I'm always open to innovation, I'm always open to applying new approaches to doing things in life.

I could actually use this not just generate 3D models for visualisation, but actually aids in the 2D documentation of my drawings;

ARC/CONS/11

…most of the market we penetrate today is using the BIM

…competitive advantage here in Nigeria

…is international best practice; it has proved itself. It's efficacy is been proven by a lot of countries and there a lot of successes, it was recorded. And, here in Nigeria the influence of ICT, the efficacy of ICT is not in question and already ICT is going to loot the whole most of the sector and our client are really happy to see something that could save them cost and bring about efficiency.

We do the training because we are already BIM trainers as an organisation, so we are really in to training BIM and at the same time procure or get BIM trained personnel as well as trained as much as we can in-house.

9.13.10 BIM Adoption Benefits

ENG./CONS/01

…we have solved a lot of issues on-site, a lot of wrongs designs which is very versatile for us.

…the workflow is more better than the previous method that we are using, I think that is one of the major of benefits that I am using BIM as I have seen

ARC/CONS/02

…they can be better managed and time constraints can be much more efficient if BIM was to truly leverage on them which of course is what we are still encouraging our client to.

If digitalization of the workflow, it will be easier for you to manage and analyse the project to make better decisions for the future projects.

ENG./CONS/03

…we found it very interesting, we found it really useful on our own singular project that we are doing. But whether it's going to help us to gain clients is something that we would find in the future.

we all understand the system of saving into the cloud and been able to from one office to be able to speak to one another.

QS/CONS-CONT./04

BIM just helps to improve and enhance our communication

…real time communication clients they really really appreciate that, for them to be able to understand the stage at which the constraints at that point requirements and everything real time.

…reducing rework, reducing loss of money on damages and clash detection those were the services BIM gives us opportunity to offer to our clients.

ARC/CONS/05

…things BIM has allowed us to offer them is realistic renders of their projects at the moment.

ARC/CONS/06

Scheduling is just the greatest advantage. Scheduling, scheduling, scheduling is the greatest advantage.

…that big data that would be available in that digital environment useful for a lot of physical planning, infrastructural development and even emergency intervention exercises. Because you look at a situation, where that digital model is available let say for a whole city; is available to the fire services, is available to the police and is available to emergency rescue workers in a particular situation it would be like over the age of an age an advantage.

QS/CONS/07

…a good visualisation of project before the construction commenced.

I find it interesting it helps me a lot, it helps me like easy to communication and easy flow and understanding of project.

BUILD/CONS/08

…cuts down waste, you can predict the time

…as built drawing, my client has the 3D model of the construction work we have done for them; and I believe if there is any need for maybe maintenance in future so I just trying to… if you know it, call me we can provide that service, we can trace such services and so on.

Is very nice, is the way to go, is a future of the industry.

BUILD/CONS-CONT./09

it was 100%, it gives me a lot of solution before the construction is been done.

…times BIM create idea for you when it is been applied even without execution.

…with the use of BIM you can easily advice and you can easily make a suggestion to whatever we are doing onsite, so is a kind of platform that bring everybody together; to be involve in that project.

…in construction sector BIM is like a millennium; yes, paradigm shift, grade one for that matter.

ARC/CONS/10

…it has actually helps in documentation and visualisation.

…design generation was more practicable

Visualisation of their proposed project, I think that is just the only services for now.

I see BIM as a game changer especially with the proliferation of the fourth industrial revolution. When you are talking about the future of construction industry, the future of CKEs; taking about smart construction, smart cities, smart buildings, I see BIM as an integral aspect of achieving the future cities we are looking up to, because we are talking about the launch of 5G connected devices all over the world.

ARC/CONS/11

…our major competitive advantage is the use of BIM

…getting to see the real time M&E that's monitoring and evaluation of their project

9.13.11 BIM Adoption Barriers/Challenges

9.13.11.1 Technology Barriers

ENG./CONS/01

…the challenge with that project is that, we couldn't get someone that can integrate the M&E so that means just like we couldn't deploy the solution with that design, so we later have to come back to CAD output; not as BIM finished product before taking it to construction.

Before the adoption, the challenges we have is getting the BIM tools itself, the cost of getting it at the time we want to adopt it,

They (BIM tools) are available; but their affordability is because of the condition of the country is not there;

Is not adequate (technology infrastructure), no! We don’t have, is not adequate.

ARC/CONS/02

…the second barrier is also the cost of the tools and the infrastructure required.

…the challenges is the cost also because when you want to adopt BIM it will take you a while for you to recoup the immediate investment there.

They are available but not so affordable.

So, things like data infrastructure in Nigeria is still very expensive. People are still buying data in bandwidth and all that – yes internet; so is quite discouraging, if everything is based on cloud and internet is expensive it will increase and that infrastructure alone is a lot of barrier to implementing digital construction.

…people still find these tools expensive so, in other countries like America because the clients already know the value of BIM, this people can charge much more for these things and cover the cost of the tools and infrastructure.

ENG./CONS/03

I think first of all is the fact that the software is not... it's expensive

I don’t think if you are looking for a licensed system is affordable.

QS/CONS-CONT./04

is the lack of infrastructure and when I mean infrastructure meaning we are referring to the internet system, a coordinated technology system we lacked that a lot in Africa you'll find a lot of time where our internet we are having internet downtime and this is definitely affects the BIM process.

…we had the challenge of high cost of implementation especially as regards to software. A lot of the software when you begin to feel that you need to use them by the time you do your findings, you noticed that they are quite expensive so a lot of firms a lot of top management feel that what is the business value of that software so they are not motivated to do it.

Presently in the country, we have very few people that we regard as BIM trained personnel.

…they are available because we have local presence of Autodesk in Nigeria. But are they affordable? For me I can say **NO** because this is largely not the fault of Autodesk but largely the fault of the economic situation of the country.

…we don't have the basic infrastructure needed and that is not only in the construction industry is across board. A lot of the industries are having issues with technology because there's no basic infrastructure to support technology across board.

ARC/CONS/05

Secondly, is the adoption of technology; we are so slow in adoption of technology not just Nigeria, around the world it's a problem in the building industry.

They (BIM tools) are available. But as for affordability, I don’t think so.

I still feel we need more infrastructure development for us to this to support BIM.

ARC/CONS/06

…the cost of bring in the BIM, we do not have supply chain software in Nigeria, do not have BIM tools developers in Nigeria. So, is a very big cost on Nigerian firms and trying to adopt BIM.

Well, the exchange rate makes it rather expensive since in Nigeria we do not have the tools developers;

Before we go to the technology infrastructure, you have to look at infrastructure on ground. You have to look at the power infrastructure, you have to look at the communication infrastructure; so it brings actually a challenge when it comes to talking about the technology infrastructure for BIM; so, the power infrastructure is a huge challenge, the communication infrastructure is still a work in progress.

QS/CONS/07

They (BIM tools) are not readily available because of the cost! They are available but they are not affordable.

No (we don't have technology infrastructure).

BUILD/CONS/08

You know, they feel the cost of acquiring this software is very high

So they feel this training and digitisation comes with software purchase and this software purchase with this Autodesk 365 software every year you have to start renewing so is kind of discourages them.

They (BIM tools) are not affordable, they are available but they are not affordable. So for building suite, I try marketing to one of the parastatals which is about N400,000 and that is a subsidy because that’s a promo; so how many private firms can get that. And beyond the N400,000 you do that for 1-year you expected to renew, is not affordable.

BUILD/CONS-CONT./09

…they (BIM tools) are available but is not affordable.

ARC/CONS/10

…when it comes to Professional licenses they are quite expensive for our economy; so they are quite expensive, so they are not affordable, they are not affordable for the average practitioners but when it comes to the top tier maybe 1%

9.13.11.2 Process Barriers

ENG./CONS/01

…other professional they still don't want to accept it, because of the condition of this environment.

…the procedure of getting those things that you need to have a complete BIM is very expensive

…these are the two major challenges; from the client and from a skill acquisition for the staff of company that want to adopt BIM.

No, we don't have (trained personnel), you have to train them; they need to be trained.

ARC/CONS/02

…in terms of collaboration it is at very low level. …the collaboration is still low.

…the first one is resistance from people, people are more used to the CAD workflow so they find it difficult to transition from BIM because they don't want to leave their comfort zone.

…also convincing your colleagues too, people that you collaborate with to also adopt the same workflow, so those are the common barriers you find in adopting be BIM.

…there was no common environment where everybody can access these files so it was quite hard to coordinate the design changes and all that.

…the industry at large is not so BIM ready because they are still that level of ignorance pertaining BIM in Nigeria.

…in Nigeria, even the clients they don't care even if BIM is use a lot; that alone is a discouragement for people that understand the value of BIM.

ENG./CONS/03

…we are training them by ourselves because we are taking time to understand the system and then train ourselves.

QS/CONS-CONT./04

Then mostly also is their resistance to change that we can see in professionals, you cannot do BIM in isolation. Like I said that our firm has adopted BIM a lot of our projects other stakeholders are not willing to accept BIM so as long as you cannot do BIM in isolation, really you cannot benefit from it unless every other person in the industry is willing to accept that change.

During, was the one I noted as regards to having other stakeholders key into the BIM process, a lot of time one of our project we serve as a BIM trainer for every project because we have to make sure that every other stakeholder is BIM compliant; so that was the challenge for us.

…a lot of people are resistant to new innovations so my experience is seeing people wanting to isolate from BIM, you see a professional when you explain a BIM concept and he refused, he doesn't need that his normal procedures are working fine.

ARC/CONS/05

…lack of knowledge, a lot of people don't know what BIM is.

Clients are always the ones to demand for these things.

…the challenges were trying to marry the traditional process with the BIM process.

…it's been tough in the sense that it's been difficult convincing people as to what it is actually.

No, I don't think so. You have to train your own staff, yes, most times it is actually even individuals that actually train themselves and then come out for the employment.

…one of the biggest challenge we face is other consultants where you're demanding information from them and most of them are still on BIM level 0 where it's… sure only CAD based.

QS/CONS/07

…the challenge I face was that, I was the only one trying to use it, no body is trying to buy into the idea for now,

…we don't get BIM trained personnel, no. But I get people trained on BIM,

BUILD/CONS/08

…these days is very difficult to get someone who is really interested in most of these things

We train them (our staff), we train them in our organisation,

So people that adopt this BIM are the operational staff, at level 8 and most times because they are not there in the board meeting where decisions are made so it becomes very difficult for them; but if you see a government official who has knowledge of this BIM I think they will like it.

<u>BUILD/CONS-CONT./09</u>

No (BIM trained personnel). In Nigeria for now, no.

<u>ARC/CONS/10</u>

…is the innate resistance to innovation, I think is something that is structured, probably structured within our society there's always fear of trying something new,

…innovative technologies tend to draw a certain level, a higher level resistance because without the young people at the seat of power or at the seat of influence, they will be difficult to be able to drive this because we all know that naturally young people are the ones that tend to understand and appreciate Innovations in society

…lack of knowledge, lack of knowledge of the benefits

…when I started using BIM is that the task, the design task especially when it comes to the modelling task makes the design process a bit more tasking; approaching design from the modelling makes it a bit more tasking than the conventional 2D approach

I think the major challenge is that a lot of people are always seen BIM as a software. So when you talked about BIM they say we are ready using BIM especially if I will relate it more from architect approach, they say will say we are already using BIM because we use ArchiCAD, we use Revit we use SketchUp so the challenge now is that telling them that no! BIM is no longer… yes before BIM was more from a software approach but right now based on global best practices, BIM is no longer from the software approach.

Is an insignificant number they (BIM trained personnel) are not readily available.

<u>ARC/CONS/11</u>

…today there is still lack of even awareness that's even existed in BIM, number one.

…because of our rigid professional structure because in our professionalism here in Nigeria when you see the Architect rigid, too much rigid on their own on the professionalism; so lack of really collaboration, clear collaboration between the provisions.

…too much independence of our professions rather than really, interrelating even doing the construction is also a barrier.

…lack of awareness is there.

…the only barriers we faced if I if at all is the persuasion issue and all that they require is something, example of what kind of projects have ever been benefited and when we're able to do that one, it was over.

…are we replacing the architect? Are we replacing the engineers? Who are we? Where are we in the scale of fees in the National public procurement? Those are really issues and we have we have to really struggle that's how we had to find ourselves, we get our self a ground and became the BIM based project management.

9.13.11.3 Policy Barriers

ENG./CONS/01

The major barrier is the end users, the government agencies…

We don't have clients requesting to do a project, when you find project, they don't give us to use BIM they give it to people that are not even professionals base on the Nigerian situations, that is number two challenge.

ENG./CONS/03

The biggest challenge is training our own engineers to understand it.

…affording training is such a big problem so you have to equate while you are doing it.

They can think of it (policy), but I don't see it happening for a while.

QS/CONS-CONT./04

One other thing that I feel is a barrier is the government un-concern, the government is really not motivated and not feeling willing to adopt BIM because if there is a government support and government policy everybody is going to saddle up and come up to the responsibility.

JCT has not been really accommodating for BIM.

But what is very critical is to ensure that we are able to execute the policy by the government. Are we will position to achieve any policy of digitalisation? For me I think no, because if any policy comes out they need some time to make sure that people are able to execute that policy.

…we see a lot of these models that are regard to BIM models but they are not information rich. So it means at production stage, at design stage a lot of

Architects don't have access to objects or libraries, to object libraries to use for their design stage and so it affects us too at the other end of the BIM chain, work chain.

ARC/CONS/05

…when there is a law people want to follow what the law says but, when there is no law everybody just, you know works differently coming up with their own standards, coming up with their forms of working.

…rich content like rich BIM objects are difficult to find especially relating to Nigeria par say

ARC/CONS/06

…first barrier is standardisation, standardisation incompetence

The way the information is put in and then to be read by everybody has not yet been agreed on which calls for the necessity of a framework for what should be legends, what should be keywords, what should be like the specifications format, what should be like attributes development parameters let say across board for everybody.

…there is also the fact that we do not have legislation in place in Nigeria to support the adoption of BIM widely. Government in support has not been there, especially for the building industry, government support has not really been an item, a prominent item in the way we have done business in Nigeria. So, standardisation within the industry itself and then legislative backing.

…we do not have a collective where local manufacturers have their model unlike the British system where they have an NBS plugin that you can actually use to select objects from manufacturers worldwide not just in UK alone

QS/CONS/07

A government policy and low collaboration between the team members, between the different professionals.

BUILD/CONS/08

…after you trained people they just leave.

…training the younger ones on this software because of there’s this fair that once you trained these people before you know it they leave you

There's no guide, none!

…on several occasions we have tried to apprised government organization, I wouldn’t start mentioning them now, and then doesn’t seem to understand it; you know they feel it cost money you start buying software and so on.

…the material library one should be able to… that's in my thinking, one should be able to get a material and under the properties toolbox you should be able to have a link to the website where you can purchase that material. Integrated process, but most times you getting material but you can’t like it, you go to the market and look for it, you don’t see it; it's a problem.

BUILD/CONS-CONT./09

…some of the things we are doing is not up to international standard; and so you know once you are doing below standard, for you to accept anything innovative it will be very very difficult.

The only challenge I have is mentoring, I find it very difficult to see somebody who would mentor me

So it was difficult; yes there are no BIM experts in Nigeria

…the major obstacle about BIM in Nigeria is funding as well. …if I want to go to South Africa and get the certification I will spend nothing less than ½ a million

ARC/CONS/10

There are no guides for now.

ARC/CONS/11

I think if there's anything that we have recorded is a bit of uncomfortable is the fact that the use of BIM is still has no particular scale of fee. So, the additional task of using the BIM is not really been paid because we are still BIM based project management; but what we being regarded is first project managers and there's no any different arrangement that was made for the fact that we are using BIM. And, so we are just using for a competitive advantage, so clients are not paying for the BIM that is it.

9.13.12 Solution to BIM Field Issues

9.13.12.1 Solution to Technology Issues

ENG./CONS/01

…government is giving out to contractors, they do have cost of tools that are going to enhance their product, is always stated in the bill, so already government is supporting it. Is left for the construction personnel to now integrate those funding given to deploy BIM.

ARC/CONS/02

as an Architect, I don't have problem with that because there are a lots of libraries online that you can download, and I can also model it myself so I don't really have problem with all this.

Yes there are some free libraries online that you can download object from.

if these tools are made a bit cheaper, and also the clients are made to get more aware of what BIM is all about it will encourage the industry to actually try a lot. So I believe is two way, is also to make the tools a bit cheaper than it currently is

<u>QS/CONS-CONT./04</u>

we have overcome that through trying to split the cost of software on all of our projects that was before.

we had to sit down and evaluate what it would cost us to procure these software which were mostly Revit, Navisworks and BIM 360 and then we decided to phase them out into any of our project. So, we need to attach a value, the usage time on each tool for each project and we need to cost that per project so and we look for ways to how to implement and subsidise this through a support by us and by our clients

So, I feel that also part of the requirements is to have manufacturers and production companies begin to produce BIM models of the products which will be available for Architect at the design stage.

<u>ARC/CONS/05</u>

Sometimes we even offer to vendors we tell them that look we can help you build your models and then you putting in the information.

<u>ARC/CONS/06</u>

We also at least need power in Nigeria to surmount challenges

<u>BUILD/CONS/08</u>

there are computers everywhere you know, I try to encourage people. You can start small you can start on a little you can; start with the little (software) ones you have, you know so they can start with that and gradually move on.

we have plans on ground to see how you can interface with manufacturers of products such that we can model the products and feed them into the database, the BIM database for use.

<u>ARC/CONS/10</u>

…they are available in the sense that you can always have free version software downloads from the vendors but is only limited to educational purposes

9.13.12.2 Solution to Process Issues

ENG./CONS/01

…whenever they are giving them training on how to use BIM solutions they always have feedback report from them and most of the feedback is related to, what is the return on investment if those people get it (BIM).

We need to inform them, create the awareness for them to see the benefit of it and for them to adopt it.

I think with time and with the right information and awareness, in no time I think, I believe the Nigerians and the Nigerian construction industry will tend to start using BIM.

ARC/CONS/02

you have to gradually overtime encourage your partners to see reasons to collaborate and of course and to approach the tools one by one until.

It's needs to be more collaborative from the onset

I think more efforts should actually go into awareness to people that are involved in the industry, the bottom-up awareness.

and also to sensitised the industry generally, including the clients themselves what they stand to gain by utilising BIM on their projects.

QS/CONS-CONT./04

we recorded success but it was hinged mostly on our traditional processes not basically because of the use of BIM.

During, like I said, we had to do some preliminary trainings for every other stakeholder on the project ensure that every other person understands what the BIM workflow is. Although, they didn't become BIM compliant but at least they to some extent understood what BIM process was and then they were able to key in to drive.

ARC/CONS/05

If we were able to enlightened people the more on benefits of this process, I believe the adoption will skyrocket.

Lets people be aware of the BIM, awareness is everything, I can't do what I have not heard of.

my suggestion is preach, preach and preach; because for everything we do as long as people are not aware, where are all those working in vain; we have to let people know that this is what is out there right now. This is the benefit I always use an example or when 3D visualisation came. It was client that made it spore because they started demanding wow… everybody wants to demand for 3D visualisation of his project. everybody is now becoming a norm. I feel at one point BIM will become a norm, if we continue preaching it, it will become a norm; then we look at the next BIG THING.

ARC/CONS/06

to make for 2 (BIM level 2) you have to be the one to pushing yourself to get there.

As at present, it could be like may be <1% in Nigeria due to obvious fact that is not a strict requirement; by the time it becomes a strict requirement, everybody would have to push themselves and meetup.

QS/CONS/07

so with the little seminars we have done, more people are coming up.

I manage the challenge by myself and like by encouraging myself and trying to read more and work more using BIM. This has benefitted for me.

BUILD/CONS/08

…there's this element of trust, I don't really see any challenge because they all understand the end from the beginning; they understand that you are not requesting for the complete model updated information because we want to cheat them or push them out of the project. There's this trust that yes this is what you really want to do with this information

Then the professionals should also trust themselves because that's the major issue we have in Nigeria, you know.

BUILD/CONS-CONT./09

through professional networking. You know in professional networking it gives you a lot of advantage and for the platform of CIOB there is nothing I want in construction industry that I would not get on the go.

the awareness should be more so that the government can look at it.

ARC/CONS/10

I am always open to any form of collaboration as you know being an active member in BIM Africa, our overall objective is driving a successful BIM mandate across the African continent and right now we are actually working to see how we can bring ourselves together and push a BIM mandate in Nigeria, so we are always open for any form of collaboration, that’s all I can say

ARC/CONS/11

Yeah in the first place as I said persuasion and were able to as I said earlier we are able to show a lot of examples of projects that have used BIM and really got to do well I've said it already

9.13.12.2.1 Management of BIM

<u>ENG./CONS/01</u>

BIM can be effectively managed through collaborations, because I believe the Architect is the first link of adopting it, so if there is a proper collaboration for all the other professional that they are going to work with knows their roles they will play, then there is need to spearhead that collaborative effort for other organisations that they are going to work with them on that platform.

I believe Architects and Project Managers that work in building industries that is for BIM in buildings; but for infrastructure, I believe Civil Engineers should take much role.

<u>ARC/CONS/02</u>

I wouldn't say anybody is much is better for that even if everybody is aware of the process everybody could simply play the traditional role as long as they collaborate properly on your a project. You don't necessarily need somebody to tag a BIM manager

<u>ENG./CONS/03</u>

I think it should be effectively managed by, within a team which we do in Nigeria you decide who is the lead consultant, and that lead consultant has that responsibility. Is like in the olden days when you had a piece of infrastructure that had so many, you had an interface engineer. So if it's really big, is either a consultant does it as in the member of the team or you have an interface person who actually actively manages the inputs.

I think it depends on the project, if it is infrastructure, I would say is the Civil/Structural Engineer; if it's building, I would say is the Architect. And, I think it depends on who lead consultant is that has been determined based on… …and I believe that, that lead should be based on volume of work or complexities; either volume or complexity of work.

<u>QS/CONS-CONT./04</u>

I feel that a lot of project management firms need to up-skill their workforce to adopt BIM management. Of a truth we cannot isolate be management in Nigerian construction industry because a lot of times the traditional processes are still the core of what is involved in every construction project. So bringing BIM in is not changing the whole process it is just enhancing the existing process. So I feel the project management firms are in the best position to adopt BIM and then to up-skill themselves on BIM and then begin to help with the implementation on project.

I feel the project manager is in the best position to implement BIM. In advanced countries, we have a separate role called BIM manager, but I feel that the Nigerian construction industry may not be ready for that yet. So before we get there we can start with having our project management professionals BIM compliant and then pushing the BIM implementation on projects.

ARC/CONS/05

I still actually feel the Architects should take this role if... although everyone has a role to play. It's not a matter of whether be the architect or… what of if the design starts from the engineers; yes, designs does start from them sometimes. So I feel whoever is the best, whoever knows best how to manage things within the team should take the role.

ARC/CONS/06

I think the ICT expert is the man who you underestimate but has a greater role to play. Because now we are not just Architects, Engineers; we now have go to an environment where somebody has to help us to keep our models; he has to be the one to make sure that the environment is safe, secure for having a model up there and then he is GDPR compliant not having my data sip out when it should not sip out, not having somebody bridge my model when it should not bridge.

QS/CONS/07

I think the Architect or QS.

BUILD/CONS/08

anybody that can walk on this software conveniently should be able to manage it.

BUILD/CONS-CONT./09

in the building industry, it is the builder; because the responsibility of any structure is solemnly on the builder. When you talk of the infrastructure, is the civil engineer, you understand. When you talk in terms of energy generation and stuff like that, you call on the electrical engineer, then when you now talk in terms of the hydro dams and whatever, you need the civil engineer then and the mechanical engineer who understand how the central sewage system works

ARC/CONS/10

1 it has to be a professional within the construction industry, it could be an Architect, could be an Engineer, could be a QS, could be a Builder the most important thing is that, the person should understand the construction delivery process which is why BIM is a process, so he should understand the construction delivery process.

ARC/CONS/11

I always advocate that it (BIM management) should come as a project management consultancy.

That's why if you attach BIM on to project management consultancy, is the justice you will do for BIM because at such all the stakeholders will have the equal right to be the BIM managers. What it should concentrate is that person should have the sufficient skills, knowledge and the experience needed to manage that project, BIM based project.

9.13.12.2.2 Who to Lead BIM Implementation

ENG./CONS/01

Is the professional that most of their work is related to BIM processes, it can be Architects, it can be Engineers, it can be even Quantity Surveyors

ARC/CONS/02

Maybe the project manager which if you have actually look at the project management anybody can still be a project manager, the Architect can still be a project manager, Structural Engineer can be a project manager, so probably the project manager on the project can still be the BIM manager.

ENG./CONS/03

I think it has to be government and either NSE or ACEN.

QS/CONS-CONT./04

Yes the government, the government plays a major role if BIM is going to be implemented in Nigeria and that is because the government is the largest paying client.

since client play a very crucial role in BIM implementation, I think the government is going to be the one to take the responsibility of leading BIM implementation.

ARC/CONS/05

The Architects. Majority of times design starts from the Architects table, when you push at early stage you won't have a problem later on.

ARC/CONS/06

I think emerging project management professional in the industry has a very vital role, he is already the one saddled with management so, he should just lead the adoption and the continuous implementation.

QS/CONS/07

The Architect.

BUILD/CONS/08

it comes in two ways, in one way professionals in the other way government just like what it happened in the UK.

BUILD/CONS-CONT./09

if you want to really make it to be generally acceptable, it has to be the 7; and the 7 are the: Architect, the Builder, the Quantity Surveyor, the Civil Engineers, the engineers we call them engineer you understand, depending the engineer and we have the Estate Surveyor and the Land Surveyor and the last one is the Planner. So they are seven in number recognised by the Nigerian constitution. So if you are talking about the leadership, all of them must have a stake for it to drive.

ARC/CONS/10

I think the professional societies. Why am I saying the professional societies is because the professional societies are like the gatekeepers, they have link to the government, in academia, in practice, in business, even in politics so is like they are more of the gatekeepers

ARC/CONS/11

The professional societies.

9.13.12.3 Solution to Policy Issues

ENG./CONS/01

government have a lot of influence adopt this framework or protocol for BIM support. Presently, we don't have any.

if we have a form of contract and is well defined with roles and protocols. The present one doesn't have, it doesn't. New form of contract have to be captured in it.

That (government policy) is a best option for us here in Nigeria, that's what we need;

if the government can take that step (policy), then a lot of people that are working for government would definitely follow the steps. So is a good thing if government can take that step.

Definitely I will be in support of it (alliance with international organisations).

The government have to create enable environment for people to have, to make it easier for their own organisation to even start from there; because government organisations should be the movers of all organisations if government could support them for them to integrate and compliant to BIM process I believe it will go a long way to resolve a lot of things in our construction industries

What I will advise government is… you know… the government need to take bull by the horn because they are the one if they decide this is what to do, all the agencies, organisations that work with government would adopt would follow the path. But for me to advice, they need to have standard, they have to have the structure that will define BIM, they have to have organisation that are going to take that responsibility to ensure that all organisations of government agencies are using BIM. And to do that, then the government must get advice from other countries where the BIM has been adopted, the processes they used, now have to create their structure for it. I think if they can do that… would start from there.

ARC/CONS/02

I think is better to start, to use the other countries' guide as a starting point then redefine it to suit our context, I think that is a better approach.

Yeah, I think that is a good idea (alliance with international organisations).

that will be a good incentive for people to actually want to try out this thing, because any people see those infrastructure as expensive but if government have support on those things. People will be more enthusiasm, easily try them all.

I think is better for first of all established some standards and protocols that's context sensitive. Like I mentioned earlier if you start with guides from other countries, you can now adopt them to context of Nigeria and Africa and from there have those guides in place so it's easier implement BIM.

ENG./CONS/03

adopt an in-house training system so we challenge ourselves; somebody that is good in understanding of that things would have… so they come to work all what they do is try and learn the software, when they do, we now begin to train other people

I think at the end of the day, even if it's adopting another country's guide; first and foremost is to ensure or make it a mandatory position that all designs should be done on BIM system or process is the first step.

we have always used British Standard so definitely adopting a British process – guide is not something to be sniped at, we can do that whilst in the process of developing ours because in the developing your own it may take you years and there is no point in losing out if can adopt another nation's process.

I think every contract can support the use of BIM. Because BIM technical tools says everyone within the ambit of the contract has responsibilities. I don't really believe that using BIM negates anybody from their responsibilities, so therefore I think it does, yeah.

I guess is about education if the outcome of it is made known to the policy makers and stuff like that, and also to the Universities, because regardless of what you think, the generation coming behind must understand the use of these things. Whilst I said tell it to the policy makers, tell it to the Associations NSE, ACEN all those bodies that are supposed to be COREN regulatory bodies and also don't forget the students, Universities.

Yes I will, bear in mind we use British Standard in Nigeria. For me is… as the cutting edge of these so working with them (alliance with international organisations) will be the easiest thing and there is no language barrier here everything

The role of government is policy, once government has made policy we as the business owners should tap into that policy and begin to look for ways to create business out of government policy;

is not about government enforcing operating an infrastructure but is about the private sector following on policy. So if policy is clear, is direct and enforced, it will be easy for businesses to key into; but if it isn't, then… so that's the only way I think government should be involve in this.

first of all we talked about policy right? And then the end users need to understand that, that's all you're going to get; and, that means if you don't have a BIM system you can't get your building passed for instance, until that happens, we are not going to have the round chicken. Even if the Architect doesn't want to use the BIM system, the client knows that still going to get my work passed so there is no problem; but when the client is the one saying I am not coming to you unless you have BIM system, so it has to go from policy to the ones who would and to the end users, and the end user has to buy into it and the only way you make the end user buy into that is make it impossible to build his building unless it goes through BIM system.

Bring home BIM to Nigeria, tell our policy makers to think about implementing this.

QS/CONS-CONT./04

to up skill my firm to make sure that we are 5D BIM compliant and then explore the other dimensions of BIM

a lot of us don't really understand the working procedures for the newly released ISO BIM but we believe that with some sort of seminars, webinars, trainings we are able to use that but then ISO BIM offers a unique ability because it offers to work across borders.

when we talk about constructions, we have geographical differences to way things are carried out in different locations so ISO BIM offers us that opportunity

The national guide came up as a proposal sometimes in the mid last year where some set of people came together and felt that we should come together and generate a BIM standard a BIM guide for the African space or for the Nigerian space.

We try our best to see how we can align both but I think the contractual documents need to be reviewed to accommodate the new BIM innovation in the construction industry.

If the government comes up to it with a policy as with regards to digitalisation is going to put every individual on their heels, everybody would need to brass-up to accept that challenge.

Yes, studies like these are quite beneficial to the industry because it tends to provide a roadmap and strategy to the government to be able to guide their decision making. So, this study is going to actually go a long way in helping that the Nigerian government are given some piece of advice, some roadmap, some strategy to use when they want to formulate digital policies.

it will help if can have international bodies come in, international professional societies come in to help develop the resources required to execute BIM in the Nigerian construction industry.

The government will play a major role if BIM is going to be adopted in Nigeria. Because the government is the greatest client that we can have, so if they have to come up with policies, there must be a wide extend to considerable extent government support to ensure that individual organisations and individual professionals are able to get the required skills, the required technology and the infrastructure to be able to adopt BIM.

this object do not take into consideration the local characteristics, so they are regarded as really not very important. A lot of them are formatted to global standard, to the standard of that country which is produced.

the solutions to BIM challenges in Nigeria and all over Africa is education. A lot of people need to be aware, there is large misconception of ideas. If you are approached average Nigerian construction professional and ask him what BIM is, they see it as a tool, as a software, and one item. So education, research, advocacy and a lot of others will go a long way to ensuring that we have actually become BIM compliant.

ARC/CONS/05

For now, I don't think so. What a lot of people do is look at UK BIM protocol and then try to adopt it for now.

I think currently right now in Nigeria I think there's a panel setup already for that to produce a white paper document for BIM adoption in Nigeria. Not set by the government, I think it's individuals, enthusiast, BIM Africa for example.

when the government is at the forefront of the things people follow because next time if it becomes a law, and when it’s a law, a lot of people like...

Yes, I will (alliance with international organisations), why not. who does not want development, I mean if we don't have the manpower in house, we can come together with the other countries that they must have already standardise their own process and then adopt, marry kind of... sort of... like you said come together get… set things in place and then…

I don't have problem with the government coming in to support. That will be some kind of big push on individuals like wow… the government says this… take for instance the UK, I think the government mandated BIM level 2 in 2016,

<u>ARC/CONS/06</u>

The challenge was won, my ability to read the software initially, the tool I am using, that was my main challenge.

A national guide would be appropriate for extra local requirements like… if Nigeria want to step up the game after looking at other countries' standards it will be proper to just coorp some principles from international standards and add the few things we think could make Nigeria BIM adoption have the cutting age over what other countries currently do.

I think it would be a good thing (BIM policy), it would make the information, that big data

a lot of training will go in the first one to three years and a lot of experimentation will take place over the fourth year; then in the fifth year we can now come out standardise together. We need a lot of calls between the first and second year to come out clean. So, five years would be appropriate so that everybody get there.

This study would benefit the people that are in charge of policies, policy making in Nigeria would serve as a tool for advising them, and then I think for industry leaders too, this study will be significant.

Would be the (alliance with international organisations) easiest… the most cost effective way. It will not just give us the… it will help us unveiling of the tools that these people have already developed, it will unveil us the opportunity to improve upon what they have developed.

these software can be available on the enthusiast that may not really be relevance based provide incentives for adoption by firms, may be tax incentives and then like exotic incentives because is just like adopting e-payments, e-payments has save government a lot. This will be now e-planning, this is basically electronic planning, electronic planning management. So, the government has nothing to lose supporting the adoption of BIM.

I take some support from…, NBS schools and other content specifications

We also at least need power in Nigeria to surmount challenges once we are knowledge ready.

Standard of information exchange, standard for creation… the important in this is have standard. Then, if you standardised the processes it does… the process should not be such that you leave one firm you have to relearn it in another firm. The process should be standard, so that your model comes to me I don’t have to learn a new code for reading models.

QS/CONS/07

There is necessary for national guide now because, with the drawings we use British Standard. If there is a good implementation and good standard, we should have our own national guide.

Yes, I will be in support of that (alliance with international organisations) because it will give us the guideline and how to do it; so when we are creating our own national guide it will be easier for us.

Yes government on adopting BIM like mandating for all public projects at first, like in the case of UK.

I think what we need now is regulation and a national guide to guide us. That should be, and the international guide they are duplicated as we read now.

BUILD/CONS/08

maybe we can start from other countries’ guides. Then, see how we can develop that but before we develop that we should have stakeholders in the BIM industry that will look at what we have in the country and see how we can… because we can't build on nothing and see how we can adapt it to save our environment.

whatever contract form you have, the basic ingredient is trust amongst the professionals, you understand. So far the JCT we have been adopting has been working because that element of trust has been taken care of.

Maybe a time frame, they can target maybe next 10 years to see how they can do that, but between that next 10 years they should be series of programmes forums, starting from school as a way of adopting this BIM.

yes 100% (alliance with international organisations).

BUILD/CONS-CONT./09

No, national guide in the sense that we need to incorporate BIM into the national building code.

the last revised national building code which was done in 2015 by the then administration there was a kind of sustainable innovation development in the guide, in the national building code. So definitely may be within the next two years when the BIM come up fully in Nigeria, we will be able to go to the council and incorporate it which is going to be part of a construction process

Yes, it (BIM policy) will be good. And the very first place they need to start from it should be on the development control and across the 36 states,

Because from the development control if they are on BIM, it will be very easy to implement BIM on the operational aspect.

Yes, ACE (association of consulting engineer) has always been the champion of all these; and there are lot lot of them that they are willing to help any country in the world. So if they come to Nigeria tomorrow, I will be the first person to be there.

And if government now say okay, I gonna sponsor 1000 professionals in Nigeria as a pilot stage, you understand, whether they bring the resource person from neighbouring country or they send us there, it’s a whole lot.

ARC/CONS/10

right now when it comes to adoption, BIM adoption in Nigeria are isolated cases so for now we are just working on driving a BIM mandate in Nigeria. So unless we get to that point ok whereby we have reached out to the government, or we reached out to organisations

I think National guide is needed but we can always referred to other countries’ guide as a reference, I think a national guide that is unique, unique to our own circumstances are all context our own culture our tradition and structured. I think we need a national guide of our own but we can always refer to other guides.

Is a welcome approach (BIM policy) as long as they are willing to apply...

is a welcome approach (BIM policy), is what we are actually looking for to train to ensure compliance, compliance to that.

a strong focus on continuous education and development yeah, continuous professional development why I'm saying so is because looking at the structure, looking at the Nigerian structure a lot of emphasis has been given to formal based learning

Definitely of course very much, international partnerships are the key forward in this global world, we actually have to leave what we preach if we really want to go to where we intend to go to.

if government can mandate a level of BIM implementation in public procured projects, what that means is that the professionals fees the funding what does projects will also consider software deployment which is actually a positive side it will actually lead to the increase of this software acquisition.

I believe that mandating BIM for large scale infrastructure projects will surely pave the way for long term adoption across the industry.

Well it should be effectively managed from Strategic approach because we have to look at it from both the process, the people and technology approach because this is why we actually need total… more of like reorientation, reorientation of the process because it requires a lot of investment and effort because successful BIM implementation you cannot treat this tricky elements in silos, you need people that will be able to understand and use…

integrate the process you need Standards that will be able to drive the implementation within organisations and the industry and you also need a technology and infrastructure that would actually aid in driving the implementation within organisations and the industry so is more like a holistic approach, holistic strategic...

the research should as much as possible be transferable, be transferable in to… much as possible able to reflect and be transferable into the circumstances that are prevalent in the Nigerian construction industry;

ARC/CONS/11

we really have to find ourselves a ground and that's how we became the project managers we first came as just BIM consultant but later we get to find out some opposition which is BIM based project management.

BIM is in our competitive advantage which itself is a cost, it gives us an access to the business so we use it as a competitive advantage but not really having any clear payment for that there's not enumeration because we use BIM.

at least we need to protocol and standard, and we don't need to adopt any country's guide, we need our own BIM protocol.

I will be happy (if government considers BIM policy).

This (BIM policy plan) needs a feasibility survey and understanding clearly of the situation on ground.

In construction in Nigeria, Architects is an independent entity, structural engineers is an independent entity, independent firm in all procurement they are been regarded separate whereas in UK you have contractor system who has all those things in-house. So, there is need for us to study the construction industry itself,

we built our own library.

we do develop the families… no don't use the inbuilt, we built it ourselves.

9.13.12.3.1 BIM Policy – Mandate Timeline (of Nigerian AEC industry)

ENG./CONS/01

To achieve the implementation, that one will take five (5) years.

ARC/CONS/02

In Nigeria, realistically that should take at least five to ten (5-10) years.

ENG./CONS/03

I would easily going to say seven to ten (7-10) years.

QS/CONS-CONT./04

if the government comes up with policy and say in the next five years what are they doing to ensure that in the next five (5) years people will be capable of executing that policy but for me I feel fine (5) years is enough time and adequate time to ensure that the industry is prepared for digital policies.

ARC/CONS/05

First of all, there will be resistance, resistance will drag for 2 years, 3 years, let me say 5 years.

ARC/CONS/06

Well, I would say… I would say five (5) years.

QS/CONS/07

I think it will take up to five to ten (5-10) years.

BUILD/CONS/08

Maybe a time frame, they can target maybe next 10 years to see how they can do that, but between that next 10 years they should be series of programmes

BUILD/CONS-CONT./09

It shouldn't be more than a year… a year minimum.

ARC/CONS/10

We were in 2018, we are in 2019 next year will be in 2020... I will say, I will say a decade (10 years).

9.13.12.3.2 Adoption Timeline (of the adopter construction firms)

ENG./CONS/01

have the right funding within one year we can change as organisation, have the process with us.

ARC/CONS/02

To fully adopt BIM, it shouldn't take more than two years to fully gets use to the right tools and setup the right processes.

ENG./CONS/03

7 to 10 years, I am also in Nigeria.

ARC/CONS/05

Well, 2-3 years most we should be at least at level 2.

ARC/CONS/06

a lot of training will go in the first one to three years and a lot of experimentation will take place over the fourth year; then in the fifth year we can now come out standardise together. We need a lot of calls between the first and second year to come out clean. So, five years would be appropriate so that everybody get there.

I am giving myself next two years (max. 2020) I will be at a level where I should be able to communicate BIM information to international standards (max. 2020).

QS/CONS/07

In less than five years.

So, we should be able to perfect it in less than five years.

BUILD/CONS/08

in the next five years. We should have stable staff in the office adopting it we're actually have plans for that.

BUILD/CONS-CONT./09

I believe if government so serious, it wouldn't take them six months. Because in funding *galaxy backbone* which is a private arm of the government providing interconnectivity for the industry, it doesn't take them a year when they did it, I think it was in 2006 or there about you understand.

Before the year's runs out, the project is on the limelight.

ARC/CONS/10

I want to be as conservative as possible, let's just give me three years. I am trying to be as conservative as possible, just give me three years.

ARC/CONS/11

We are really using it, really fully.

9.13.13 The BIM Adopter Firms' Ambition

ENG./CONS/01

I can see that in the future we would see the people that are pioneering the process of adopting BIM and giving the awareness to other organisations, even training them if possible for them to integrate BIM process. I think we see ourselves in that, taking the fore steps to give direction to others.

ARC/CONS/02

I am more a BIM evangelist, so I see myself getting more versatile and knowledgeable about BIM. And, I also love to actually implement a lot of the processes to projects of more efficient compared to the previous projects.

QS/CONS-CONT./04

I see myself more in the construction management sector, so I feel that since I am transitioning to senior roles in the construction management I need to also begin to advocate BIM and then begin to at least up-skill a lot of my other people. So I feel that I am position at the forefront of leading BIM in implementation in the future.

ARC/CONS/05

I am not aiming for BIM level 2, I am aiming for level 3. Although it's not yet defined but that's where my eyes are.

ARC/CONS/06

I see myself going all the way BIM even though for now I am not picking up as much pace as I would have… I see myself going all the way, no limits, going up to all the levels that will come even after the building lifecycle if there is any level after the building lifecycle; I think I will go all the way.

QS/CONS/07

Yes, I see myself and my company in full implementation of BIM, working under level 3 BIM; in the nearest future.

BUILD/CONS/08

I see myself being one of the forerunner pioneer of the BIM adoption in the country because I believe is the way to go.

BUILD/CONS-CONT./09

I see myself as a BIM expert even before the year runs out, I will get the certification, the ISO certification.

ARC/CONS/10

I see myself more as a professional BIM manager specialising in the management and standardisation of BIM processes. So I think for me that is where I see myself in future, as a BIM manager.

ARC/CONS/11

Really as a BIM pioneers in Nigeria.

9.14 APPENDIX – 14: RGU RESEARCH ETHICS AND GUIDELINES

ROBERT GORDON UNIVERSITY ABERDEEN

RESEARCH ETHICS POLICY

GENERAL PRINCIPLES

Ethical conduct

Ethical conduct depends on:

- consideration of the impact of the research, including

  - the potential implications of research for subjects and participants
  - the potential implications of research for non-participants, and
  - the uses to which research can be put.

- guidance covering the treatment of participants, including

  - informed consent
  - confidentiality and anonymity (see section 3.3 below), and
  - special consideration of vulnerable respondents.

- academic considerations. Researchers are enjoined to

  - maintain research of high quality
  - display competence
  - act responsibly towards others in their field, and
  - advance their discipline.

- guidance concerning research relationships. These include

  - the responsibilities of the researcher to the body commissioning the research,
  - responsibilities to the university,
  - commitments to fellow researchers, and
  - integrity in dealing with subjects, participants and stakeholders.

The impact of research

Researchers should ensure engagement in research does not cause unnecessary harm to participants, stakeholders, the environment, the economy and other living beings.

The principles of beneficence and non-maleficence are fundamental to all research activity. Beneficence is the requirement to promote the interests and wellbeing of others. It is the ethical principle of 'doing good' in the widest sense. Non-maleficence is the principle of 'not doing harm'. Both principles must be applied to all entities directly or indirectly affected by the research. In practice these principles frequently conflict, for example as in animal *versus* human welfare.

Researchers have a moral obligation to attempt to minimise the risk of physical and/or mental harm to themselves, human and animal participants, research subjects, stakeholders and the environment which may result from their research.

Ethical procedures

Ethical procedure depends in part on consideration of the impact of research, but more specifically on impacts for those who are directly affected by the process of research. Examples are procedures to obtain consent, to ensure anonymity, to protect confidentiality and to ensure the position of vulnerable subjects.

The application of these procedures depends on the nature of the research, and cannot be determined by simple rules without careful ethical consideration.

Research in the public sphere may not require the consent or approval of research subjects. The advice of the Canadian Tri-Boards is that "REBs (research ethics boards) should recognize that certain types of research - particularly biographies, artistic criticism or public policy research - may legitimately have a negative effect on organizations or on public figures in, for example, politics, the arts or business. Such research does not require the consent of the subject ... Consent is not required from organizations such as corporations or governments for research about their institutions".

There is a general presumption that consent should be obtained from subjects whenever the information is private. The requirement to seek consent can, however, be waived in certain exceptional cases, for example where there is necessary deception, or where the consent of a subject may jeopardise the welfare of an informant. All such cases require explicit ethical review and an extended justification.

Private data should be presumed to be under the control of the person or organisation to whom it relates. Anonymity is not a sufficient condition for confidentiality. Removing names from a report, or using aggregate data, may not be enough to ensure that respondents cannot be recognised or identified; and even where material is not identifiable except by the person who gave it, using it in ways that go beyond the terms on which it has been given may be a breach of trust.

The protection of subjects who are vulnerable calls for particular consideration to be given by researchers. This may apply, for example, to human subjects who are regarded as vulnerable (e.g. children or vulnerable adults) and to animals. Consent and anonymity should not be taken as sufficient protection.

Academic quality

Researchers are enjoined to maintain research of high quality, display competence, act responsibly towards others in their field, and advance their discipline.

Research relationships

As an academic community, the Robert Gordon University has a responsibility to encourage the highest possible standards of care, consideration and integrity within all research. Research integrity extends to accountability for the ethical basis for all aspects of the research; for the safety of both the participants and the researchers; for the probity of the financial management of the project; for the reliability of results and for making every best effort to provide value for public or private funds invested in the project.

Consideration should be given to potential conflicts of interest that may arise given the source of research funding and the nature of the research project.

All funds shall be managed in accordance with the university's financial guidelines.

Dissemination of research findings

It is expected that the researcher disseminate and publish all research findings, unless major confidentiality issues arise and subject to contractual provisions.

When publishing research, all reasonable steps must be taken to ensure that published reports, statistics and public statements about research activities and performance are complete, accurate and unambiguous. The nature of financial or in kind support should normally be acknowledged in all reports of research outcomes, both to acknowledge the support and to enable readers to make their own judgement over any prejudicial influences this support may have had upon the direction of the research.

The university is committed to pushing the boundaries in all areas of research in order to advance human knowledge but, at the same time, to benefit humankind. Therefore researchers should be aware of the use, potential misuse and abuse of published research.

All researchers who have contributed to the development of results and dissemination will be appropriately acknowledged.

Where research findings have commercial potential, consideration should be given to appropriate forms of protection prior to dissemination.

UNIVERSITY RESPONSE TO NON-COMPLIANCE

Non-compliance and ethical misconduct are addressed in the *Research Governance Policy*.

RESEARCH ETHICS POLICY REVIEW

The *Research Ethics Policy* will be regularly reviewed and updated, and amendments will require the approval of the university's Board of Governors.

Version 1: Approved Board of Governors, 23 June 2003
Version 2: Approved Board of Governors, 25 March 2004
Version 3: Approved Board of Governors, 18 December 2008; updated 29 July 2011
Version 4: Updated 02 September 2014
Version 5: *draft*